Living Resources Committee **ICES CM 1998/G:14**

REPORT OF THE

WORKSHOP ON OTOLITH AGEING OF NORTH SEA WHITING

Hirtshals, Denmark
23-28 October 1998

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1 INTRODUCTION

1.1 Terms of Reference

At the ICES Annual Science Conference in Baltimore in September 1997 it was decided (C.Res. 1997/2:29) that a Workshop on Otolith Ageing of North Sea Whiting (WKOAW) (Chairman: Mr A. Newton, UK) will be held in Hirtshals, Denmark, at a time to be decided during 1998 to:

a) Review existing knowledge on otolith ageing and ageing problems of whiting;
b) Estimate growth of whiting by analysis of size frequency distributions;
c) Use patterns in otolith microstructures to infer annual increment patterns in whiting otoliths;
d) Analyse growth from otoliths of individuals with known age (e.g., reared or recaptured whiting);
e) Provide guidelines for the interpretation of otolith annuli in whiting;
f) Suggest an intercalibration programme for ageing of whiting between laboratories based on the exchange of reference material;
g) Evaluate possibilities for recalibrating existing age data;
h) Ensure that new age readers are well calibrated against experienced age readers in other institutes.

Financial support for the meeting was obtained from the European Union via an Accompanying Measure to the FAIR project - European Fish Ageing Network (FAIR PL.96.1304); grant MAC/04/98.

1.2 Participation

The Workshop met in Hirtshals from 23–28 October 1998 with the following participants:

Trevor Boon	UK (England)
Anne-Marie Bratt	Sweden
Ken Coull	UK (Scotland)
Jean Louis Dufour	France
Helen McCormick	Ireland
Willy McCurdy	UK (N Ireland)
Johan Modin	Sweden
Andrew Newton (Chair)	UK (Scotland)
Ellen Ongenae	Belgium
Finn Dahl Poulsen	Denmark
Philip Prince	Denmark
Helle Rasmussen	Denmark
Gerrit Rink	Netherlands
Peter Wright	UK (Scotland)

Henrik Mosegaard and Kai Wieland attended some of the Workshop sessions and made individual presentations. Gudrun Furstenberg of Germany was unable to attend due to ill health.

2 GENERAL

2.1 Review of whiting biology

Spatial distribution

Whiting *(Merlangius merlangus)* are widely distributed in the eastern North Atlantic shelf waters from Iceland and northern Norway south to the coast of Portugal. It is abundant in the North Sea, the Irish Sea and the Channel. The species is almost absent from the eastern Baltic but more numerous in the western Baltic Sea. Their presence in southern Europe is limited to the eastern Mediterranean and the Black Sea where it occurs as a separate population of the sub-species *M. merlangus euxinus* (Beatrice Nin-Morales pers. com.)

Habitat

Whiting are benthopelagic at depths from 10 to 200 metres. They mainly live on mud and gravel bottoms but are also to be found on sand and rock. The young are predominantly found in shallower waters less than 100 metres in depth and are frequently associated with jellyfish.

Feeding

Major food items of whiting less than 20 cm in length are crustaceans such as euphausiids and Crangon shrimps. The diet varies according to season e.g., during part of the year annelids or cephalopod molluscs may form a significant part of the diet. The importance of fish prey increases when the predator grows to a bigger size and whiting of > 30 cm in length feed almost entirely on fish, including small species like Norway pout, sprat, sandeel and the younger age classes of larger species, such as herring, cod, haddock and even members of its own species. In fact, because of the composition of its diet and the size of the stock, whiting is considered to be the major predator of fish in the North Sea.

Life history

Whiting are very fecund fish with fecundity estimates ranging from 200,000 to 1 million eggs depending on the size of the fish. A female of 30 cm length may produce 400,000 ripe eggs during the spawning season, which is 1700 eggs per gram body weight. The eggs, which are pelagic and spherical and take about ten days to hatch, are shed in numerous batches over a period that may last up to fourteen weeks. The eggs do not contain an oil globule and range in diameter from 0.97–1.32 mm; they can be confused with the eggs of poor cod and blue whiting so it is not possible to identify the eggs with great certainty. The pelagic larvae start feeding when they are 2.4 mm long, and their main prey are the naupli and copepodite stages of copepods. The first of the 0-group whiting change to the demersal habitat during July or August and there is some evidence of a nocturnal migration into mid-water.

The spawning period is protracted, starting in January and lasting until September and whilst spawning is said to occur all over the North Sea the spatial distribution of pelagic 0-group whiting (3–5 cm) during summer shows considerable differences. The northern North Sea, the areas south of Shetland and west of Denmark, are densely populated by 0-group whiting during summer, whereas densities are lower in the central North Sea, the southern German Bight, and off the English east coast.

Frequently, inshore shallow areas and sea lochs are colonised by 0-group whiting during summer and autumn. A gradual emigration into the open sea occurs in spring.

On the basis of tagging experiments and analyses of incidence of infection by parasites, it is suggested that whiting to the north and south of the Dogger Bank form two separate stocks that mix very little, and that movements in the northern North Sea are mainly directed along the Scottish coast, rather than inshore/offshore. Part of the whiting stock in the Skagerrak probably migrates into the north-eastern North Sea to spawn.

2.2 Review of Whiting Otolith Exchanges and Workshops

In 1959 an exchange of whiting otolith and scales commenced among a few North Sea research institutes. The preliminary results suggested that it was possible to read whiting otoliths but that there was no standard interpretations of the bands of growth viewed by the readers. As a consequence a Workshop was convened in IJmuiden in August 1960 to further investigate the problems surrounding whiting otoliths.

Five countries attended the Workshop and 2 batches of otoliths (each of 244 samples) were read from the northern North Sea. The results from this Workshop were tabled as paired agreements between the institutes involved.

% Agreement of Age Readings

Batch 1

Denmark	England	Germany	Holland	
75	71	91	45	Scotland
	69	71	55	Denmark
		75	51	Holland
			43	Germany

Batch 2

Denmark	England	Germany	Holland	
37	90	74	66	Scotland
	40	37	55	Denmark
		74	67	Holland
			66	Germany

The conclusions of the Workshop were "It was felt at the meeting in IJmuiden that, although agreement could be obtained while working together, it would not be possible to maintain this agreement when working apart. Further work is needed to arrive at a single interpretation, especially using otoliths collected at different times of the year. It would also be desirable to extend the work of whiting from different sea areas, since only the northern North Sea region has been studied so far."

Subsequent to the IJmuiden meeting there may have been informal otolith exchanges but the next chronological reference in the literature relates to an Irish Sea/Celtic Sea whiting otolith exchange in 1985. Four institutes were involved in this exchange - DANI (Coleraine), FRC (Dublin), IFREMER (Lorient) and MAFF (Lowestoft). All the otoliths were transversely broken and two batches were read, one of Irish Sea otoliths and the other Celtic Sea otoliths. The results of the exchange showed a 54% - 94% agreement between pairs of institutes for the Irish Sea and 38% - 71% agreement for Celtic Sea otoliths.

The results from the 1985 exchange scheme prompted the convening of a second whiting otolith Workshop held in Dublin in May 1987. In total there were eight participants from England, France, Ireland, the Netherlands and Northern Ireland. 633 whiting otoliths from the Irish Sea and 173 otoliths from the Celtic Sea were read and the results showed a 80% agreement between pairs of readers for the Irish Sea and 75% agreement for the Celtic Sea. The Workshop concluded that there was no evidence of systematic errors and bias was not a serious problem. Another way to evaluate the precision of otolith reading is to compare individual readers age determinations with the modal age i.e., the age determined by the majority of readers. Prior to the Hirtshals Workshop the results from 198 Irish Sea otoliths and 173 Celtic Sea otoliths were re-evaluated against the modal age (Table 2.2.1). It should be noted that two of the readers were classified as "Occasional" and whilst their determinations were included in the analysis there is no doubt that excluding their results would have increased the overall level of precision.

Table 2.2.1 Percentage Agreement with Modal Age (1985)

Reader	Institute	Skill	Irish Sea	Celtic Sea
1	MAFF	Regular	87	89
2	IFREMER	Regular	86	85
3	DANI	Occasional	-	46
4	IFREMER	Occasional	60	67
5	FRC	Regular	80	74
6	MAFF	Regular	89	93
7	RIVO	Regular	92	84
8	DANI	Regular	83	84
All			83	80

When these results are compared with the previous exchange scheme it is obvious that a workshop is a useful tool for improving the precision between individual readers.

No further work on the problems of whiting age determination in the North Sea was undertaken until 1990 when a new otolith exchange scheme was conducted by MAFF. 115 otoliths were read by 10 individual readers from seven institutes. Table 2.2.2 shows the % agreement with the modal age for all participants.

Table 2.2.2 Percentage Agreement with modal age (1990)

Reader	%
1	84
2	88
3	79
4	83
5	38
6	70
7	77
8	65
9	36
10	41

The results from this exchange prompted the call for a third whiting otolith workshop and this was convened in Hirtshals in October 1998.

2.3 Problems with whiting otoliths

Gambell and Mestorff (1964) reviewed the problems with northern North Sea whiting otoliths and highlighted several features that appeared to cause difficulties during age estimation.

The nucleus - the central zone, or nucleus, can be either translucent or opaque.

Double zones - the second and third translucent zones can appear as double structures, almost as though it is composed of two unusually thin translucent bands separated by a very thin opaque band. Gambell and Mestorff maintain that thin, closely packed translucent zones are not a feature in North Sea whiting and thus such features should be interpreted as one annulus.

Bowers' zone - first described by Bowers in 1954. This can be seen when the nucleus is bounded by a thin translucent zone inside the first true winter zone. It appears to be present in North Sea whiting when they take up the bottom-living habit, in about July or August of their first summer life. This zone may be connected with the change from the pelagic to the demersal habitat, together with the associated change in feeding.

Broad first translucent zone - the first annual translucent is much larger than normal and the centre is composed of a confused mass of translucent and opaque bands. It is suggested that this feature is caused by breaking or sectioning across two projections of a heavily crenulated otolith.

Spacing of zones - there are many translucent zones, which cannot be easily followed round the entire otolith. On observing such features it should be borne in mind that Gambell *et al* maintain that thin, closely packed translucent zones are not a feature of North Sea whiting.

3 MICROSTRUCTURE

3.1 The Formation of False Rings

At the Whiting age reading Workshop, 27 October 1998 in Hirtshals some preliminary results on otolith formation and structure appearance in cod sagitta were presented.

It has previously been shown that otoliths continue to grow even at no or negative weight gain in individual fish. Further, the appearance of different otolith growth structures seems to be influenced by environmental factors affecting the physiology of the fish.

A number of working hypotheses have been proposed and are currently under investigation to account for the morphological and structural characteristics of otoliths formed under different conditions.

- Otolith growth rate increases with increasing temperature.
- There is no time lag in the otolith growth response to temperature.
- The further the feeding conditions differ from the temperature specific optimal conditions the more transparent the otolith growth structures will be.
- There is a time lag in the response to changes in feeding condition related to protein turnover and thus inversely related to fish size.
- Opaque otolith formation is a function light being dispersed by protein incorporation and space between crystals producing surfaces reflecting light at different angles.
- Transparent otolith formation is related to the homogeneous growth of densely packed aragonite crystals.
- Although otolith formation is an extra-cellular process the morphology seems to be under genetic and ontogenetic control (identification based on otoliths is often possible to the species level).
- Local otolith growth is subject to some physiological influence.
- Optimal somatic growth conditions result in local apical otolith growth being associated with opaque structures that appear to be concentrated in the fast growing accessory primordia. Under good feeding conditions in cod an elongated sagitta is produced with a periphery of pronounced lobes.
- During sub-optimal growth conditions otolith surfaces between lobes will grow relatively more than the lobes making the otolith shape rounded and the surface smoother.

- At the daily level optical contrast in primary increments is more pronounced under optimal than under sub-optimal feeding conditions.
- Daily increments will generally be wider but less conspicuous with increasing temperature.

Specific otolith growth characteristics produced by temperature and feeding conditions may have a profound influence on the otolith shape and 3-D density distribution. It may be speculated that there will be a complex interaction between the total fish growth history and the combined effects of time and temperature duration (read age) on the final morphology of the otoliths. Further information on otolith accretion may be found in the EFAN report 1/98 (www.efan.no)

3.2 The use of otolith microstructures as an aid to age determination

Introduction

There is now considerable evidence that microstructural observations can assist in the interpretation of otolith macrostructure (see Arneri *et al.*, EFAN report 1/98 for review). Counts of microscopic daily increments have been used to directly verify that one opaque and translucent zone represents an annulus (Victor and Brothers, 1982; Taubert and Tranquilli, 1982). However, this direct verification approach is limited by the problem in detecting fine microscopic increments in fish > 1 year old and the need for validation of the daily periodicity of increment structures. Due to these problems daily increments have generally been used to validate just the first annulus. However, changes in microstructure may also provide a means of distinguishing between seasonal zonations and secondary structures. In temperate species daily deposition can be very compressed or arrested in cold periods (Taubert and Coble; 1977; Campana and Neilson, 1985) and using light microscopy an annulus often appears as a discontinuity preceded by increasingly narrow increments (Victor and Brothers, 1982). Seasonal differences in increment width may also be associated with changes in micro-crystal thickness and compaction (Morales-Nin, 1987). In contrast to the seasonal opaque-translucent transition, observations on presumed false rings (thin translucent zones) of *Ammodytes marinus* found no evidence of a reduction in increment width (Anon., 1994). As such there may be microstructural differences between annuli and secondary structures.

Objectives

The purpose of this study was to:

- Determine whether microstructure could be used to distinguish secondary structures from true seasonal zonations
- Use this approach to prepare a reference collection of otoliths with known secondary structures as reference material for the age reader

Methods

Due to the high opacity of gadoid sagittae microstructural examination requires the preparation of very thin sections. For this purpose sagitta otoliths were embedded in Araldite resin and cut into 0.6 mm sections along the transverse using a low speed diamond saw. The sections were then ground down to approximately 50 µm using 600 and then 2500 grit paper lubricated with Hyprez fluid on a lapping wheel, at 200 rpm. Otolith sections were cleared in immersion oil and then examined using both reflected and transmitted light at magnifications ranging from 25 - 1000x.

The periodicity of microscopic increment formation in 1 and 2- year old whiting was estimated by rearing fish for a 26 day period. For this purpose a group of 15 whiting were caught by bottom trawling near Gairloch, in ICES area VIa and then held in a sea cage (35 metres ^{3}) for 26 days between 13 August and 9 September.

In order to characterise the microstructural features of true zones within the annulus zones and secondary features as described in Section 2.3 otoliths (n = 15) from collections made in April and August were prepared for microstructural analysis. Where possible daily increment counts were made from the nucleus to the opaque zone of the second annulus. All transitions in opacity were examined for the features given below. By this means an age was assigned to each otolith.

During the workshop age readers were asked to assign age and describe their interpretation of 10 thin sectioned otoliths. By comparing the age determined from microscopic observations with those read macroscopically an indication of age reading accuracy was obtained. However, it is important to note that the thin sectioned material suffered from some artefacts associated with very thin sectioning which made interpretation of macrostructure more difficult than in normal sectioned otoliths.

Daily increments were not visible throughout translucent zones, but some counts were possible for opaque zones. These micro-increment counts provided one approach for distinguishing false rings within the first opaque zone.

Results

1. Daily increment verification of annuli

A prominent transition in opacity and increment width was observed corresponding to the period of the cage experiment (Figure 3.2.1). The number of microscopic increments observed in the recent translucent zone was not significantly different from the duration of the experiment (D-test t = -1.96; P = 0.12) indicating that these increments were formed daily.

Counts of daily increments were used to verify the first annulus from fish estimated to be 1 and 2 years old (see Table 3.2.1). Post-hatch ages of fish caught in April and August, based on hatching from peak spawning in mid-April, would be expected to be approximately 340 and 450 days, respectively. However, because of the long spawning season of this species age ranges in April and August could be as much as 230 - 390 and 340 – 500 days, respectively. A further limitation to daily increment counts arises because of the difficulty in preparing a section which goes through the core of the otolith. Increments formed near the core are typically < 1 µm and very difficult to discern even in fish < 100 days old. As a result of this problem increment counts may be expected to underestimate true age by at least 30 days. Despite these caveats counts of daily increments did enable verification of the first annulus in 1 and 2 year old fish (see Table 3.2.1). Counts for opaque zones indicate that the active growing period is around 4–5 months. Increment counts in secondary structures observed in the first year of growth were < 30, indicating that these structures are formed over much shorter periods to that of the season zones.

2. Microstructural features of seasonal zones

Based on seasonal zones verified from daily increment counts the transition between seasonal opaque and translucent zones were characterised by:

- an initial translucent check
- a rapid change in opacity
- poor differentiation between L- and D- zones
- a decline in increment width in within 10 increments of the transluscent zone to < 2/3rds of those found in the opaque zone.

An example of the seasonal opaque-translucent transition is shown in Figure 3.2.2

3. Secondary structures

In order to characterise secondary structures, whiting otoliths with macroscopic features corresponding to the descriptions given by Gambell and Mestorff (1964) were described from microscopic observations.

Nucleus region

The central zone, or nucleus, can be either translucent or opaque in whiting.

However, increment widths in both translucent and opaque nuclear regions of the first annuli were found to be significantly broader (> 1.5x) than in subsequent annuli.

Double zones

The second and third translucent zones can appear as double structures, almost as though appearing as two unusually thin translucent bands separated by a very thin opaque band when viewed at low magnification. These double zones or split rings can be seen in Figure 3.2.3. Microscopically the translucent zone is not characterised by a rapid decrease in increment width until after the second organic matrix rich band (Figure 3.2.4). The opaque bands are comprised of a small number < 10 of very broad increments (> 1.5x translucent increment width).

Bowers' zone

First described by Bowers in 1954 this structure can be seen when the nucleus is bounded by a thin translucent zone inside the first true winter zone (Figure 3.2.5). It appears to be present in North Sea whiting when they take up the bottom-living habit, in about July or August of their first summer life. This zone may be connected with the change from the pelagic to the demersal habitat, together with the associated change in feeding (Figure 3.2.6). In contrast to the transluscent zone of winter, increment width in this zone is similar (i.e., > 2/3[rds]) to that found in the previous opaque material. The width of this false ring is less than half of the first translucent zone.

Broad first translucent zone - the first annual translucent is much larger than normal and the centre is composed of a confused mass of translucent and opaque bands. It is suggested that this feature is caused by breaking or sectioning across two accessory growth centres away from the nucleus.

4. Evaluation of age reading accuracy based on microscopically verified ages

Ages were verified from increment counts of the first annulus and from identification of true and secondary structures using the structures described above.

Results of this exercise are given in Table 3.2.2 for 9 readers including 1 Scottish reader (0) who was not present at the workshop. The age reader numbers correspond to those given in Tables 6.2.2 and 6.2.5. In general, experienced readers gave more accurate age estimates than novice readers. However, several readers appeared to have difficulties in reading 1-year otoliths. Of those readers that provided comments on interpretation it would appear that the errors arose from a failure to distinguish Bower zones and split rings in the first translucent zone.

Table 3.2.1 Expected and estimated number of micro-increments in the first annulus identified by most age readers for specimens collected in two months. N = sample size.

Month	Expected annulus age range (days)	Estimated annulus age (days)		
		Median	Range	N
April	230 - 390	300	240–348	5
August	340 - 500	322	311–350	3

Table 3.2.2 Comparison between reader estimated and verified ages. Result summaries given refer to the sum difference between reader and verified annuli counts (total years), the number of incorrectly aged fish (total N) and the mean age estimated for a 1 year old fish.

Specimen	Month	verified age	0	2	3	4	5	7	8	9	10
1	8	1	1	1	1	2	1	1	1	2	1
2	9	1		2	2	2	2	2	1	2	1
3	4	2	2	2	2	1	2	2	2	2	2
4	4	1	1	1	3	1	2	1	2	2	1
5	4	1	1	1	2	2	2	2	2	2	1
6	4	1	1	1	2	1	1	1	1	1	1
7	4	3	3	3	3	4	3	3	7	3	3
8	4	1	1	1		0	1	1	1	1	0
9	4	2	2	2	2	2	2	3	3	2	2
10	8	1	2	1	1	2	2	1	1	1	1
		total years	1	1	5	3	4	3	7	4	1
		total N	1	1	4	7	4	3	4	4	1
		mean age 1	1.1	1.1	1.8	1.7	1.6	1.3	1.3	1.6	1.1

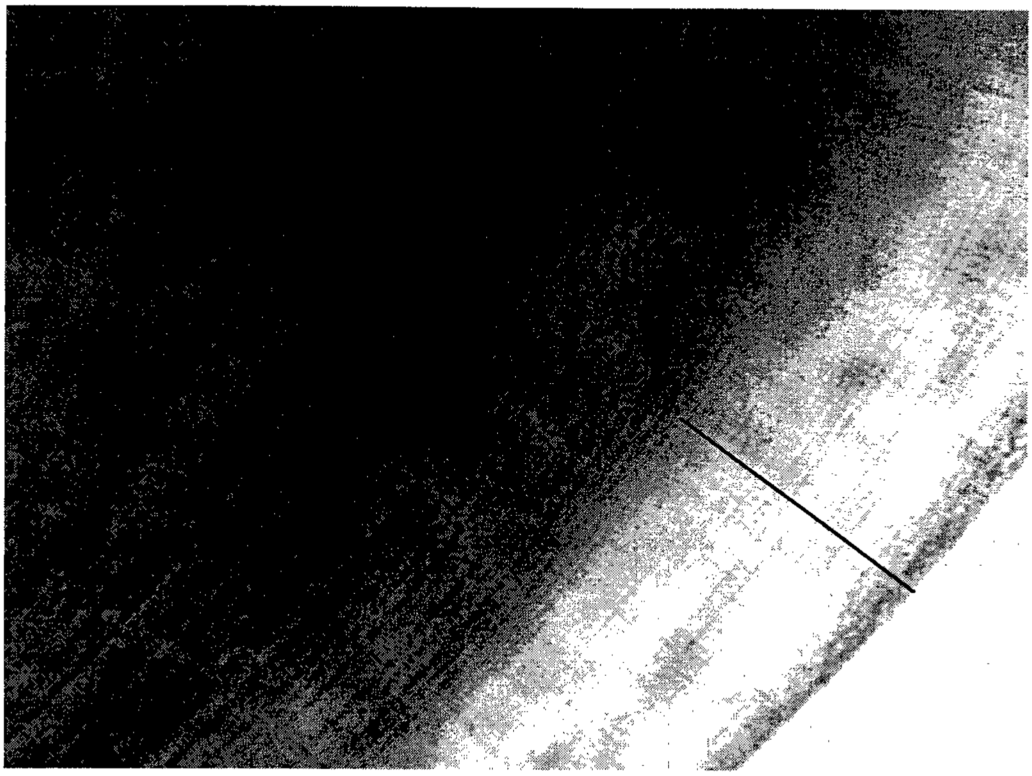

Figure 3.2.1 Otolith of 1 year old Whiting showing increments formed whilst held in a sea cage.

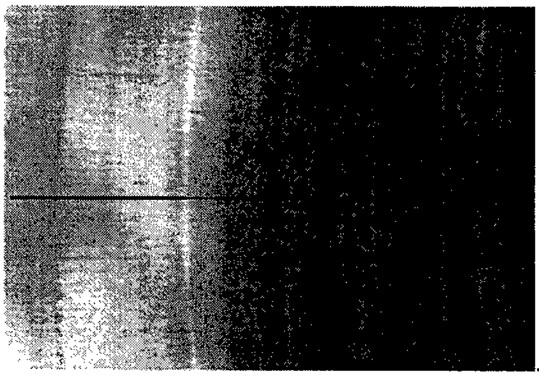

Figure 3.2.2 Opaque-translucent zone transition of a true annulus. Note that translucent zone is characterised by a change in opacity, a translucent check and poor differentiation between L- and D- zones.

Figure 3.2.3 Whiting otolith viewed under reflected light showing a split ring. Magnification x100.

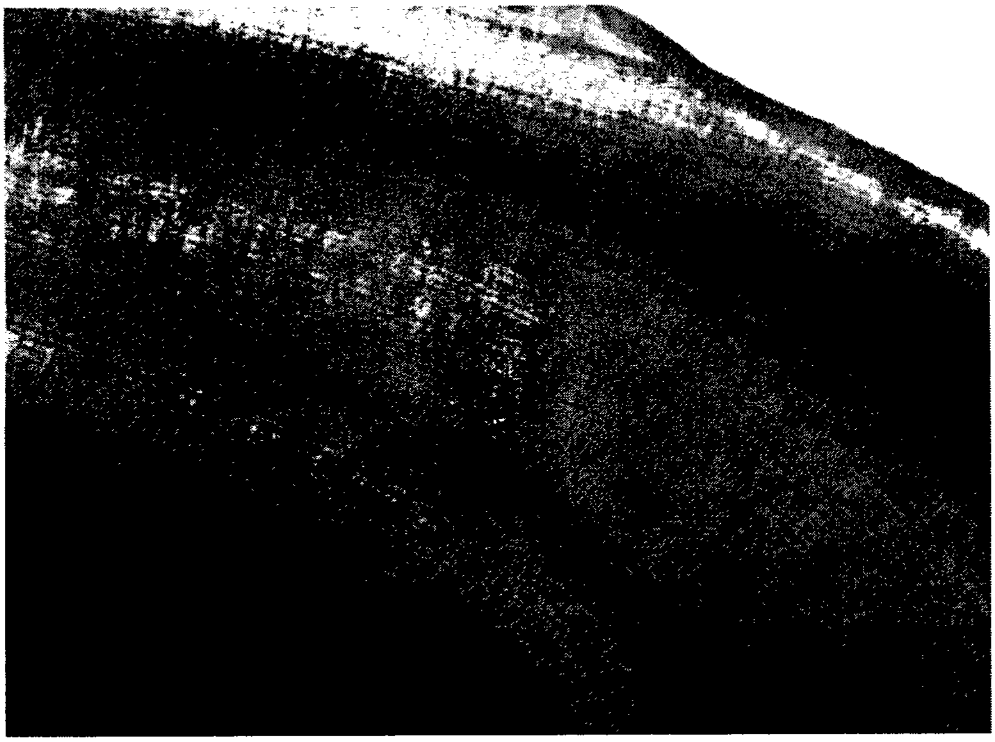

Figure 3.2.4 Incremental structure of a split ring showing dense (opaque) increments (indicated by arrows) interspersed by transluscent increments. Magnification x 400.

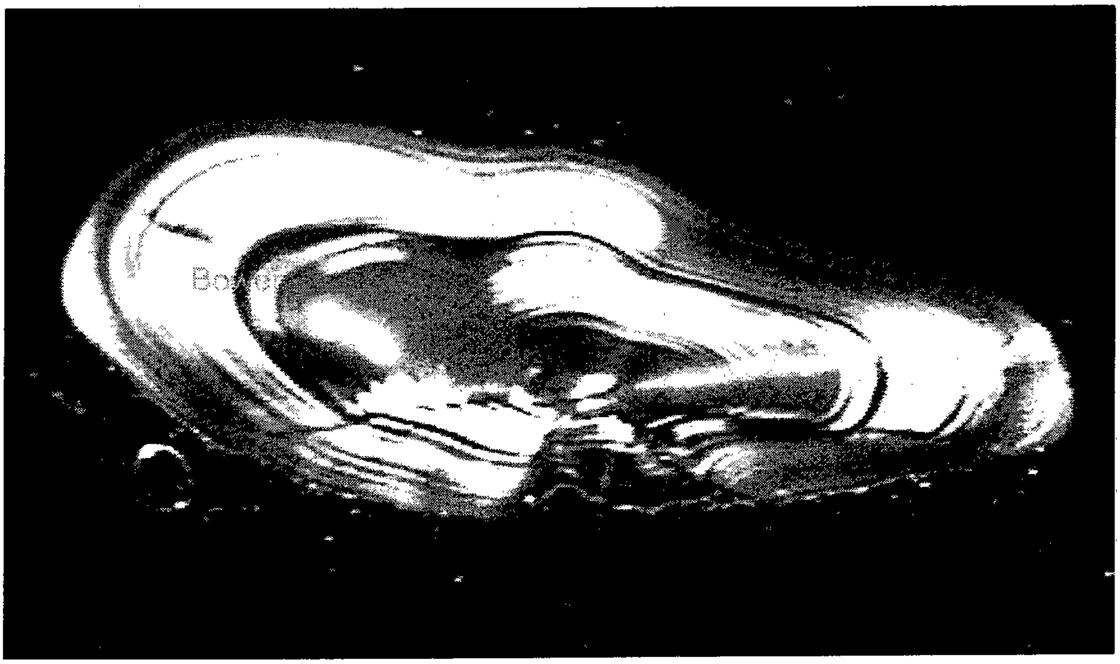

Figure 3.2.5 Whiting otolith viewed under reflected light showing Bower's zone or false ring. Magnification x 25.

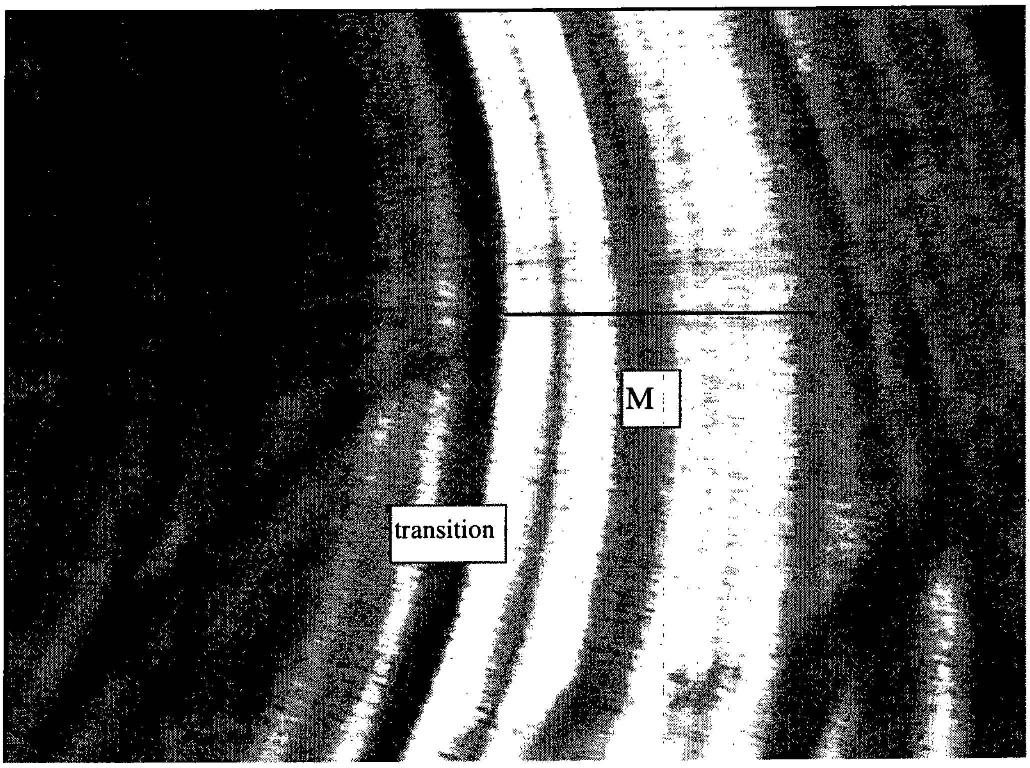

Figure 3.2.6 Microstructure of a false ring showing translucent material interrupted by matrix rich check (M). Magnification x400.

4 OTOLITH EXCHANGE

4.1 Results of exchange programme prior to Workshop

In advance of the Whiting Otolith Workshop an exchange of otolith material was arranged to gauge the present level of ageing agreement internationally and to focus delegates attention on the problems encountered when ageing whiting otoliths.

Of the Institutes contacted, 11 registered an interest in taking part in an exchange and 6 offered otoliths for circulation. The exchange material amounted to otoliths from 182 fish and covered both of the broad preparation techniques i.e., broken (120 fish) and sectioned (62 fish). All of the material was collected during 1996, was evenly distributed between quarter 1 and quarter 3 and covered a length range from 12 to 50 cm. Between the beginning of March and the end of September the exchange material circulated round all of the 11 institutes, with one providing answers from two readers. In addition one delegate at the Workshop, who had not been involved in the exchange, was able to read the sectioned material.

Analysis of the results was carried out using an Excel spreadsheet, similar to that used in other otolith exchange exercises and originally provided by Guus Eltink of RIVO-DLO. The principle of the analysis is to determine the modal age for a fish and then to score each reader as correct or incorrect against that age. In the event of there being more than one modal age, the first one arrived at, reading the spreadsheet left to right, is the one used. Thus it can be seen that the order in which the readers are keyed into the spreadsheet may have an affect on the results. In this exchange, 18 fish of the 182 had more than one modal age. Therefore any estimate of correctness for a particular reader, based on all of the material, will fall within a range of, potentially, 10 percentage points.

Initial analyses indicated that there were no consistent differences in ageing caused by the time of year. However, differences did appear between the type of preparation of the otoliths. Consequently results are shown treating broken and sectioned material separately. This had an additional benefit as two institutes read only the sectioned otoliths. In each of the two analyses the readers were entered into the spreadsheet in an approximate order of experience. The most novice reader, still in the early stages of training, was left out of the analyses. Results are summarised in Table 4.1.1 below and more extensive details are provided in Tables 4.1.2 – 4.1.5 and Figures 4.1.1 – 4.1.2.

Table 4.1.1

Percentage agreement

	Eng	Sco	Nor	Bel1	Den1	Den2	Ger	Ire	Swe	Neth	Fra	N Ire	All
Broken	65	78	66	33	38	52	74	68	47	63			58
Sectioned	79	90	37	13	70	63	74	80	42	82	84	93	67

Considering that North Sea whiting are classified as a difficult stock to age and that there was a wide range of experience amongst the readers in the exchange exercise, the overall results were not too discouraging. Broken material provided the lower overall agreement. This is perhaps not surprising, as the use of broken material requires the additional skills of breaking the otolith in the correct plane and identifying the correct plane on broken pieces of otolith. In addition broken material tends to deteriorate as it circulates on the exchange. Only two readers show marked difficulties in interpreting sectioned material but six showed improved agreement. Overall the tendency was to over estimate the age of young fish and to under estimate that of older fish.

Table 4.1.2 **WHITING OTOLITH EXCHANGE 1998 broken material**

Year	Sample	Fish no	Fish length	Landing month	SR Sco Reader 1	SR Nor Reader 2	SR Ger Reader 3	SR Swe Reader 4	SR Bel1 Reader 5	BR Den1 Reader 6	BR Den2 Reader 7	BR Eng Reader 8	BR Ire Reader 9	SR Net Reader 10	Fra Reader 11	N Ire Reader 12	MODAL AGE	Age difference	Average
96	??	1	12.0	??	1	1	1	1	3	1	1	1	1	1	-	-	1	2	1 20
96	??	2	14.0	??	1	1	1	2	3	2	2	2	1	1	-	-	1	2	1 60
96	??	3	15.0	??	1	1	1	1	3	2	1	1	1	1	-	-	1	2	1.30
96	??	4	15.0	??	1	1	1	1	3	2	1	1	1	1	-	-	1	2	1.30
96	??	5	16.0	??	1	1	2	2	4	2	3	2	1	1	-	-	1	3	1.90
96	??	6	17.0	??	1	1	1	2	4	2	3	1	1	1	-	-	1	3	1 70
96	??	7	19.0	??	1	1	1	2	5	2	3	2	2	1	-	-	1	4	2.00
96	??	8	20.0	??	1	1	1	2	3	3	3	2	2	1	-	-	1	2	1.90
96	??	9	21.0	??	1	1	1	2	4	3	3	2	2	1	-	-	1	3	2.00
96	??	10	23.0	??	2	2	2	2	4	3	3	2	2	2	-	-	2	2	2.40
96	??	11	24.0	??	2	2	2	2	4	3	3	2	2	2	-	-	2	2	2.40
96	??	12	24.0	??	1	1	1	2	4	2	2	1	2	1	-	-	1	3	1 70
96	??	13	25.0	??	2	2	2	2	4	3	2	2	2	3	-	-	2	2	2.40
96	??	14	25.0	??	4	3	4	3	6	4	3	4	4	5	-	-	4	3	4.00
96	??	15	25.0	??	2	2	2	3	4	3	2	2	2	2	-	-	2	2	2.40
96	??	16	26.0	??	3	2	3	3	4	4	3	3	3	3	-	-	3	2	3.10
96	??	17	26.0	??	3	3	3	3	5	5	3	4	3	3	-	-	3	2	3.50
96	??	18	27.0	??	2	2	2	2	5	3	3	2	2	2	-	-	2	3	2 50
96	??	19	28.0	??	2	3	3	3	5	3	3	2	2	2	-	-	3	3	2 80
96	??	20	29.0	??	3	3	3	4	4	4	3	3	3	3	-	-	3	1	3 30
96	??	21	29.0	??	2	3	3	3	5	3	3	3	3	4	-	-	3	3	3.20
96	??	22	30.0	??	3	3	3	4	5	5	3	3	3	4	-	-	3	2	3.60
96	??	23	30.0	??	4	4	4	3	5	5	4	4	3	4	-	-	4	2	4.00
96	??	24	30.0	??	3	4	3	4	7	4	4	3	3	3	-	-	3	4	3.80
96	??	25	30.0	??	3	4	5	4	5	4	3	4	3	3	-	-	3	2	3.80
96	??	26	31.0	??	2	3	3	4	5	4	3	3	3	3	-	-	3	3	3.30
96	??	27	31.0	??	3	3	3	3	5	3	3	3	3	3	-	-	3	2	3 20
96	??	28	32.0	??	8	5	8	5	8	9	6	8	-	8	-	-	8	4	7.22
96	??	29	32.0	??	4	5	4	4	5	5	4	5	4	4	-	-	4	1	4 40
96	??	30	32.0	??	3	4	3	4	5	5	3	5	3	3	-	-	3	2	3.80
96	??	31	32.0	??	3	4	5	4	5	3	3	4	2	2	-	-	3	3	3.50
96	??	32	32.0	??	3	4	4	3	4	4	3	3	3	4	-	-	3	1	3 50
96	??	33	34.0	??	5	4	5	6	6	6	6	5	5	7	-	-	5	3	5.50
96	??	34	34.0	??	3	4	4	5	5	5	5	4	4	4	-	-	4	2	4.30
96	??	35	35.0	??	5	5	5	6	5	6	5	5	5	6	-	-	5	1	5.30
96	??	36	35.0	??	7	5	7	6	6	8	6	7	7	8	-	-	7	3	6 70
96	??	37	35.0	??	4	4	5	5	4	5	4	5	4	5	-	-	4	1	4 50
96	??	38	36.0	??	4	4	5	5	5	6	5	5	4	5	-	-	5	2	4.80
96	??	39	37.0	??	5	5	5	5	5	6	-	5	4	5	-	-	5	2	5.00
96	??	40	37.0	??	5	4	4	5	5	6	3	5	5	4	-	-	5	3	4.60
96	??	41	37.0	??	5	5	5	5	5	6	4	5	5	4	-	-	5	2	4 90
96	??	42	37.0	??	5	5	5	4	4	6	3	4	4	5	-	-	5	3	4.50
96	??	43	39.0	??	4	5	5	5	5	6	3	4	5	4	-	-	5	3	4 60
96	??	44	39.0	??	4	4	5	5	5	5	3	4	5	4	-	-	5	2	4 40
96	??	45	39.0	??	3	5	4	4	5	5	3	3	4	3	-	-	3	2	3 90
96	??	46	40.0	??	8	6	8	9	7	9	7	8	9	8	-	-	8	3	7.90
96	??	47	40.0	??	3	5	3	6	6	4	3	3	4	3	-	-	3	3	4 00
96	??	48	41.0	??	7	6	7	7	7	8	6	7	7	7	-	-	7	2	6 90
96	??	49	41 0	??	5	5	5	5	6	5	4	5	5	5	-	-	5	2	5 00
96	??	50	41.0	??	3	5	5	5	5	4	3	3	4	4	-	-	5	2	4.10
96	??	51	43.0	??	6	6	6	5	7	8	6	7	4	7	-	-	6	4	6 20
96	??	52	43.0	??	4	4	4	5	5	4	3	4	4	4	-	-	4	2	4.10
96	??	53	44.0	??	4	5	4	5	5	4	4	4	4	4	-	-	4	1	4.30
96	??	54	44.0	??	3	4	4	4	5	4	3	3	4	3	-	-	4	2	3.70
96	??	55	45 0	??	3	4	4	5	5	4	3	4	4	4	-	-	4	2	4.00
96	??	56	46.0	??	5	6	6	5	6	6	4	4	5	4	-	-	6	2	5.10
96	??	57	46.0	??	3	6	5	5	4	4	4	4	4	3	-	-	4	3	4 20
96	??	58	47.0	??	5	6	-	5	4	5	5	-	5	5	-	-	5	2	5 00
96	??	59	48 0	??	4	8	4	6	6	4	4	4	4	4	-	-	4	4	4.80
96	??	60	50.0	??	8	7	8	8	8	10	6	7	7	8	-	-	8	4	7 70
96	??	101	13.0	??	0	0	0	0	1	0	1	0	0	0	-	-	0	1	0.20
96	??	102	14.0	??	0	0	0	0	3	0	2	0	0	0	-	-	0	3	0.50
96	??	103	16.0	??	0	1	1	1	1	1	1	1	1	1	-	-	1	1	0.90
96	??	104	17.0	??	1	1	1	1	3	1	3	1	1	1	-	-	1	2	1 40
96	??	105	18.0	??	1	1	1	1	2	1	2	1	1	1	-	-	1	1	1 20
96	??	106	19 0	??	1	1	1	1	3	2	2	1	1	0	-	-	1	3	1 30
96	??	107	20 0	??	2	2	2	2	2	3	2	3	2	2	-	-	2	1	2 30
96	??	108	21 0	??	2	2	3	2	2	3	3	2	2	2	-	-	2	1	2.30
96	??	109	22.0	??	2	2	2	3	3	3	2	3	2	2	-	-	2	1	2.40
96	??	110	22 0	??	1	2	2	2	2	3	2	2	1	2	-	-	2	2	1 90
96	??	111	23 0	??	1	2	2	2	4	3	3	1	2	1	-	-	2	3	2 10
96	??	112	24.0	??	2	2	2	2	3	3	3	2	2	2	-	-	2	1	2 30
96	??	113	25.0	??	2	2	2	2	2	3	2	2	2	2	-	-	2	1	2.10
96	??	114	25.0	??	1	2	2	2	2	3	2	1	1	1	-	-	2	2	1 70
96	??	115	25 0	??	1	2	2	2	2	2	2	1	2	2	-	-	2	1	1 80
96	??	116	26 0	??	3	3	3	2	3	3	3	3	2	2	-	-	3	1	2 70
96	??	117	27.0	??	2	2	2	3	3	2	2	2	2	2	-	-	2	1	2 20
96	??	118	27.0	??	2	3	4	3	4	2	2	3	2	2	-	-	2	2	2 70
96	??	119	28.0	??	2	3	4	4	5	3	2	3	2	3	-	-	3	3	3.10
96	??	120	28.0	??	2	2	4	2	3	3	3	3	2	2	-	-	2	2	2.60
96	??	121	29 0	??	3	3	7	4	3	6	3	4	4	4	-	-	3	4	4 10
96	??	122	29.0	??	2	2	2	3	3	3	2	2	2	2	-	-	2	1	2 30
96	??	123	29.0	??	3	3	4	3	3	4	3	3	3	3	-	-	3	1	3 20
96	??	124	30.0	??	2	3	2	3	3	4	2	2	2	3	-	-	2	2	2 60
96	??	125	31.0	??	5	3	5	5	4	6	4	5	4	5	-	-	5	3	4 60
96	??	126	31.0	??	3	3	-	4	4	5	3	4	4	2	-	-	4	3	3 56
96	??	127	31.0	??	2	3	2	3	3	3	3	2	3	2	-	-	3	1	2 60
96	??	128	31 0	??	2	3	3	2	3	2	3	3	2	2	-	-	2	1	2.50
96	??	129	32 0	??	3	4	5	4	4	4	4	5	3	4	-	-	4	2	4 00
96	??	130	33 0	??	6	4	7	4	6	7	5	7	-	7	-	-	7	3	5.89
96	??	131	33.0	??	5	4	5	4	5	5	4	5	4	4	-	-	5	1	4 50
96	??	132	33 0	??	2	3	2	3	3	3	3	2	2	2	-	-	2	1	2.50
96	??	133	34.0	??	6	5	6	5	5	7	5	6	5	6	-	-	5	2	5 60
96	??	134	34.0	??	4	4	5	4	5	5	4	5	4	5	-	-	4	1	4 50
96	??	135	34.0	??	3	3	4	4	3	3	2	3	2	2	-	-	3	2	2.90
96	??	136	35 0	??	6	5	7	6	6	7	6	7	6	7	-	-	6	2	6 30
96	??	137	36.0	??	3	3	3	4	4	4	3	3	3	3	-	-	3	1	3.30
96	??	138	36.0	??	3	3	3	3	4	5	3	4	3	2	-	-	3	3	3 30
96	??	139	37 0	??	3	3	5	4	5	4	3	3	3	3	-	-	3	2	3.60

96	??	140	37.0	??	-	3	-	4	5	4	3	3	-	4	-	-	3	2	3.71
96	??	141	37.0	??	3	4	4	5	4	4	4	3	3	2	-	-	4	3	3.60
96	??	142	37.0	??	3	3	3	4	4	3	3	3	3	2	-	-	3	2	3.10
96	??	143	38.0	??	4	4	4	5	5	4	3	4	4	4	-	-	4	2	4.10
96	??	144	38.0	??	4	4	4	4	5	5	4	4	4	4	-	-	4	1	4.20
96	??	145	39.0	??	7	7	8	7	8	9	7	9	7	7	-	-	7	2	7 60
96	??	146	39.0	??	5	4	5	4	5	5	5	5	3	3	-	-	5	2	4.40
96	??	147	40.0	??	3	4	4	4	6	3	3	3	3	3	-	-	3	3	3.60
96	??	148	41 0	??	6	6	7	7	6	7	5	8	5	7	-	-	7	3	6.40
96	??	149	41.0	??	4	5	5	5	6	5	4	4	3	5	-	-	5	3	4.60
96	??	150	41.0	??	3	4	4	4	5	3	3	3	3	9	-	-	3	6	4.10
96	??	151	41.0	??	3	4	4	4	5	4	3	3	3	3	-	-	3	2	3.60
96	??	152	42.0	??	8	5	8	7	8	9	3	8	7	3	-	-	8	6	6.60
96	??	153	43.0	??	6	6	6	5	6	6	6	6	5	5	-	-	6	1	5.70
96	??	154	43.0	??	6	6	7	5	6	5	5	6	5	6	-	-	6	2	5.70
96	??	155	44.0	??	5	6	5	6	5	5	5	5	5	4	-	-	5	2	5 10
96	??	156	45.0	??	9	7	10	8	9	9	7	10	8	9	-	-	9	3	8 60
96	??	157	45 0	??	4	4	6	5	5	4	5	4	3	4	-	-	4	3	4.40
96	??	158	46 0	??	8	7	8	7	8	8	7	9	6	7	-	-	8	3	7 50
96	??	159	46 0	??	7	7	9	7	9	8	7	8	7	8	-	-	7	2	7 70
96	??	160	47 0	??	5	5	5	6	5	6	4	5	3	5	-	-	5	3	4.90
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96	??		??	??	-	-	-	-	-	-	-	-	-	-	-	-			
96	??		??	??	-	-	-	-	-	-	-	-	-	-	-	-			
96	??		??	??	-	-	-	-	-	-	-	-	-	-	-	-			
96	??		??	??	-	-	-	-	-	-	-	-	-	-	-	-			
96	??		??	??	-	-	-	-	-	-	-	-	-	-	-	-			
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96	??		??	??	-	-	-	-	-	-	-	-	-	-	-	-			
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				Total read	119	120	117	120	120	120	119	119	117	120	0	0			
				Total NOT read	1	0	3	0	0	0	1	1	3	0	120	120			
				Empty rows	80	80	80	80	80	80	80	80	80	80	80	80			

WHITING OTOLITH EXCHANGE 1998 broken material

Table 4.1.3 The mean age recorded, 2stdev, the number of age readings and the agreement with modal age are presented by modal age for each reader and for all readers combined. The number of age readings and the agreement is given for age groups 0-15 combined.

Reader 1 (Sco)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	0.00	0.93	1.81	2.82	3.61	4.74	5.80	6.67	8.00	9.00	-	-	-	-	-	-	
2stdev	0.00	0.53	0.80	0.78	1.00	1.31	0.89	1.03	0.00	#####	-	-	-	-	-	-	
Number of age readings	2	14	21	28	18	19	5	6	5	1	-	-	-	-	-	-	119
Agreement with modal age	100%	93%	81%	82%	61%	68%	80%	67%	100%	100%	-	-	-	-	-	-	78%

Reader 2 (Nor)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	0.00	1.00	2.19	3.38	4.33	4.68	5.80	5.83	6.00	7.00	-	-	-	-	-	-	
2stdev	0.00	0.00	0.80	1.35	2.28	1.50	0.89	2.34	2.00	#####	-	-	-	-	-	-	
Number of age readings	2	14	21	29	18	19	5	6	5	1	-	-	-	-	-	-	120
Agreement with modal age	100%	100%	81%	62%	67%	53%	80%	33%	0%	0%	-	-	-	-	-	-	66%

Reader 3 (Ger)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	0.00	1.07	2.29	3.61	4.35	5.00	6.40	7.50	8.00	10.00	-	-	-	-	-	-	
2stdev	0.00	0.53	1.29	1.99	1.21	0.69	1.10	1.67	0.00	#####	-	-	-	-	-	-	
Number of age readings	2	14	21	28	17	18	5	6	5	1	-	-	-	-	-	-	117
Agreement with modal age	100%	93%	81%	54%	71%	89%	60%	67%	100%	0%	-	-	-	-	-	-	74%

Reader 4 (Swe)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	0.00	1.50	2.33	3.69	4.50	5.05	5.20	6.33	7.20	8.00	-	-	-	-	-	-	
2stdev	0.00	1.04	0.97	1.42	1.57	1.24	0.89	2.42	2.97	#####	-	-	-	-	-	-	
Number of age readings	2	14	21	29	18	19	5	6	5	1	-	-	-	-	-	-	120
Agreement with modal age	100%	50%	67%	31%	33%	63%	20%	67%	20%	0%	-	-	-	-	-	-	47%

Reader 5 (Bel1)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	2.00	3.21	3.14	4.59	4.83	5.00	6.20	7.00	7.80	9.00	-	-	-	-	-	-	
2stdev	2.83	1.95	1.71	1.97	1.24	1.15	0.89	2.53	0.89	#####	-	-	-	-	-	-	
Number of age readings	2	14	21	29	18	19	5	6	5	1	-	-	-	-	-	-	120
Agreement with modal age	0%	7%	24%	17%	28%	68%	80%	17%	80%	100%	-	-	-	-	-	-	33%

Reader 6 (Den1)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	0.00	1.86	2.81	3.86	4.39	5.58	6.40	7.83	9.00	9.00	-	-	-	-	-	-	
2stdev	0.00	1.33	1.02	1.67	1.00	1.38	2.28	1.51	1.41	#####	-	-	-	-	-	-	
Number of age readings	2	14	21	29	18	19	5	6	5	1	-	-	-	-	-	-	120
Agreement with modal age	100%	29%	24%	38%	61%	37%	40%	33%	20%	100%	-	-	-	-	-	-	38%

Reader 7 (Den2)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	1.50	2.14	2.48	2.97	3.78	4.17	5.40	6.00	5.80	7.00	-	-	-	-	-	-	
2stdev	1.41	1.73	1.02	0.65	1.29	1.85	1.79	1.79	3.29	#####	-	-	-	-	-	-	
Number of age readings	2	14	21	29	18	18	5	6	5	1	-	-	-	-	-	-	119
Agreement with modal age	0%	29%	52%	90%	56%	33%	60%	33%	0%	0%	-	-	-	-	-	-	52%

Reader 8 (Eng)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	0.00	1.36	2.10	3.17	4.11	4.72	6.00	7.67	8.00	10.00	-	-	-	-	-	-	
2stdev	0.00	0.99	1.25	1.20	1.17	1.34	2.45	1.63	1.41	#####	-	-	-	-	-	-	
Number of age readings	2	14	21	29	18	18	5	6	5	1	-	-	-	-	-	-	119
Agreement with modal age	100%	64%	62%	72%	67%	67%	40%	50%	60%	0%	-	-	-	-	-	-	65%

Reader 9 (Ire)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	0.00	1.29	1.90	2.93	3.78	4.37	5.00	6.60	7.25	8.00	-	-	-	-	-	-	
2stdev	0.00	0.94	0.60	1.08	0.86	1.52	1.41	1.79	2.52	#####	-	-	-	-	-	-	
Number of age readings	2	14	21	28	18	19	5	5	4	1	-	-	-	-	-	-	117
Agreement with modal age	100%	71%	90%	71%	78%	53%	20%	80%	0%	0%	-	-	-	-	-	-	68%

Reader 10 (Net)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	0.00	0.93	2.00	3.14	3.83	4.74	5.80	7.33	6.80	9.00	-	-	-	-	-	-	
2stdev	0.00	0.53	0.89	2.60	1.71	1.87	2.61	1.03	4.34	#####	-	-	-	-	-	-	
Number of age readings	2	14	21	29	18	19	5	6	5	1	-	-	-	-	-	-	120
Agreement with modal age	100%	93%	81%	55%	61%	42%	20%	67%	60%	100%	-	-	-	-	-	-	63%

Reader 11 (Fra)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
2stdev	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Number of age readings	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Agreement with modal age	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	#DIV/0!

Reader 12 (N Ire)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
2stdev	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Number of age readings	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Agreement with modal age	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	#DIV/0!

ALL READERS	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	0.35	1.53	2.30	3.42	4.15	4.81	5.80	6.88	7.39	8.60	-	-	-	-	-	-	
2stdev	1.63	1.74	1.32	1.86	1.55	1.57	1.76	2.17	2.82	2.15	-	-	-	-	-	-	
Number of age readings	20	140	210	287	179	187	50	59	49	10	-	-	-	-	-	-	1191
Agreement with modal age	80%	63%	64%	57%	58%	57%	50%	51%	45%	40%	-	-	-	-	-	-	58%

Table 4.1.4 **WHITING OTOLITH EXCHANGE 1998 sectioned material**

					SR	SR	SR	SR	SR	BR	BR	BR	BR	BR	BR	BR			
		Fish	Fish	Landing	Eng	N Ire	Fra	Ire	Net	Sco	Ger	Swe	Nor	Bel	Den1	Den2	MODAL	Age	
Year	Sample	no	length	month	Reader 1	Reader 2	Reader 3	Reader 4	Reader 5	Reader 6	Reader 7	Reader 8	Reader 9	Reader 10	Reader 11	Reader 12	AGE	difference	Average
96	??	61	28.0	??	2	2	2	3	4	2	3	3	3	5	2	3	2	3	2.83
96	??	62	29 0	??	2	2	2	4	2	2	3	4	3	5	2	3	2	3	2.83
96	??	63	30 0	??	3	3	3	3	3	3	7	4	3	5	3	4	3	4	3.67
96	??	64	31.0	??	2	2	2	3	4	3	2	3	3	5	2	3	2	3	2.83
96	??	65	32.0	??	3	3	3	3	3	3	3	3	3	6	3	3	3	3	3.25
96	??	66	33 0	??	3	3	3	3	3	3	3	4	3	5	3	3	3	2	3.25
96	??	67	34.0	??	6	6	6	6	6	6	6	5	4	7	6	6	6	3	5.83
96	??	68	35 0	??	5	4	3	4	4	4	2	5	4	5	3	4	4	3	3.92
96	??	69	36.0	??	5	4	4	4	5	4	3	4	4	5	4	3	4	2	4.08
96	??	70	37.0	??	4	4	4	4	4	4	3	4	4	5	4	4	4	2	4.00
96	??	71	38.0	??	4	4	4	4	4	4	3	5	4	7	4	4	4	4	4.25
96	??	72	39.0	??	5	5	5	4	5	5	5	6	5	7	5	4	5	3	5.08
96	??	73	40.0	??	-	-	-	-	5	5	-	4	5	6	-	3	5	3	4.67
96	??	74	41.0	??	3	3	3	3	3	4	3	4	4	6	3	3	3	3	3.50
96	??	75	42 0	??	4	3	3	3	3	3	3	4	4	6	3	3	3	3	3 50
96	??	76	43 0	??	4	4	4	4	4	4	4	4	4	6	4	4	4	2	4.17
96	??	1	34.0	??	3	3	4	5	4	3	3	3	4	5	3	3	3	2	3.58
96	??	2	35 0	??	4	4	4	4	4	4	3	4	4	5	4	4	4	2	4.00
96	??	3	35.0	??	3	3	4	3	3	3	3	3	4	6	3	5	3	3	3.58
96	??	4	37 0	??	3	3	3	3	3	3	3	3	4	6	3	3	3	3	3 33
96	??	5	37.0	??	3	3	3	3	3	3	3	4	4	6	3	3	3	3	3 42
96	??	6	28 0	??	2	2	2	2	2	2	2	3	3	4	3	2	2	2	2.42
96	??	7	28.0	??	2	2	2	2	2	2	2	3	3	4	2	2	2	2	2.33
96	??	8	29.0	??	2	4	3	3	3	3	3	4	4	6	5	3	3	4	3.58
96	??	9	29.0	??	2	2	2	2	2	2	2	4	3	5	3	3	2	3	2 67
96	??	10	29.0	??	2	2	2	2	2	2	3	4	3	6	3	3	2	4	2.83
96	??	11	29.0	??	2	2	2	2	3	2	2	3	3	4	2	2	2	2	2.42
96	??	12	29.0	??	2	2	2	2	2	2	3	3	3	5	4	2	2	3	2.67
96	??	13	31 0	??	3	3	3	3	3	3	3	3	4	5	3	3	3	2	3.25
96	??	14	30.0	??	2	3	4	3	4	3	3	4	4	8	3	2	3	6	3 58
96	??	15	30.0	??	3	3	3	3	3	3	3	5	4	6	3	3	3	3	3.50
96	??	161	27.0	??	2	2	2	2	2	2	2	2	3	7	2	4	2	5	2.67
96	??	162	28.0	??	3	3	4	3	3	3	3	3	4	3	4	3	3	1	3.25
96	??	163	29.0	??	3	2	2	2	2	2	2	3	4	4	3	3	2	2	2.67
96	??	164	30.0	??	2	2	2	2	2	2	2	3	3	3	2	2	2	1	2 25
96	??	165	31.0	??	5	5	5	5	5	5	5	5	5	5	6	4	5	2	5 00
96	??	166	32.0	??	7	6	6	6	7	7	7	8	6	7	8	6	7	2	6.75
96	??	167	33.0	??	5	5	5	5	4	5	5	6	5	5	6	4	5	2	5.00
96	??	168	34.0	??	7	7	7	6	5	7	7	7	7	7	9	6	7	4	6 83
96	??	169	35 0	??	6	5	5	6	5	5	5	5	5	6	6	5	5	1	5.33
96	??	170	36 0	??	5	4	5	4	4	4	5	5	5	6	5	5	5	2	4.75
96	??	171	37.0	??	6	5	6	5	5	5	5	7	6	6	7	5	5	2	5.67
96	??	172	38.0	??	7	7	7	6	7	7	7	7	7	7	8	6	7	2	6.92
96	??	173	39.0	??	6	6	6	5	5	6	5	5	6	6	6	5	6	1	5.58
96	??	174	40 0	??	7	6	6	6	6	6	6	7	6	8	6	5	6	3	6 25
96	??	175	41.0	??	5	4	4	4	4	4	5	6	5	6	5	4	4	2	4.67
96	??	176	42.0	??	6	6	6	6	5	5	6	5	6	7	6	6	6	2	5 83
96	??	16	27.0	??	2	2	2	2	2	2	2	2	3	4	2	2	2	2	2.25
96	??	17	28 0	??	2	2	2	2	2	2	2	3	3	4	2	2	2	2	2.33
96	??	18	28.0	??	2	2	2	2	2	2	2	2	3	4	3	2	2	2	2.33
96	??	19	29 0	??	3	4	4	2	4	3	3	3	4	4	4	3	4	2	3 42
96	??	20	29 0	??	2	2	3	3	3	2	2	2	3	5	3	3	3	3	2.75
96	??	21	29.0	??	2	2	2	2	2	2	2	2	3	5	2	2	2	3	2.33
96	??	22	29.0	??	2	2	3	2	2	2	2	3	3	5	2	2	2	3	2.50
96	??	23	29.0	??	2	2	3	2	2	2	2	2	3	4	2	2	2	2	2.33
96	??	24	31 0	??	2	2	2	2	2	2	2	2	3	4	2	2	2	2	2.25
96	??	25	31 0	??	2	2	2	2	2	2	2	2	3	4	2	2	2	2	2 25
96	??	26	31.0	??	2	2	2	2	2	2	2	2	3	4	2	2	2	2	2 25
96	??	27	31 0	??	3	3	3	3	3	3	3	4	4	6	4	4	3	3	3 58
96	??	28	32.0	??	3	4	4	4	4	4	5	4	4	6	4	5	4	3	4 25
96	??	29	32.0	??	2	2	2	2	2	2	2	2	3	4	2	2	2	2	2 25
96	??	30	32 0	??	3	3	4	3	3	3	2	3	4	5	3	3	3	3	3 25
96	??		??	??	-	-	-	-	-	-	-	-	-	-	-	-			
96	??		??	??	-	-	-	-	-	-	-	-	-	-	-	-			
96	??		??	??	-	-	-	-	-	-	-	-	-	-	-	-			
96	??		??	??	-	-	-	-	-	-	-	-	-	-	-	-			
96	??		??	??	-	-	-	-	-	-	-	-	-	-	-	-			
96	??		??	??	-	-	-	-	-	-	-	-	-	-	-	-			
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96	??		??	??	-	-	-	-	-	-	-	-	-	-	-	-			
96	??		??	??	-	-	-	-	-	-	-	-	-	-	-	-			
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96	??		??	??	-	-	-	-	-	-	-	-	-	-	-	-			
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96	??		??	??	-	-	-	-	-	-	-	-	-	-	-	-			
96	??		??	??	-	-	-	-	-	-	-	-	-	-	-	-			

96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
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96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
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96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
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96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
96	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
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??	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
??	??	??	??	-	-	-	-	-	-	-	-	-	-	-	-
			Total read	61	61	61	61	62	62	61	62	62	62	61	62
			Total NOT read	1	1	1	1	0	0	1	0	0	0	1	0
			Empty rows	138	138	138	138	138	138	138	138	138	138	138	138

WHITING OTOLITH EXCHANGE 1998 sectioned material

Table 4.1.5 The mean age recorded, 2stdev, the number of age readings and the agreement with modal age are presented by modal age for each reader and for all readers combined. The number of age readings and the agreement is given for age groups 0-15 combined.

Reader 1
Eng

Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	-	-	2.05	2.88	4.11	5.33	6.25	7.00	-	-	-	-	-	-	-	-	
2stdev	-	-	0.43	0.97	1.56	1.03	1.00	0.00	-	-	-	-	-	-	-	-	
Number of age readings	-	-	22	17	9	6	4	3	-	-	-	-	-	-	-	-	61
Agreement with modal age	-	-	95%	76%	44%	67%	75%	100%	-	-	-	-	-	-	-	-	79%

Reader 2
N Ire

Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	-	-	2.00	3.00	4.00	4.83	6.00	6.67	-	-	-	-	-	-	-	-	
2stdev	-	-	0.00	0.71	0.00	0.82	0.00	1.15	-	-	-	-	-	-	-	-	
Number of age readings	-	-	22	17	9	6	4	3	-	-	-	-	-	-	-	-	61
Agreement with modal age	-	-	100%	88%	100%	83%	100%	67%	-	-	-	-	-	-	-	-	93%

Reader 3
Fra

Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	-	-	2.09	3.29	3.89	5.17	6.00	6.67	-	-	-	-	-	-	-	-	
2stdev	-	-	0.59	0.94	0.67	0.82	0.00	1.15	-	-	-	-	-	-	-	-	
Number of age readings	-	-	22	17	9	6	4	3	-	-	-	-	-	-	-	-	61
Agreement with modal age	-	-	91%	71%	89%	83%	100%	67%	-	-	-	-	-	-	-	-	84%

Reader 4
Ire

Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	-	-	2.18	3.12	3.78	4.83	5.75	6.00	-	-	-	-	-	-	-	-	
2stdev	-	-	1.00	0.97	1.33	1.51	1.00	0.00	-	-	-	-	-	-	-	-	
Number of age readings	-	-	22	17	9	6	4	3	-	-	-	-	-	-	-	-	61
Agreement with modal age	-	-	86%	94%	89%	50%	75%	0%	-	-	-	-	-	-	-	-	80%

Reader 5
Net

Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	-	-	2.23	3.12	4.11	4.71	5.50	6.33	-	-	-	-	-	-	-	-	
2stdev	-	-	1.22	0.66	0.67	0.98	1.15	2.31	-	-	-	-	-	-	-	-	
Number of age readings	-	-	22	17	9	7	4	3	-	-	-	-	-	-	-	-	62
Agreement with modal age	-	-	86%	88%	89%	71%	50%	67%	-	-	-	-	-	-	-	-	82%

Reader 6
Sco

Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	-	-	2.05	3.00	3.89	4.86	5.75	7.00	-	-	-	-	-	-	-	-	
2stdev	-	-	0.43	0.71	0.67	0.76	1.00	0.00	-	-	-	-	-	-	-	-	
Number of age readings	-	-	22	17	9	7	4	3	-	-	-	-	-	-	-	-	62
Agreement with modal age	-	-	95%	88%	89%	86%	75%	100%	-	-	-	-	-	-	-	-	90%

Reader 7
Ger

Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	-	-	2.18	3.12	3.44	5.00	5.75	7.00	-	-	-	-	-	-	-	-	
2stdev	-	-	0.79	2.11	2.03	0.00	1.00	0.00	-	-	-	-	-	-	-	-	
Number of age readings	-	-	22	17	9	6	4	3	-	-	-	-	-	-	-	-	61
Agreement with modal age	-	-	82%	82%	11%	100%	75%	100%	-	-	-	-	-	-	-	-	74%

Reader 8
Swe

Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	-	-	2.73	3.53	4.33	5.43	5.50	7.33	-	-	-	-	-	-	-	-	
2stdev	-	-	1.41	1.43	1.73	1.95	2.00	1.15	-	-	-	-	-	-	-	-	
Number of age readings	-	-	22	17	9	7	4	3	-	-	-	-	-	-	-	-	62
Agreement with modal age	-	-	41%	41%	56%	43%	0%	67%	-	-	-	-	-	-	-	-	42%

Reader 9
Nor

Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	-	-	3.05	3.76	4.11	5.14	5.50	6.67	-	-	-	-	-	-	-	-	
2stdev	-	-	0.43	0.87	0.67	0.76	2.00	1.15	-	-	-	-	-	-	-	-	
Number of age readings	-	-	22	17	9	7	4	3	-	-	-	-	-	-	-	-	62
Agreement with modal age	-	-	0%	24%	89%	86%	75%	67%	-	-	-	-	-	-	-	-	37%

Reader 10
Bel

Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	-	-	4.50	5.59	5.44	5.86	7.00	7.00	-	-	-	-	-	-	-	-	
2stdev	-	-	1.72	2.01	1.76	1.38	1.63	0.00	-	-	-	-	-	-	-	-	
Number of age readings	-	-	22	17	9	7	4	3	-	-	-	-	-	-	-	-	62
Agreement with modal age	-	-	0%	6%	11%	29%	25%	100%	-	-	-	-	-	-	-	-	13%

Reader 11
Den1

Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	-	-	2.32	3.24	4.00	5.83	6.00	8.33	-	-	-	-	-	-	-	-	
2stdev	-	-	1.14	1.12	1.00	1.51	0.00	1.15	-	-	-	-	-	-	-	-	
Number of age readings	-	-	22	17	9	6	4	3	-	-	-	-	-	-	-	-	61
Agreement with modal age	-	-	73%	82%	78%	33%	100%	0%	-	-	-	-	-	-	-	-	70%

Reader 12
Den2

Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	-	-	2.36	3.18	3.89	4.29	5.50	6.00	-	-	-	-	-	-	-	-	
2stdev	-	-	1.16	1.27	1.20	1.51	1.15	0.00	-	-	-	-	-	-	-	-	
Number of age readings	-	-	22	17	9	7	4	3	-	-	-	-	-	-	-	-	62
Agreement with modal age	-	-	68%	76%	67%	43%	50%	0%	-	-	-	-	-	-	-	-	63%

ALL READERS

Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	-	-	2.48	3.40	4.08	5.10	5.88	6.83	-	-	-	-	-	-	-	-	
2stdev	-	-	1.66	1.85	1.50	1.43	1.34	1.47	-	-	-	-	-	-	-	-	
Number of age readings	-	-	264	204	108	78	48	36	-	-	-	-	-	-	-	-	738
Agreement with modal age	-	-	68%	68%	68%	64%	67%	61%	-	-	-	-	-	-	-	-	67%

WHITING OTOLITH EXCHANGE 1998 broken material

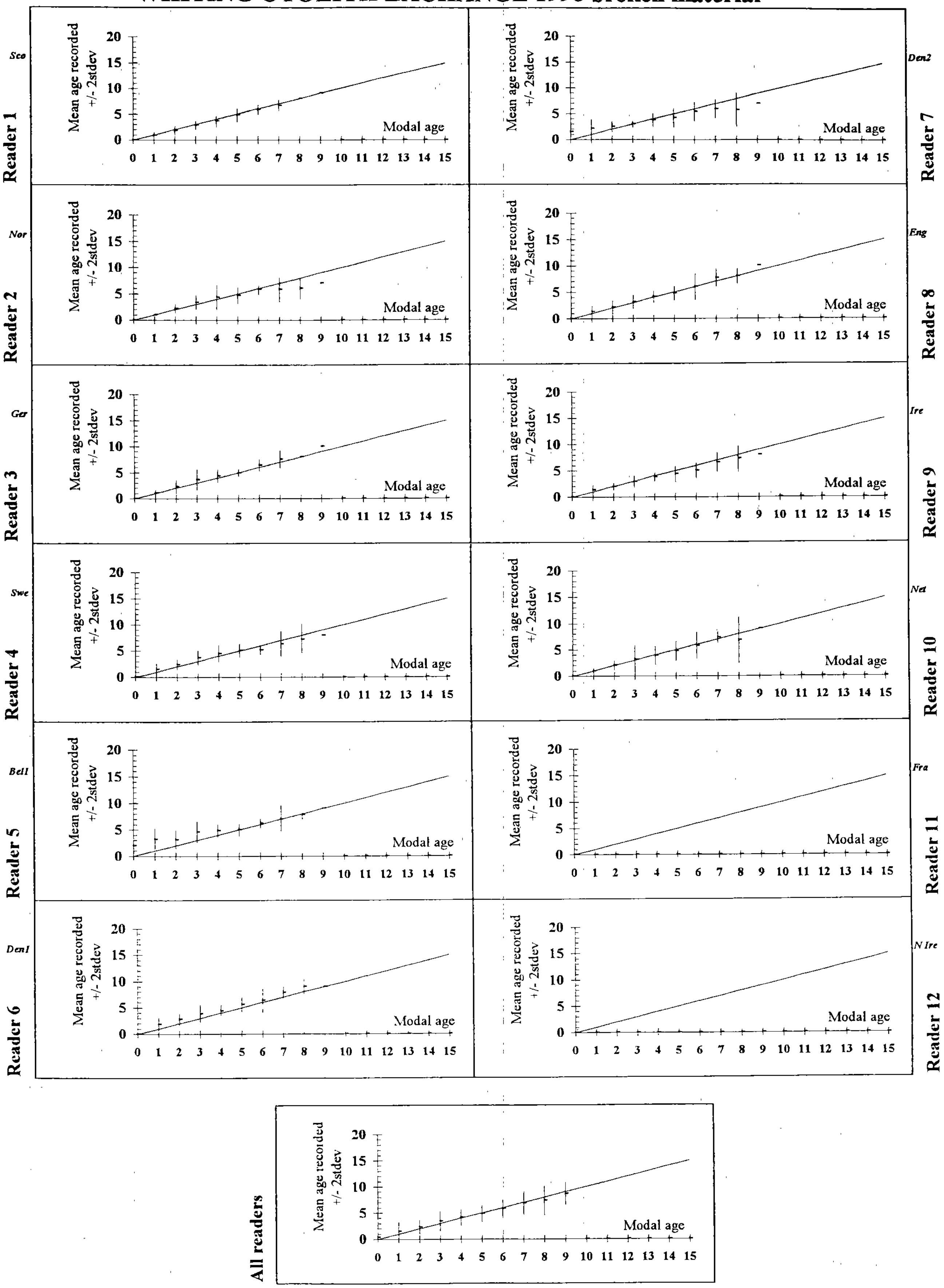


Figure 4.1.1 In above age bias plots the mean age recorded +/- 2stdev of each age reader and all readers combined is plotted against the modal age.

WHITING OTOLITH EXCHANGE 1998 sectioned material

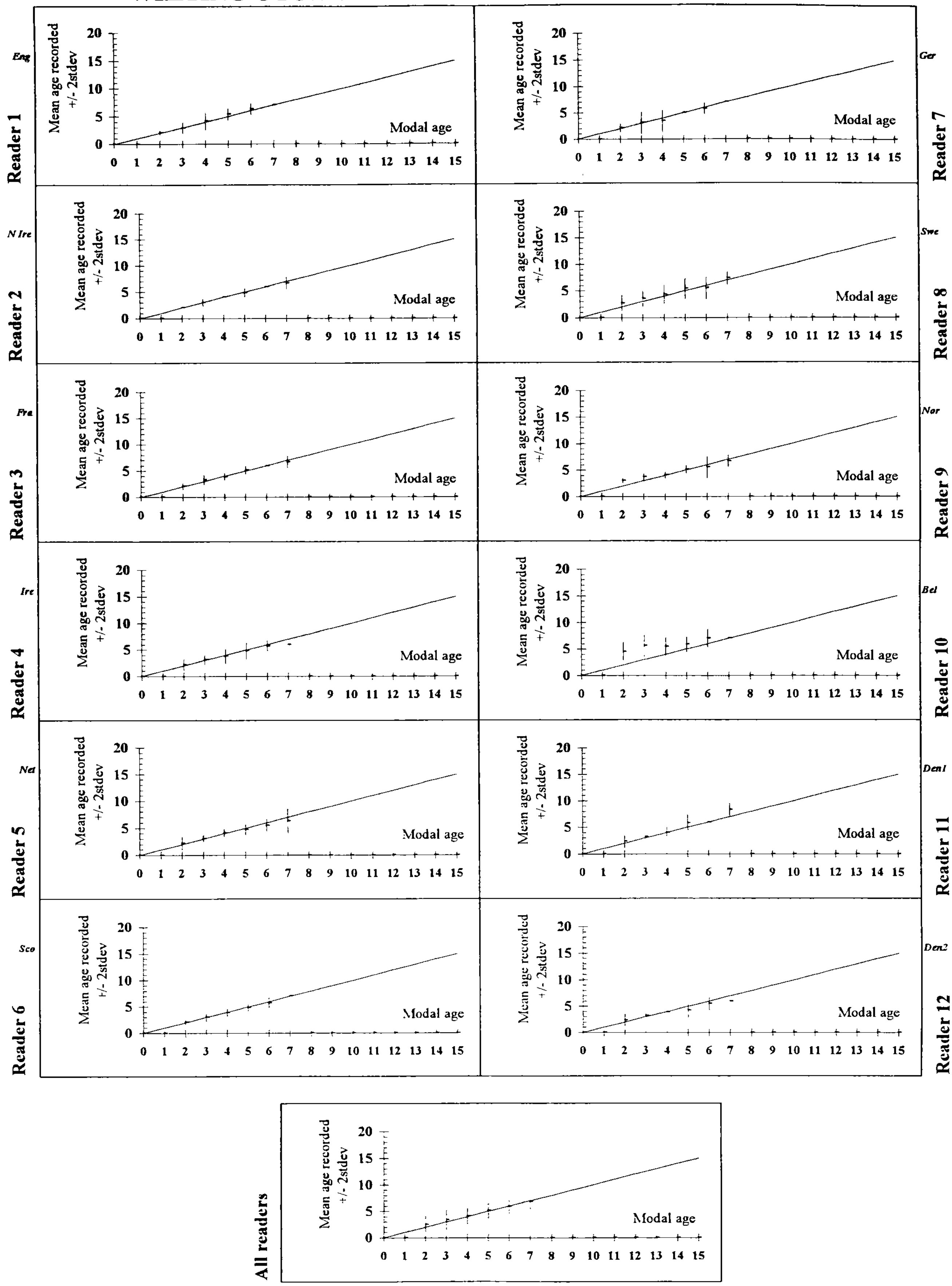


Figure 4.1.2 In above age bias plots the mean age recorded +/- 2stdev of each age reader and all readers combined is plotted against the modal age.

4.2 National procedures

Belgium

After removal from the fish, the otoliths are cleaned, dried and stored in small paper envelopes. Whiting otoliths are broken across the nucleus. If the otolith is not properly broken across the nucleus, a dry grinding stone is used to remove further material. In order to determine the age, the otoliths are submerged in methanol and read against a black background using a binocular microscope. The annuli are counted by looking at the broken surface. Usually there are two broken surfaces that can be looked at for each fish. All otolith orientations are used. Top light and side light from the microscope bench lamp is used to illuminate the otolith. Only reflected light is used. The microscope is a 'Stemi 200' Zeiss instrument with x10 eyepieces and varying objective magnifications (x0.65-x4.5). The preferred magnifications are the smallest ones (x6.5-x10), but sometimes the readers switch to larger magnifications.

There are two whiting otolith readers in the institute. One of them has read and prepared otoliths for at least 15 years. It must be said, however, that it is only in the last three years that a regular market sampling program for whiting has existed. This provides about a thousand otoliths a year. Prior to 1995 the number of whiting otoliths varied. The second otolith reader has only just joined the reading process.

Denmark

To look at the otoliths we use a binocular microscope with a magnification from x6.3 to x16. To provide the light we use a free standing bench lamp or a cold light lamp. To break the otoliths we use our fingernails or a small wire cutter. If it is not broken in the right place we have a low speed grinding machine standing next to the microscope. The grinding stone is a fine one, 150mm in diameter, dipped into water and turning at 150 rpm. We hold the otolith very carefully with our fingers and grind till we have reached the nucleus. The otolith is held by a pair of tweezers and dipped into water or alcohol, or a mixture of both. The Hirtshals readers prefer to use reflected light and the Charlottenlund reader has put up the lamp so that he can switch between reflected and side transmitted light.

Whiting otoliths are not sampled from the commercial fishery in the North Sea on a regular basis due to the fact that there are very small landings of this species for human consumption. Whiting more or less only occur in the small-mesh fishery for industrial purposes. From this fishery the institute gets around 400 samples spread over the year and since whiting are not present in them all we do not get a large amount of whiting otoliths from the commercial fishery; we obtain the bulk of our whiting otoliths from Danish research vessel surveys. From the surveys we get some otoliths depending on the area DANA has to cover on the 2 yearly trips to the North Sea. The amount of otoliths varies between 400 to 1500 per survey. The last 4 years of whiting otoliths have not been read, due to lack of personnel. The otoliths are archived in Charlottenlund.

The experience of reading whiting otoliths is connected to 2 different departments, one in Hirtshals, reading the otoliths from the industrial landings, and one in Charlottenlund, reading whiting otoliths from the discard sampling programme covering the Kattegat and the Baltic. None of the readers have much experience with whiting, but have some or a lot of experience in reading other gadoid species.

England

Otoliths are embedded in black polyester resin blocks. Thin sections (0.6–0.7mm) are cut from the blocks using an adapted engineering surface grinding machine fitted with an industrial diamond grit saw blade run at high speed (3,000rpm). The sections are mounted on glass microscope slides using clear resin and the top surface is protected with a glass cover slip. There are a large number of otolith readers in the institute but North Sea whiting are read or checked by one person only. The preferred equipment of that reader is a binocular microscope set at x6.25 magnification. Occasionally older fish otoliths may be viewed at x12.5. Lighting is provided by a free standing bench lamp adjustable both for focus and brightness. Reflected light is preferred but bottom transmitted light may also be used. All combinations of lighting and otolith orientation may be used with difficult otoliths. Whiting otoliths are sometimes read using camera and monitor equipment when the age will be determined by a committee of 2 or 3 readers of varying experience. The person responsible for North Sea whiting ageing has 30 years experience of otolith reading with 10 years on whiting, recently reading 5–7000 a year. He also has extensive experience with both preparation methods (broken and sectioned).

France

Otoliths are encapsulated in resin blocks. Originally clear resin was used but now it is coloured black. Two or three thin sections (0.2–0.3mm) are cut from each row of otoliths to be sure to have a least one of the sections passing through the nucleus. The cutting is done with a high-speed industrial machine and a diamond grit saw blade. The sections are not mounted so before reading both surfaces are 'cleared' with oil. The equipment used for reading is a binocular microscope with x8-x15 magnification, fitted with a camera and monitor display. Transmitted light is used from a source adjustable for brightness. Reading is done from the monitor.

North Sea and English Channel whiting otoliths are read from surveys and a market-sampling program. The reader has 15 years experience of gadoid ageing, reading 4–5,000 whiting otoliths a year.

Germany

The otoliths are sawed through the centre. They are investigated by side light from a free standing bench lamp with the surface shaded. That means, they are analysed by transmitted light under a binocular microscope, mostly set at x10 magnification.

The main reader has 13 years of otolith reading experience on different gadoid species, including whiting (ca.3000/year).

Ireland

Method 1. This method is used for all otoliths from commercially sized fish from market samples. Otoliths are embedded in blocks of black polyester resin. Using a double blade low speed isomett saw a transverse section (0.4mm thick) is cut through the nucleus. The sections are mounted onto glass microscope slides using Histokitt resin as a mounting medium. A thin layer of Histokitt is painted over the section to protect the surface of the section. Sections are read at x6 magnification using transmitted light. There is a camera and television monitor attached to the microscope and all the images are read from the monitor. In some cases it may be necessary to read down the eyepieces.

Method 2. This method is used for otoliths taken during the discard programmes and for small fish taken on research surveys. The otoliths are broken through the nucleus using a scalpel and mounted in plasticine. The broken sections are not ground. Transmitted light is shone through the side of the otolith while the surface of the otolith is shaded with the index finger. Baby oil is used as a 'clearing' agent. The otoliths are read in a similar way to that used in method 1.

The Irish reader responsible for ageing of whiting from ICES areas VIa, VIIa and VIIg has seven years experience reading otoliths. Approximately 2,500 sectioned otoliths and 1,500 broken otoliths are read annually.

Netherlands

Until 1996 otoliths were prepared for reading by breaking. After this the sectioning method was adopted. From 1997 the otoliths from cod and whiting were put into small blocks and sectioned. The sections are mounted on glass and are not protected; the reason being that in future years people may wish to do some more research with them. During reading oil is used as a 'clearing' agent. The equipment used is a binocular microscope with x12 magnification and transmitted light is preferred.

There is only one reader who has 10 years experience. North Sea whiting otoliths are derived from both survey and market sources and number between 2,000 and 2,500 annually.

Northern Ireland

Otoliths are embedded in resin blocks from which thin sections (0.3–0.4mm) are cut using a slow speed saw fitted with a pair of diamond compound wafering blades. The sections are mounted on double sized glass microscope slides using high quality clear styrene resin (casting resin) and the top surface is protected with a glass cover slip. The existing equipment is a binocular zoom microscope. The preferred magnification is x9.5, however, difficult otoliths may be viewed using higher magnification and, where necessary, the light source may be switched between transmitted and reflected mode to clarify the nature of certain growth zones. The microscope is fitted with a bright field/dark field base unit and the transmitted light output from the bright field section is relatively powerful for this type of work. A video camera and monitor are used to discuss difficult otoliths with other readers.

There is one otolith reader at the institute who reads whiting, cod, haddock and herring otoliths. Approximately 5,000 whiting otoliths are read each year collected from market sampling, discard surveys and research cruises. The reader has 18 years experience in preparing and reading whiting otolith sections.

Norway

The whiting otoliths are broken in half and mounted in plasticine with the cut surface uppermost. A thin film of oil or water is applied to this surface. The otoliths are examined using a stereo zoom microscope with x10 eyepieces, generally 0.64 objective. Otoliths are read using reflected light by a free standing bench lamp. Adjustable for focus and brightness. The persons responsible for the whiting ageing have 15–20 years experience of reading. We are reading about 500 a year.

Scotland

Otoliths are cut in half using a scalpel and mounted with the cut surface uppermost and the proximal surface to the outside of a circular container (jar or bottle top) filled with plasticine (modelling clay). A thin film of baby oil is applied to the cut surface and the otolith is examined using a stereo zoom microscope with x10 eyepieces and, generally, a 1.5–2.0 objective. The otolith is then illuminated from the side using a free standing bench lamp, which is adjustable for focus and brightness. By holding a finger between the lamp and otolith a shadow is cast over the broken surface which allows the 'side transmitted' light to highlight the opaque and translucent zones.

Whiting otoliths taken from commercial samples are read by one person who has 20 years experience with this species as well as experience with cod, haddock, saithe, anglerfish and megrim. All demersal otoliths collected from the Discard Sampling Project are read by another person who has ten years experience. In the case of whiting, this reader regularly refers to more experienced readers and a low level of checking is routinely carried out. Currently between 12,000 and 15,000 whiting otoliths are aged per year from commercial samples and 4,000 – 6,000 from the discard programme.

Sweden

Otoliths are taken, cleaned in water and stored in small zip-lock plastic bags. The bag is marked with the date and a code, which corresponds to the measuring protocol. The right otolith is used for analysis unless this otolith has been damaged or is considered to be unreadable (e.g., crystallisation). The otolith is broken transversally through the estimated core position with cutting nippers. The otolith is moistened with water and held with a pair of forceps under a stereo binocular microscope (Leica MZ6). Magnification is normally kept at x10 (ocular x10, objective x1) but may incidentally be increased to enhance difficult sections of the otolith. The otolith is viewed by side-transmitted cold light (Leica CLS 150W) repeatedly shadowed by a pencil or finger in order to enhance contrast.

The Swedish reader has experience in age estimation from cod otoliths since 1988, around 50,000 otoliths being read since then. Age determination of whiting started in 1989 and currently 1400 – 2000 otoliths are read annually. The whiting otoliths have been exclusively collected during research surveys. The reader has a minor experience of sectioned material, which has mainly been achieved during exchanges and workshops on Baltic cod.

4.3 Difficulties associated with exchange otoliths

Prior to the group discussion, results were analysed in order to rank the otoliths by age so that attention could be focused on the otoliths giving most difficulty. A series of otoliths were selected for viewing by projecting the images on to a large screen monitor. As this method proved to be unsuitable for viewing broken otoliths, the session concentrated on sectioned material.

A problem in the interpretation of the first translucent zone was raised, where the depth of the zone was unclear along the preferred plane of reading (nucleus - ventral). The general impression gained was that this might be typical of a fish that had hatched early in the spawning season and therefore had extended growth. A typical example was made available for microstructure study in the hope that the agreed interpretation could be validated.

There were several instances where a check on a translucent zone gave problems, particularly when reading in the nucleus - ventral plane. In these cases the difficulty was often resolved by following the particular zone to another area such as the proximal - distal quadrant. Using reflected light, a bright check is sometimes rather prominent, giving the impression of an additional opaque zone. Clarification was often obtained by switching between reflected and transmitted light. The benefit of having a variable intensity light source was well demonstrated and is recommended for all users if possible. Another factor, which contributed to the difficulty with interpretation of checks, was the over magnification of an otolith by some readers.

Although it did not appear to cause a problem in this exchange, the situation where discontinued zones create difficulty for the reader was suitably demonstrated. In these cases the area of difficulty normally relates to the distal and proximal surfaces, with the ventral and distal regions largely remaining unaffected. Readers should bear this in mind if they have to look at other areas of the otolith for confirmation of their findings in the favoured nucleus - ventral plane.

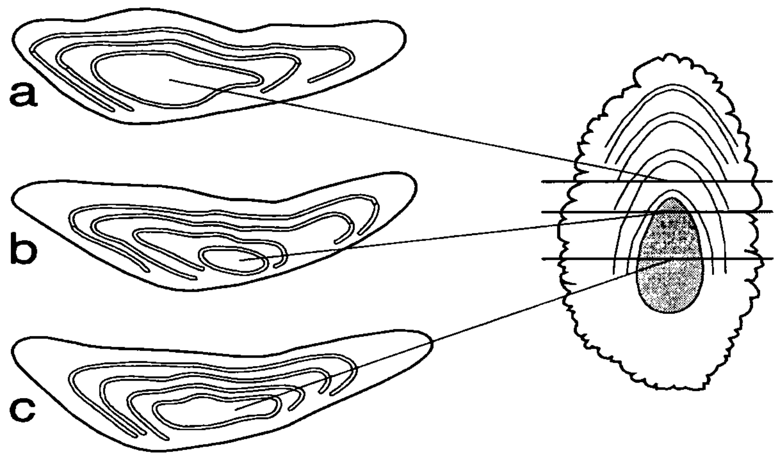
In an instance where there was doubt in relation to determining if a zone was a split or annulus, the need to take into account the relative continuity in distance between annuli was demonstrated. This procedure can also be put to good effect on the occasions when the first translucent zone is very faint and has been excluded due to the lack of intensity rather than location in relation to other zones. It was noted that the completion of the translucent zone tended to be completed earlier in young fish than in older fish. Several readers commented on the difficulties that this could create in the interpretation of the final zone when reading across a wide range of ages.

One feature which caused difficulty, particularly when viewing sectioned otoliths with reflected light, was the presence of a series of small sharp well-defined translucent zones in the shape of a crescent (in the ventral quadrant) followed by very bright opaque material. Previous experience by readers indicated that this feature was not present in the first annuli and very seldom in the second annuli. This tended to result in an unexpected growth pattern on the edge of the otolith.

Difficulty was encountered in ageing sections where the otolith was not sectioned through the proper plane. This highlighted the need to demonstrate to staff involved, the procedure for breaking and sectioning otoliths properly (see Figure 4.3.1). Staff involved in this process should also be made aware of the variations in techniques that are available to them, particularly in breaking, where the current methods include; breaking by hand, cutting by scalpel or knife and breaking with pliers or wire cutters.

Within the group it was very clear that difficulty in interpretation could be attributed to ageing samples by a method that was not familiar to the reader. Future exchange projects should attempt to make both otoliths available to allow the participants to use their own preferred method of preparation and ageing.

Figure 4.3.1



The varying appearance of the ring structure of a cod otolith when broken

(a) missing the nucleus completely
(b) through one end of the nucleus
(c) through the centre of the nucleus

(After Williams and Bedford)

5 LENGTH ANALYSIS

5.1 Length analysis of juvenile whiting

Prior to the Workshop a project was initiated to obtain samples of otoliths where the interpreted ages could be supported by a study of the relevant length compositions. This would allow the Workshop participants to study the actual otoliths collected over a 12 months period with a relatively high degree of confidence in their findings.

This task was carried out by utilising data and material collected from the existing Scottish sampling programmes. As the study was only likely to be effective with the younger age groups it was clear that the Market Sampling Project could not provide suitable material. The Research Vessel Surveys could certainly provide the relevant data and otoliths, but the continuity required could not be achieved over the course of the year. The Discard Sampling Programme proved to be the best option. Although the sampling programme is aimed at quarterly sampling periods it was possible, by extending the collection area to two or three adjoining areas (Figure 5.1.1), to obtain an adequate coverage over the year.

With a relatively high level of commercial activity off the north east of Scotland it was possible to obtain sufficient material from the Buchan, Moray Firth and Forties areas (Table 5.1.1). The obvious weaknesses of this collection related to the different selection characteristics of the different gear types and also the likelihood of differences in length composition (Table 5.1.2) from area to area. However, in the time available this was the best option to obtain adequate coverage.

The first impression gained on examining the length frequencies for each month (Figure 5.1.2) was that in most cases at least two distinct length groups were present. In the case of the first month (August 1997) there was a definite break between the first and second length groups. The first group, with a modal length of 7 cm could confidently be classed as 0-group.

Results from Scottish research vessel surveys show that whiting in the range 1.5 cm - 6.5 cm were caught in mid-water during the month of June. (The eggs and larvae of the main demersal species are pelagic and in line with these, whiting assume a demersal existence after a few months.)

By following the progression of the smaller group (0-group) through each month it would seem that this age group (if that is what they are) progresses in length to a size of 21 cm (modal length) by July of the following year (1998). If this is the case there would seem to be justification in assuming that the second distinct group in the August (1997) length frequency is one year older than the first group. At first glance it appears that a similar conclusion could be drawn about the progression of the second length group (1-group). However, in some cases it seems that the length range of the second group is extended and becomes confused in that there appears to be more than one or two peaks in the distribution.

The otoliths from the samples obtained had already been aged within Scotland in order to process the Scottish discard sampling data. However, during the course of the Workshop a sample of 76 otoliths from the Scottish study were examined by four experienced readers attending the meeting and total agreement in ageing was achieved. The mean length at age was plotted for each month and is presented in Figures 5.1.3 - 5.1.11.

Examination of the graphs obtained, support the assumption made earlier that the first age group can be confidently identified throughout the course of the year although the overlap between the first and second year group becomes a problem by the month of April. The second year group was relatively easily identified in the months of August and October but it should be noted that there were very few fish older than 2 years (third size group) present in the sample. From November onwards it is generally quite clear that you can identify the lower range for the second age group but within a few centimetres, the presence of one or two other year classes are also present.

It would seem that it would not be possible to confidently age whiting beyond the first eighteen months or so by simply studying the length frequency. From this study it would seem to be unwise to use the length measurements for ageing purposes for fish greater than 21 cm or so.

By plotting the mean length of each age group over the period of the study (Figure 5.1.12) it is possible to show the natural progression through the first two to three years. This study appears to provide a reasonable degree of support to the actual ageing that took place.

Bhattacharya's method of separating a length frequency distribution into a series of normal distributions (Bhattacharya 1967, Sparre *et al.* 1989, King 1955) was applied to the data available. This method was unable to provide any satisfactory dis-aggregation of data beyond the third year class, and also proved unsuitable for the data collected in July (1998) where only 490 fish were measured. The resultant mean length of each age class was plotted (Figure 5.1.13) and shows significant differences in the second and third year groups from those obtained from the calculations based on the age determinations carried out.

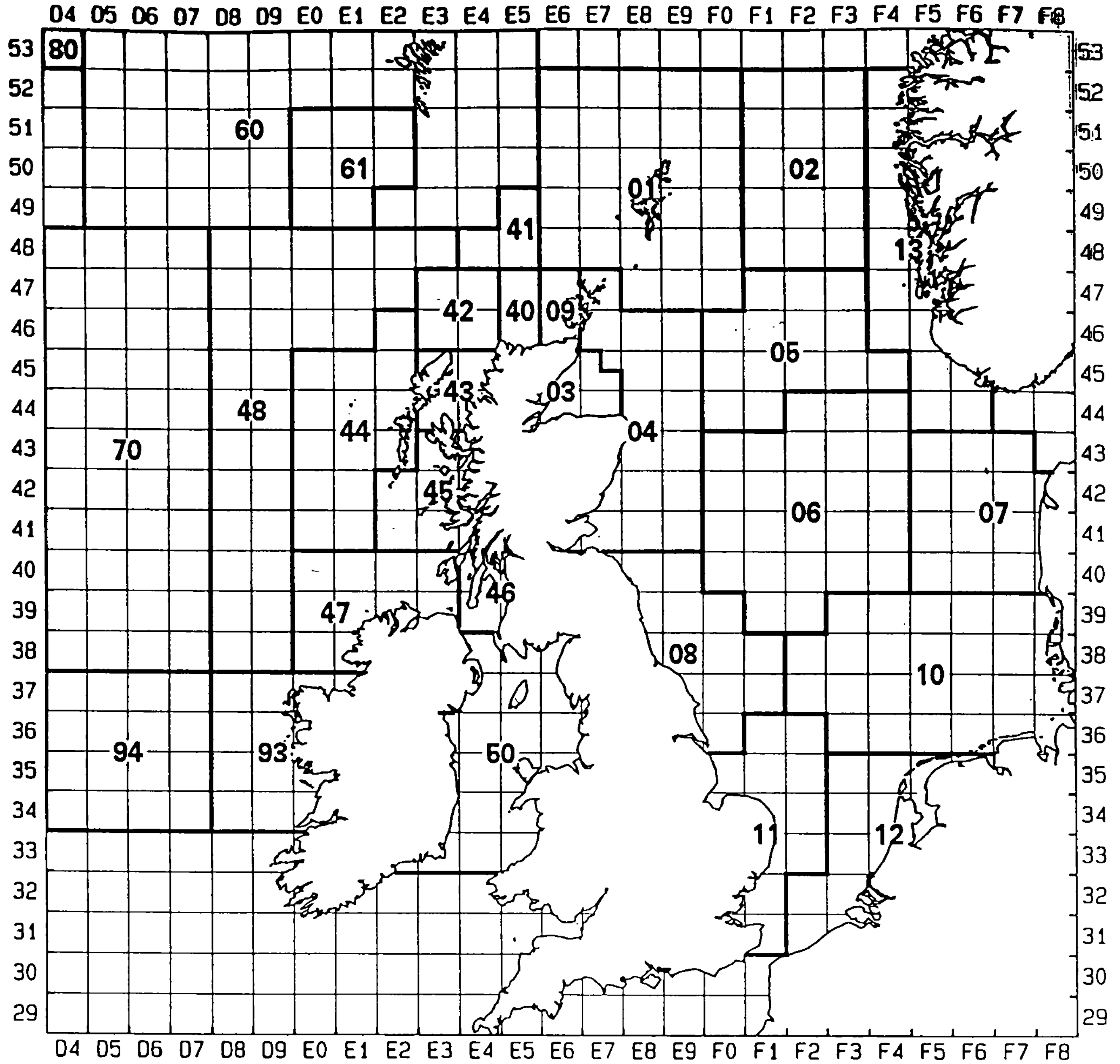
Table 5.1.1 – Samples used for age/length analysis

Month	Area	Gear	Vessel name
August	Buchan	Nephrop Trawl	Launch Out
October	Buchan	Nephrop Trawl	St. Adrian
November	Moray Firth	Seine Net	Destiny
January	Buchan	Seine Net	Destiny
February	Forties	Nephrop Trawl	Golden West
April	Buchan	Light Trawl	Sharona
May	Buchan	Nephrop Trawl	Opportune
June	Buchan	Seine Net	Destiny
July	Buchan	Pair Trawl	Rebecca

Table 5.1.2 – Whiting Length Frequencies

Length	August	October	November	January	February	April	May	June	July
5	6								
6	10								
7	35								
8	15		4						
9	6	52	4						
10		198	37						
11		336	52		67	4			
12		564	108	12	230	6			
13		694	123	24	381	46	205		
14		904	128	34	416	53	339		
15	7	682	238	48	336	115	590	112	
16	21	482	233	38	226	127	1021	634	
17	92	214	136	12	201	142	1436	1406	
18	135	65	45	90	81	140	1403	1744	10
19	332	52	16	54	71	124	1504	2400	24
20	255	72	56	109	72	102	1120	2046	39
21	136	144	198	194	106	107	1094	1612	118
22	47	226	380	527	233	162	1785	1784	34
23	19	188	646	1088	620	220	3483	2423	30
24	12	77	748	1268	872	243	5372	3330	24
25	4	23	841	1150	1110	232	6894	3837	
26	4	3	624	1151	1081	184	7209	3977	35
27		8	144	938	921	136	6893	3957	15
28		3	259	596	678	34	5944	3418	10
29			191	414	372	34	3935	2298	
30			112	264	161	14	1752	1362	49
31			80	166	166	9	576	848	15
32			42	84	136	14	482	347	35
33			27	46	68	17	375	319	36
34			9	29	44	12	250	230	2
35			7	22	19	9	143	77	3
36			3	4	15	4	98	38	3
37				15	10	2	62	38	3
38			1			1	27		2
39			1				18		2
40			3	2			9		1
41									
42							9		
43									
44									
45									
46									
Total	**1136**	**4987**	**5496**	**8379**	**8693**	**2293**	**54028**	**38237**	**490**

Demersal Sampling Areas



01 Shetland
02 Viking
03 Moray Firth
04 Buchan
05 Forties
06 Central
07 Danish Coast
08 Humber
09 West Orkney
10 German Bight
11 Thames
12 IJmuiden
13 Utsire
40 Solan
41 Rising Ground
42 Butt of Lewis
43 Inner Hebrides
44 Outer Hebrides
45 South Minch
46 Clyde
47 North Ireland
48 Western Deeps
50 Irish Sea
60 Faroe Plateau
61 Faroe Bank
70 Rockall
80 Iceland
93 West Ireland
94 Porcupine Bank

Whiting - Monthly Length Frequencies

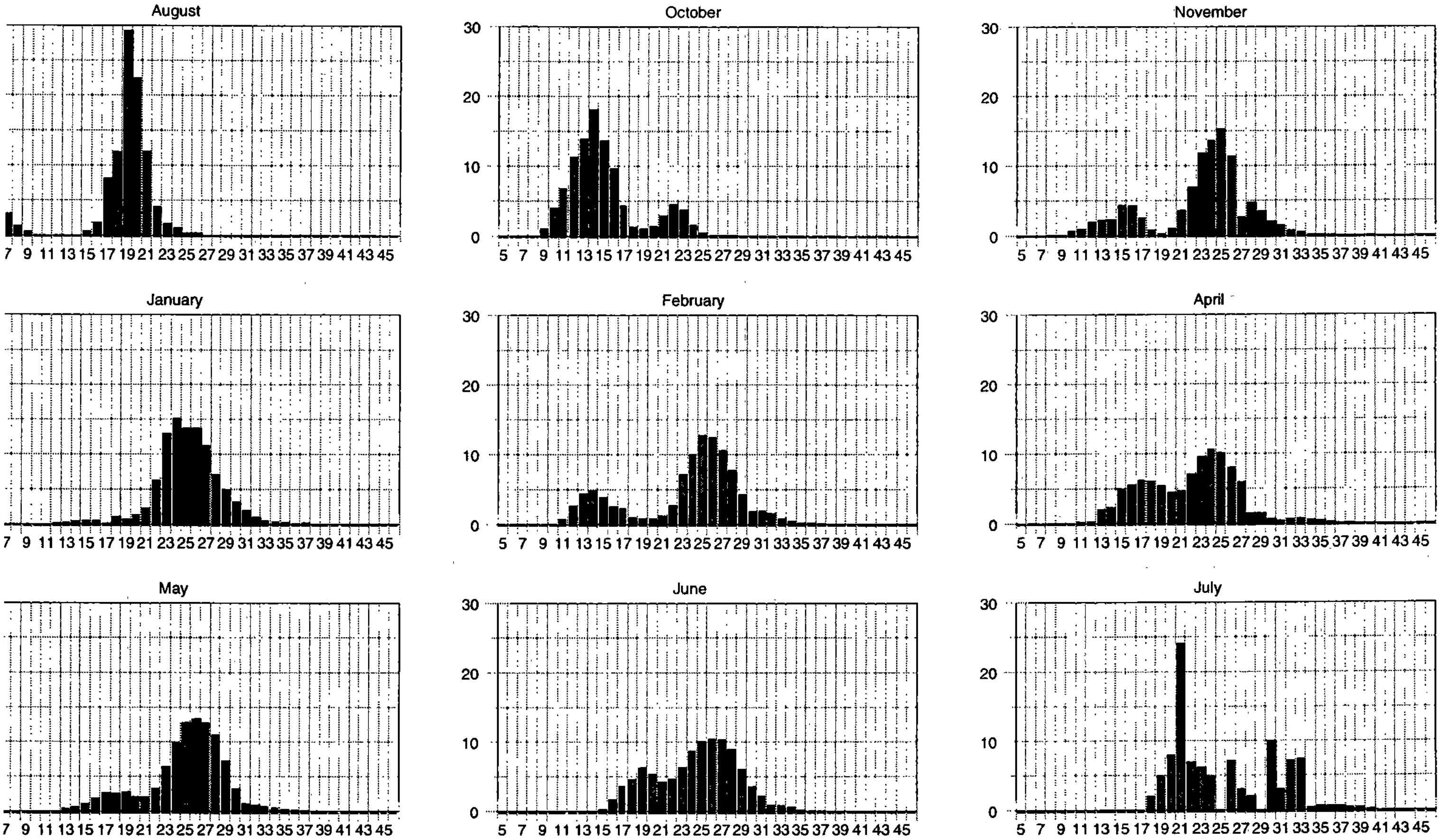


Figure 5.1.2

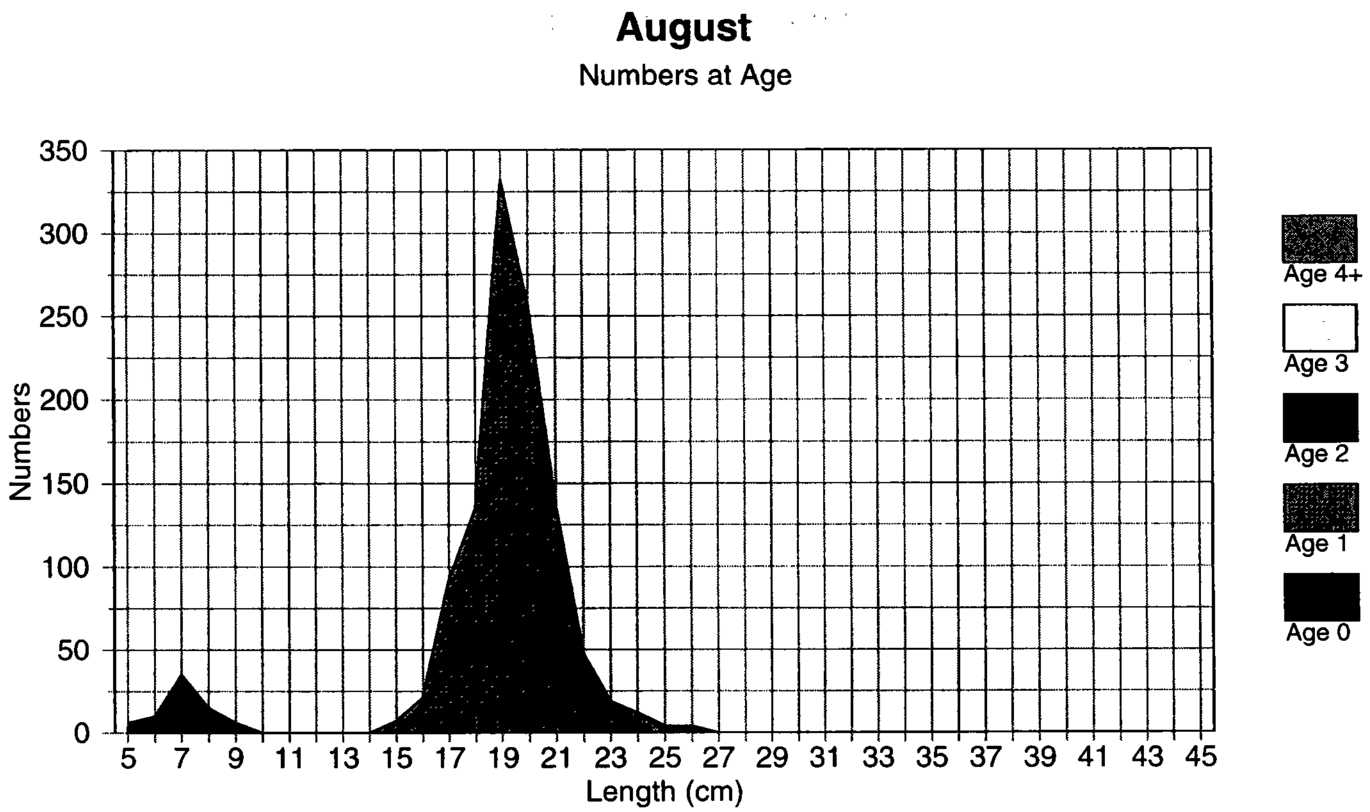


Figure 5.1.3

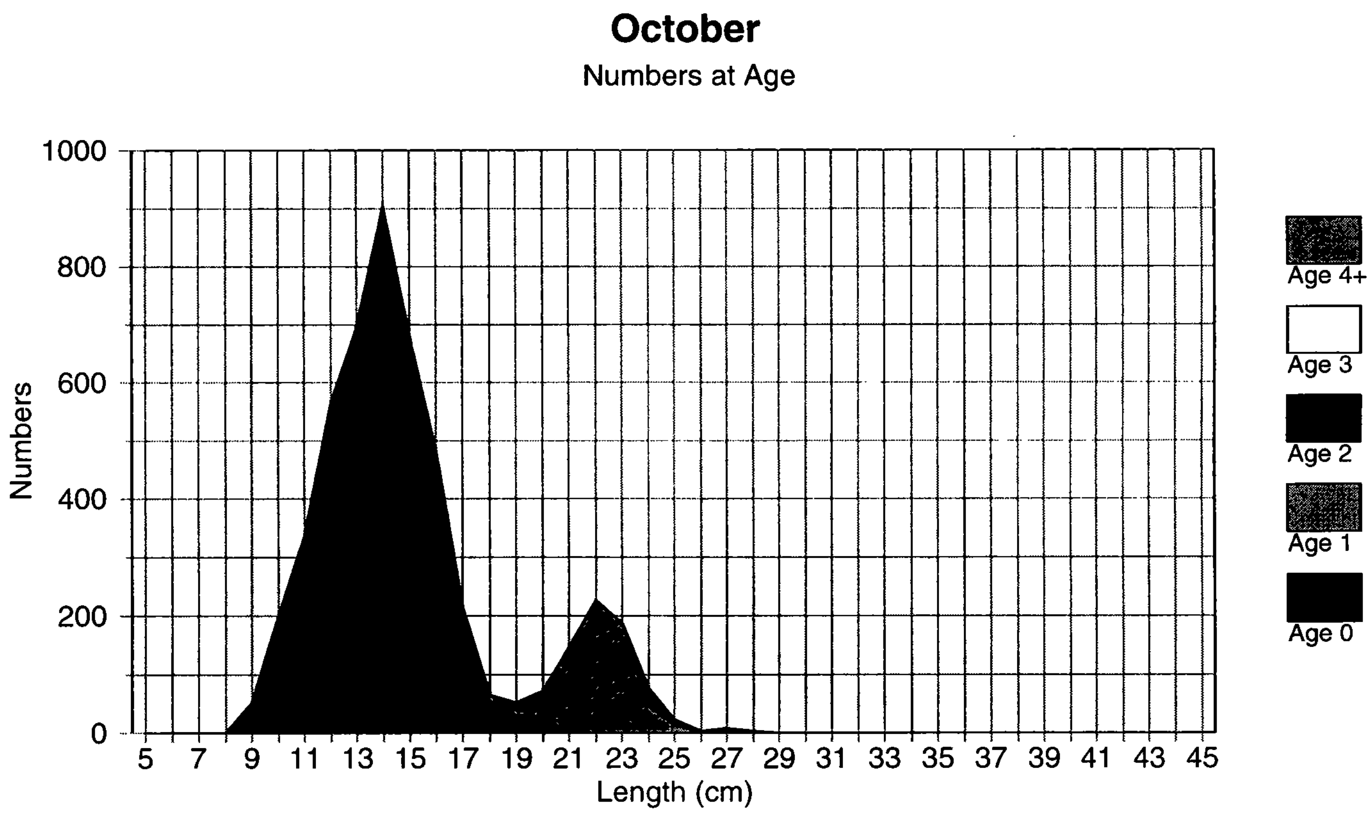


Figure 5.1.4

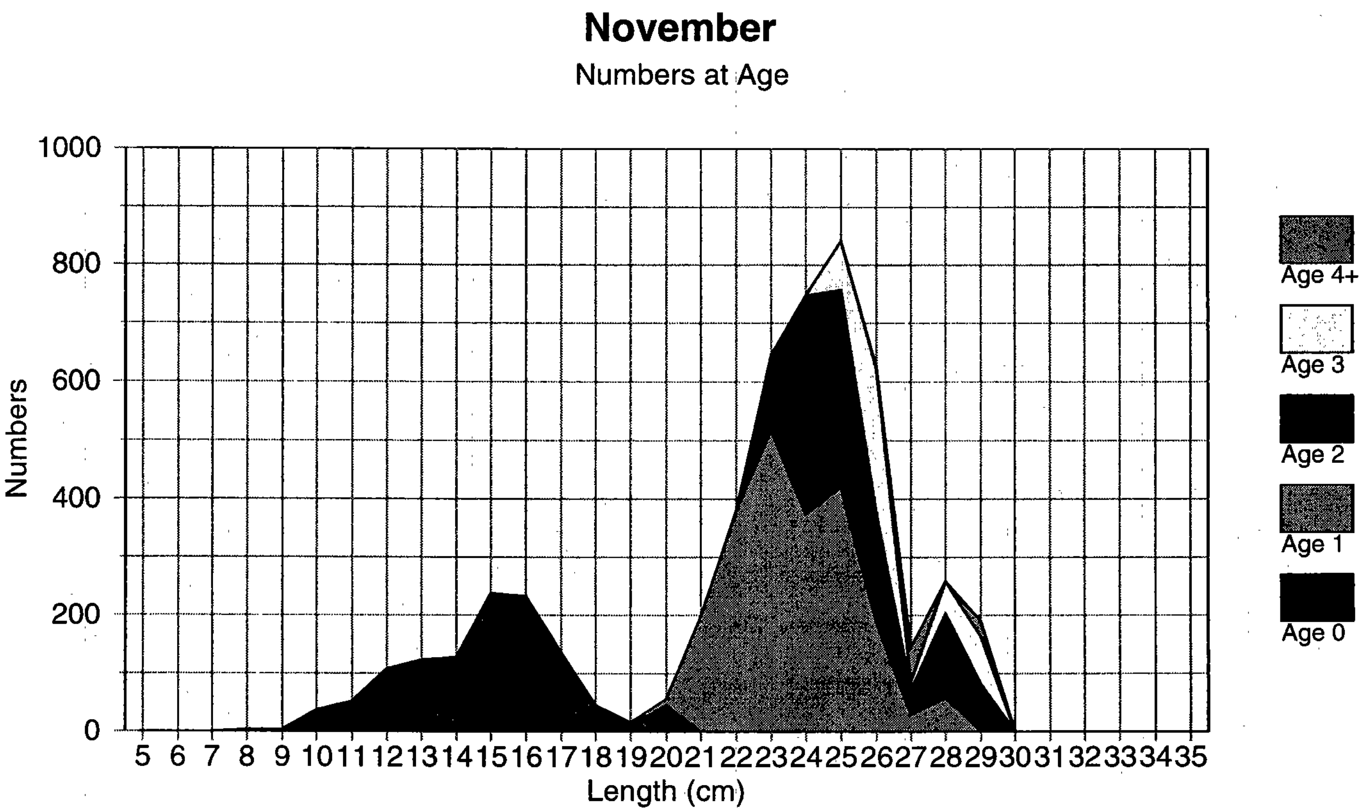


Figure 5.1.5

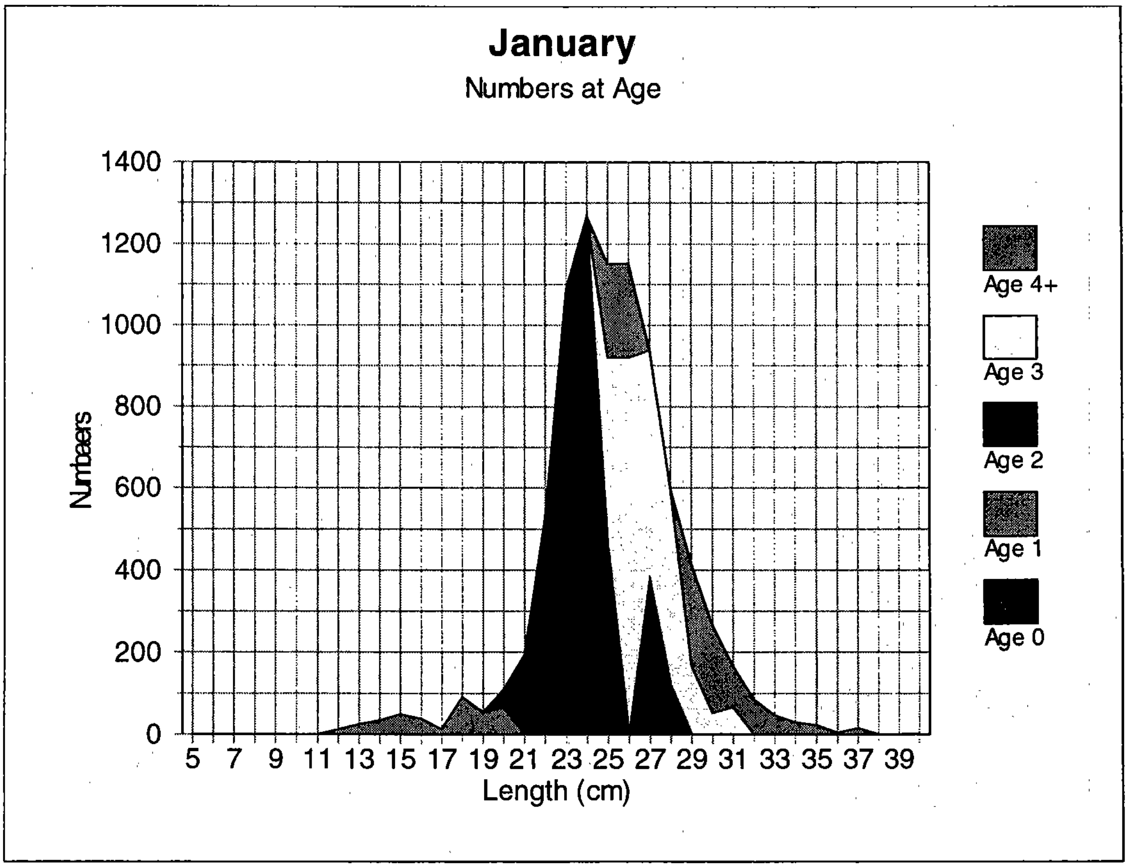


Figure 5.1.6

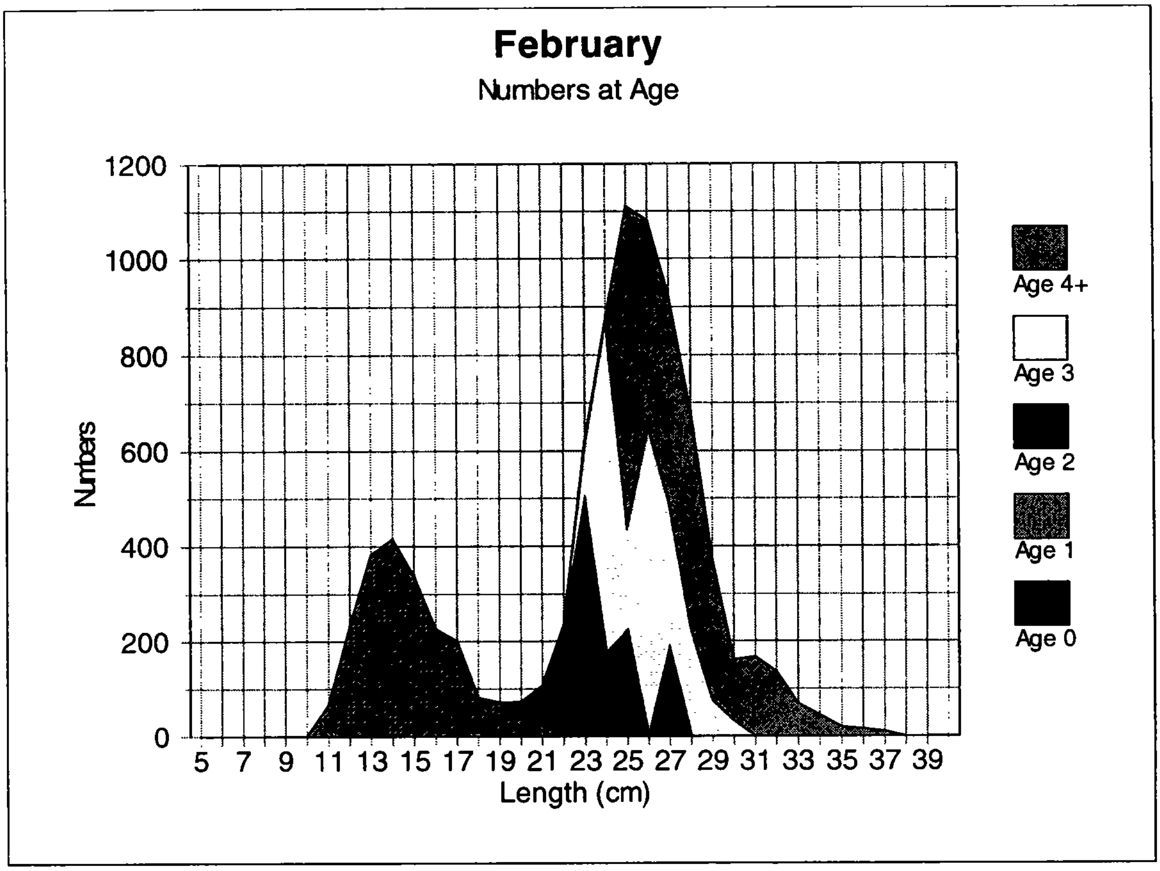


Figure 5.1.7

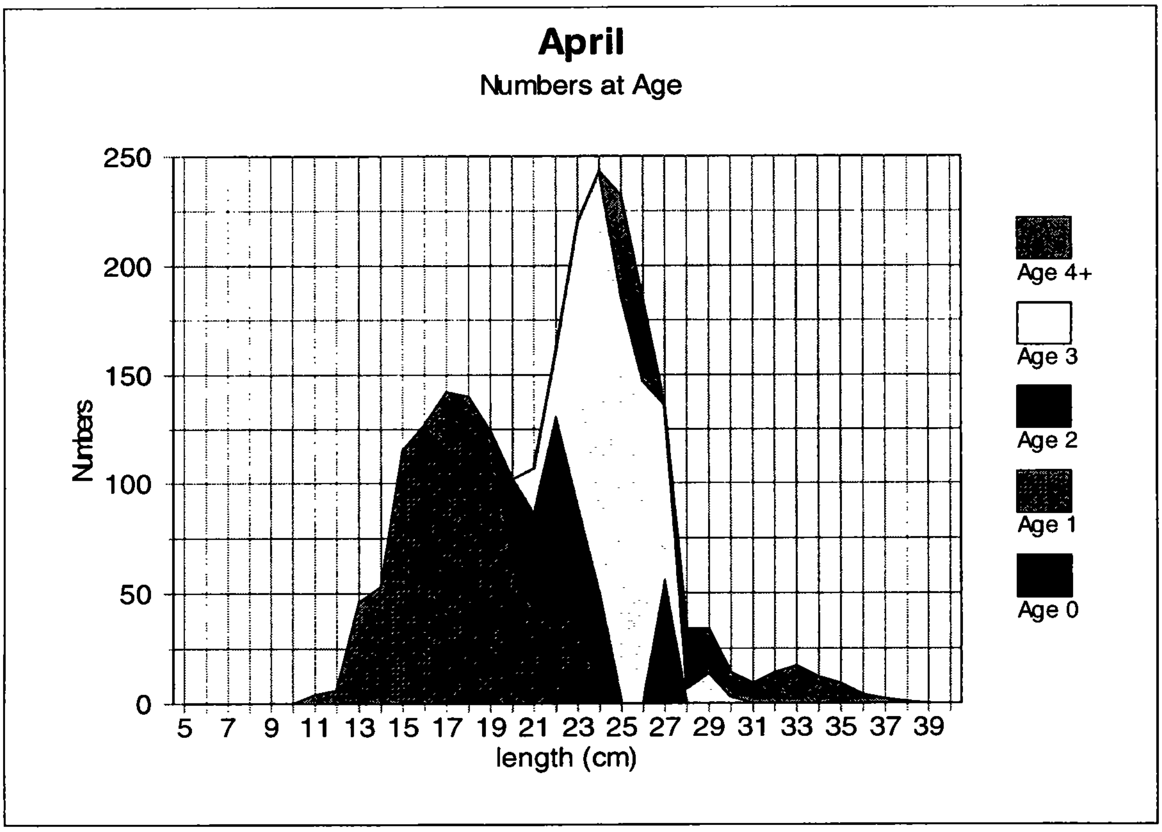


Figure 5.1.8

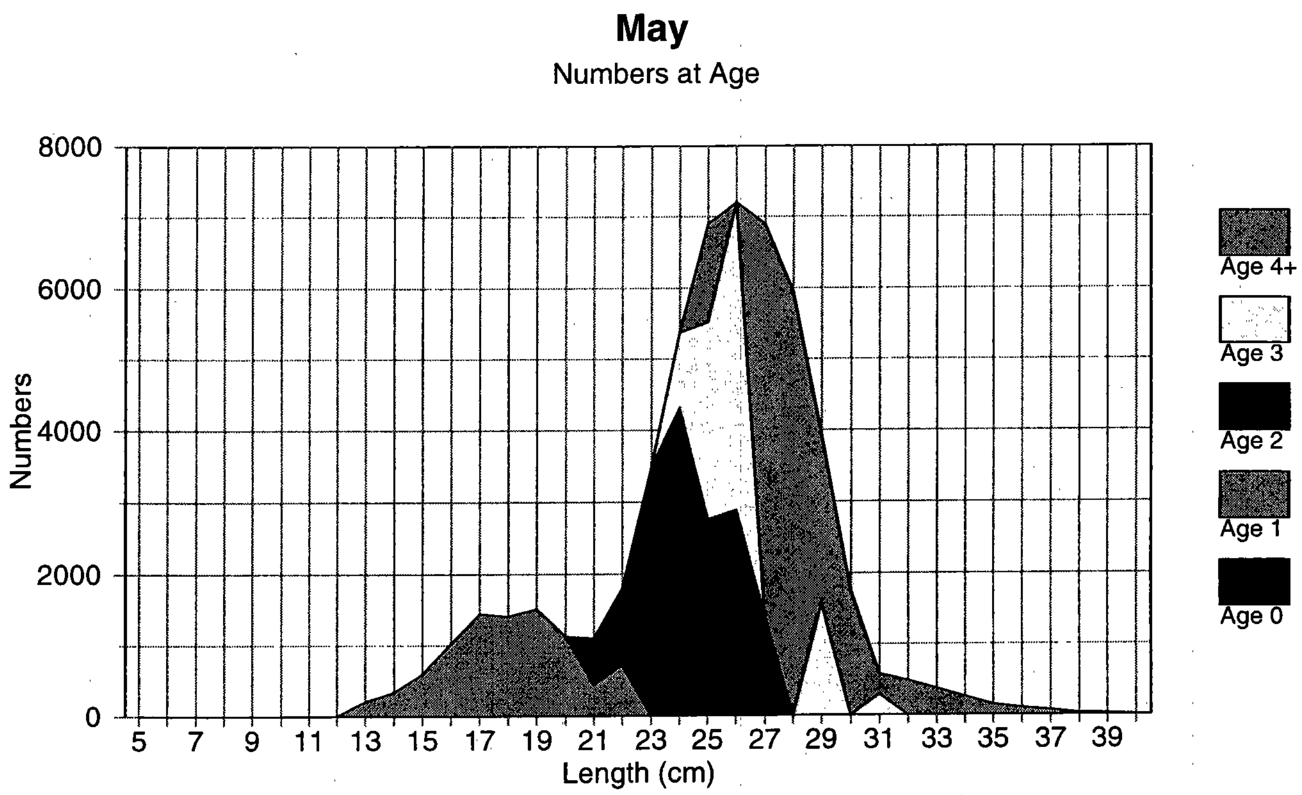


Figure 5.1.9

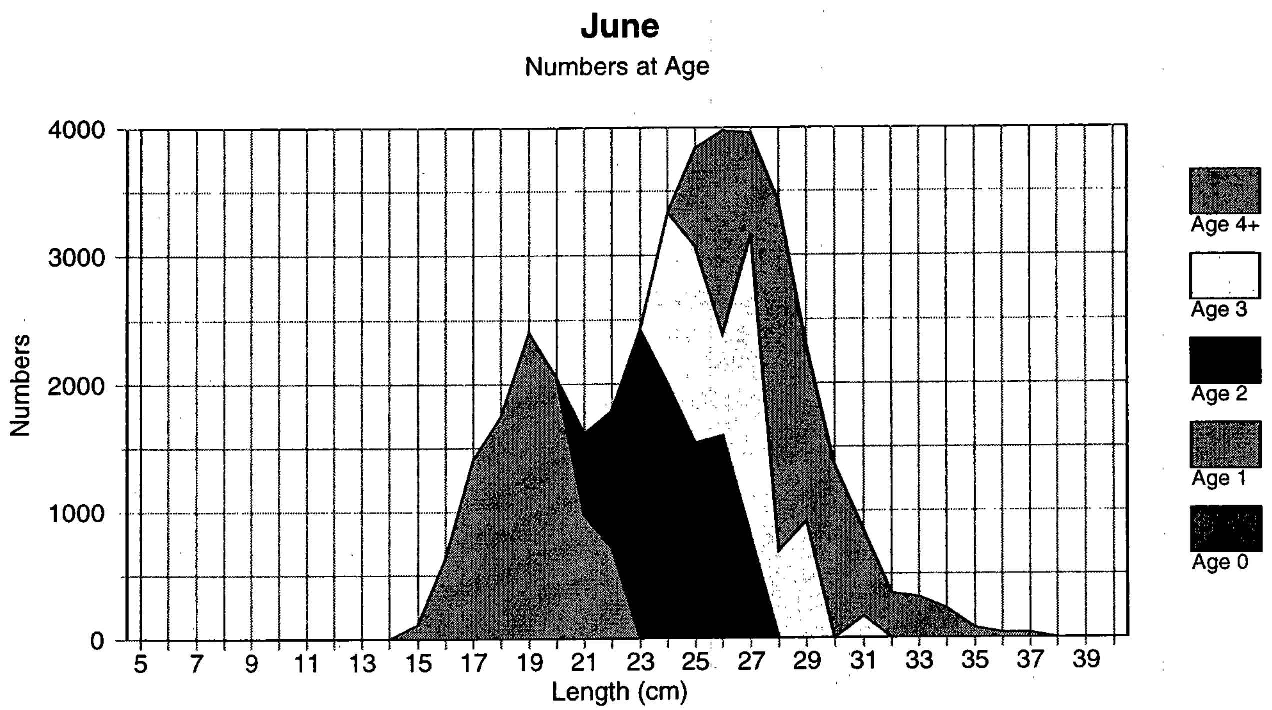


Figure 5.1.10

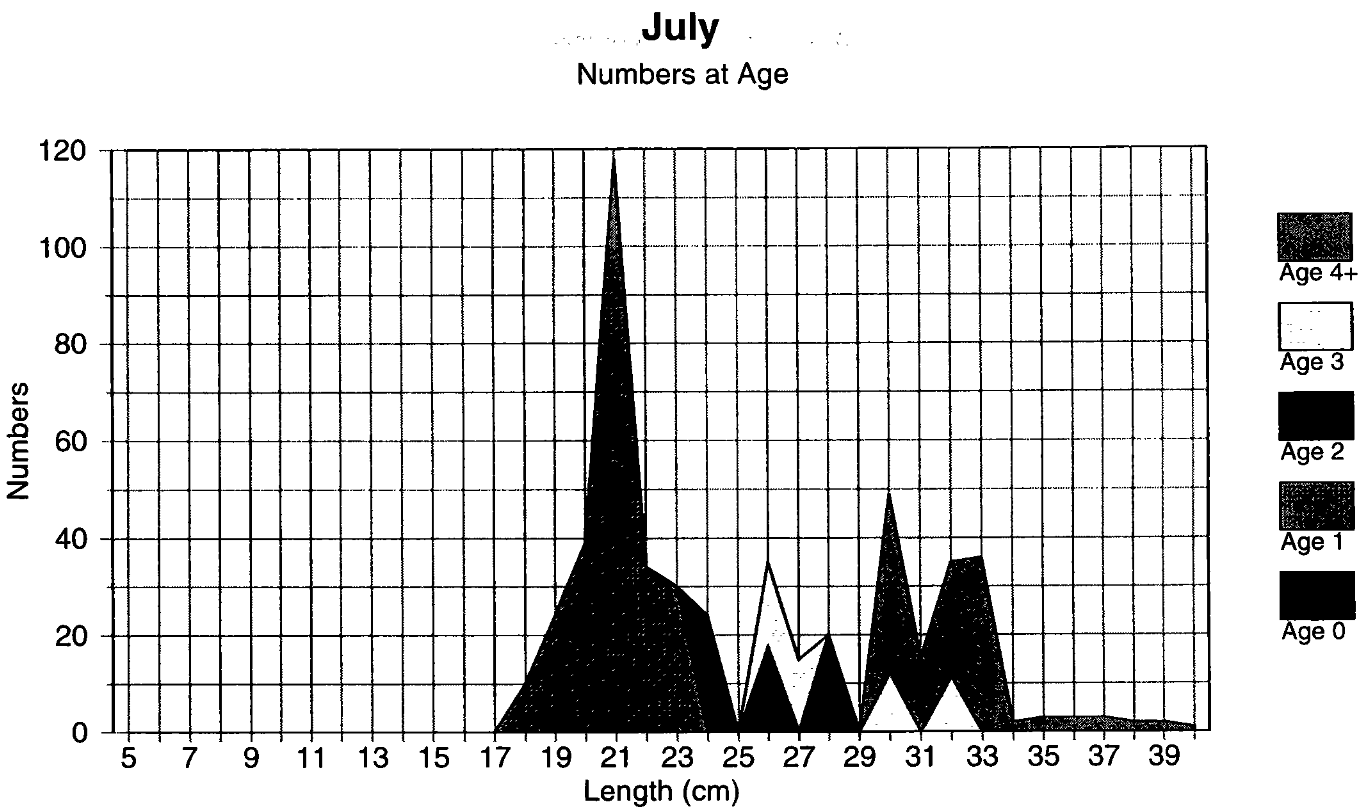


Figure 5.1.11

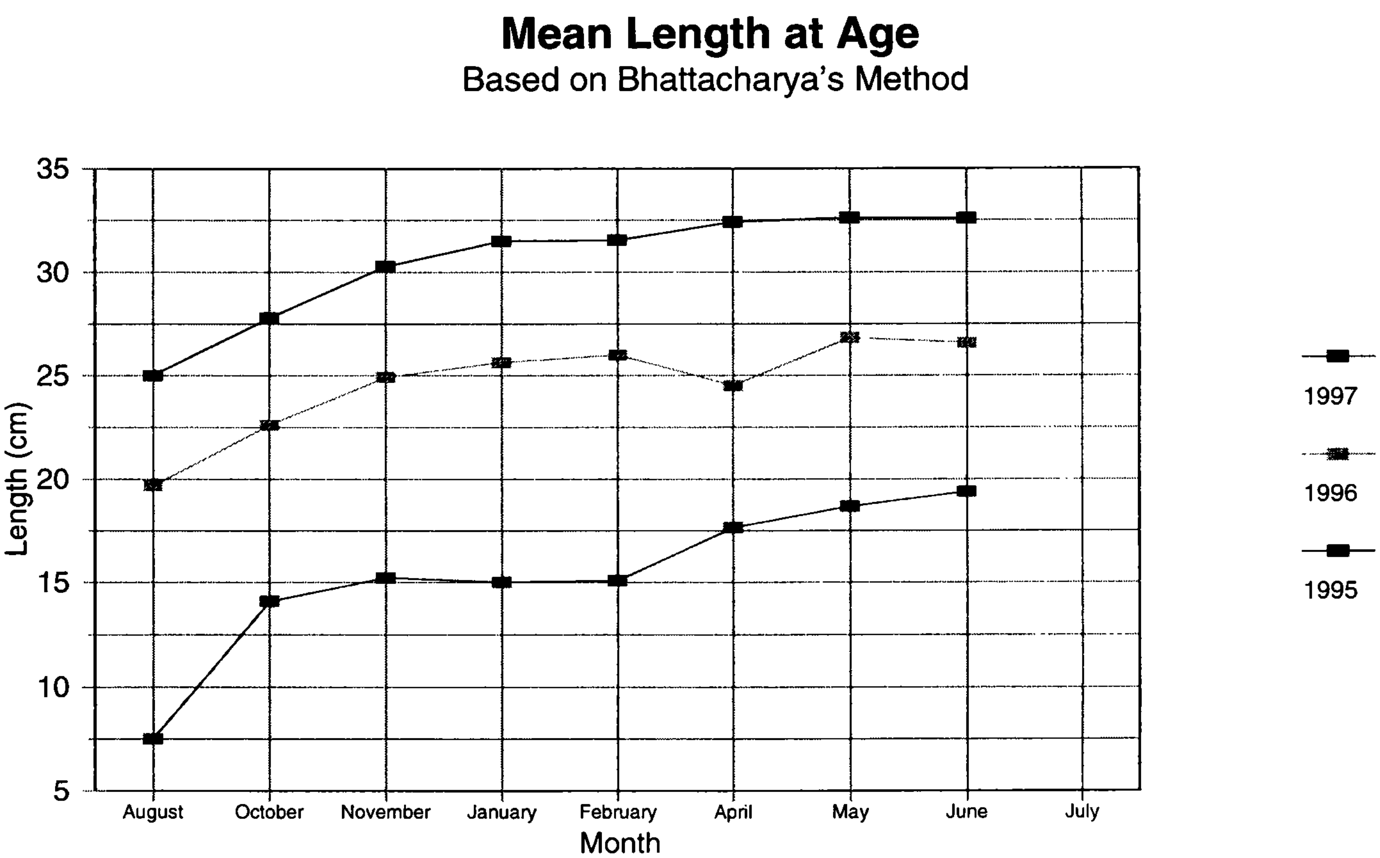


Figure 5.1.12

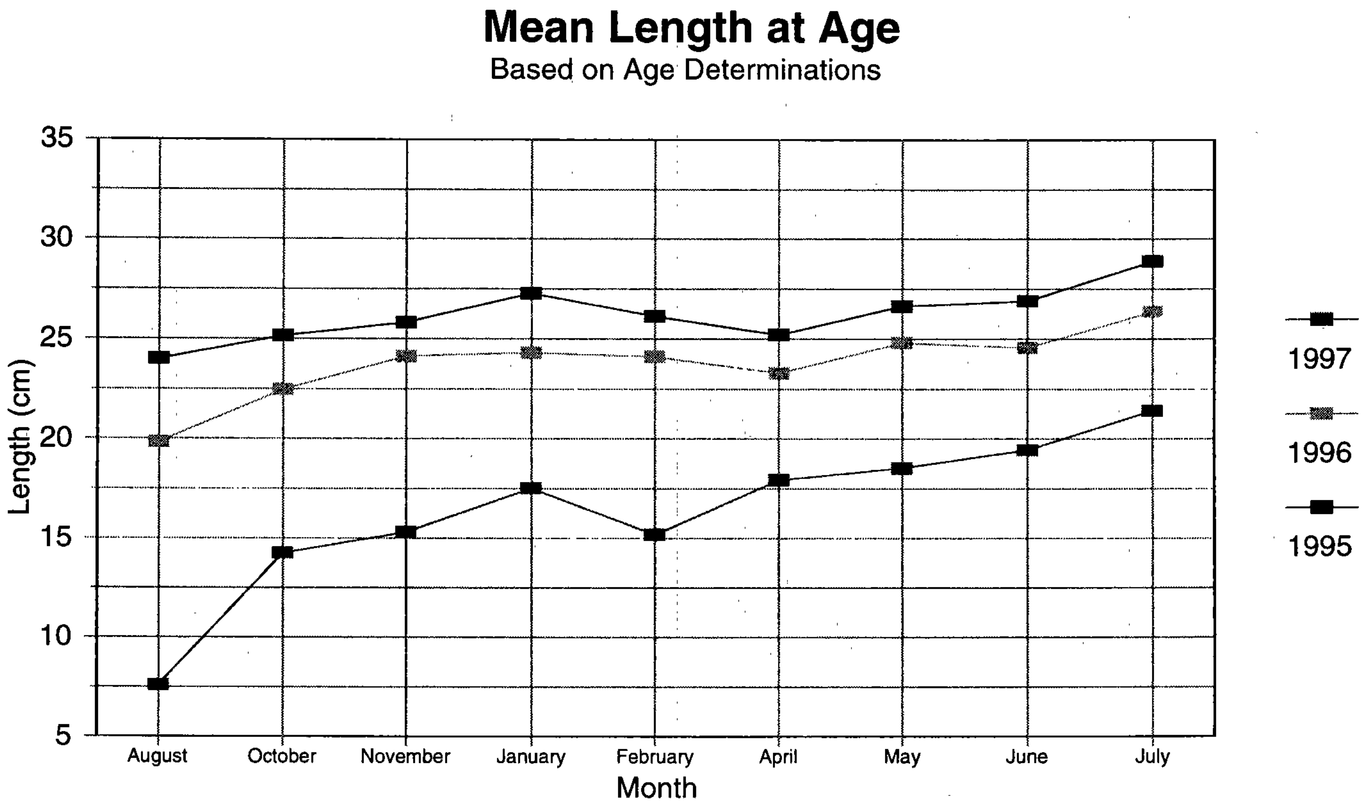


Figure 5.1.13

5.2 Decomposition of length distributions by Bhattacharya's method

Bhattacharya's method of separating a length frequency distribution into a series of normal distributions (Bhattacharya 1967, Sparre *et al.* 1989, King 1995) was applied to data from bottom trawl catches of North Sea whiting for which corresponding age readings were not available. The catch data originated from three different locations in the central North Sea in August/September 1989 (Figure 5.2.1). The sampling was originally designed to collect whiting stomachs, and bottom trawl hauls were made at about 4 hour time intervals over a period of 2 to 3 subsequent days, each at a single station (see Wieland *et al.* 1998 for a detailed description of the data set). The catches were standardised to 1 hour trawling time, and the frequency distributions of average catch by 0.5 cm length interval are given in Figure 5.2.2 for each station. The single length distributions were pooled and the width of the length interval was increased to 1 cm (Figure 5.2.2). The pooled length frequency distribution was analysed with Bhattacharya's method using the FiSAT Software (Gayanilo *et al.* 1996) in order to obtain age dis-aggregated data.

The Bhattacharya method is a modal progression analysis technique and does not require an estimate of the number components included in the observed distribution. It is based on approximating an assumed normal (bell shaped) curve of a length frequency distribution as a parabola, which is then converted to a straight line (Figure 5.2.3). The straight line has the form dt(lnN) = a + b (L), where dt(lnN) is the difference of the natural logarithms of the number in one length class and the number in the preceding length class, and L is the upper limit of the preceding length class. The straight line crosses the length axis at a point which is the mean (and the mode) of the length frequency distribution, i.e., the normal distribution has a mean of –a/b, and a variance of –dL/b, where dL is the length class interval.

If the length frequency distribution consists of a (unknown) number of overlapping cohorts the Bhattacharya method may be used to separate normal distributions starting on the left-hand side of the overall distribution. Once the first normal distribution has been determined it is removed from the total distribution and the same procedure is repeated for the next cohort. This sequential procedure as implemented in the FiSAT Software is illustrated in Figure 5.2.4 and can be divided into the following steps:

Step 1: Determine an uncontaminated (clean) slope of a normal distribution on the left side of the total distribution.

Step 2: Determine the normal distribution of the first cohort by means of a transformation to a straight line.

Step 3: Determine the number of fish per length interval belonging to that first cohort and then subtract them from the total distribution.

Step 4: Repeat the process for the next normal distribution from the left, until no more clean normal distributions can be found.

The output from FiSAT includes mean length and standard deviation as well as number per length class for each cohort, which can then be used to construct an age length key (ALK).

The decomposed length frequency distribution of whiting from the central North Sea in Aug./Sept. 1989 and the resulting ALK are shown in Figure 5.2.5. An ALK for whiting in roundfish areas 1 to 4 (Figure 5.2.1) from the Scottish Groundfish Survey in the 3rd quarter 1989 is given in Figure 5.2.6 for comparison. The ALK's, although they were not derived from the same material, compare fairly well demonstrating that Bhattacharya's method can provide satisfactory results for the youngest age groups. However, it is noteworthy that the Scottish age readings indicate a larger overlap of age 2 and age 3+ (Figure 5.2.5) than the ALK derived from the length decomposition (Figure 5.2.6).

The Bhattacharya method identifies modes of successive older age groups as long as a sufficient signal is present in length frequency distribution. It may thus provide an alternative way of deriving age dis-aggregated data, especially for juvenile fish. However, the underlying assumption that the length frequency distribution of a cohort follows a normal distribution might be violated if the spawning period is long and late hatched larvae experience a short growth period as it can be the case in North Sea whiting. Hence, biological information and results from age readings should be considered for correct interpretation and validation of the results obtained by Bhattacharya's method.

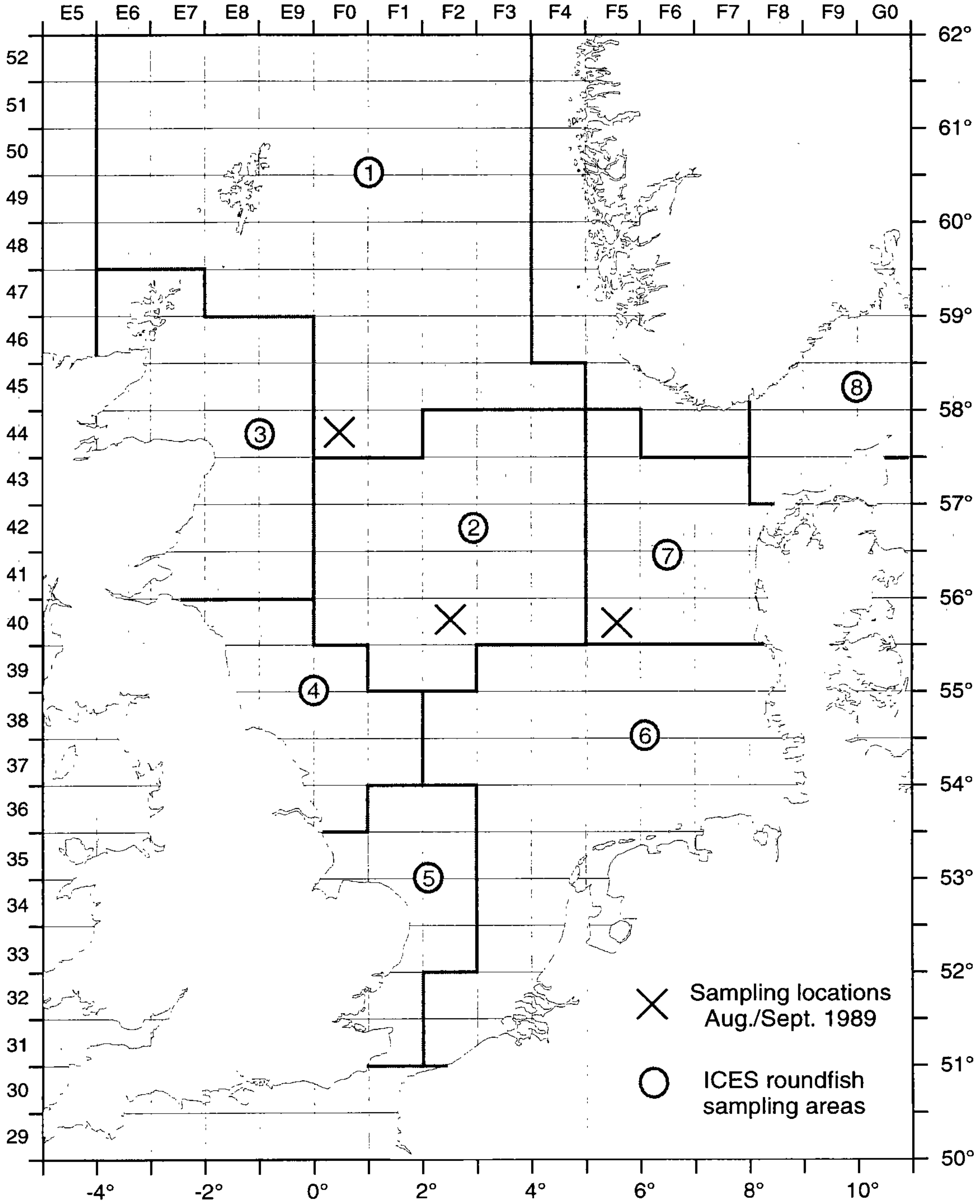


Figure 5.2.1: Sampling locations for whiting in August/September 1989.

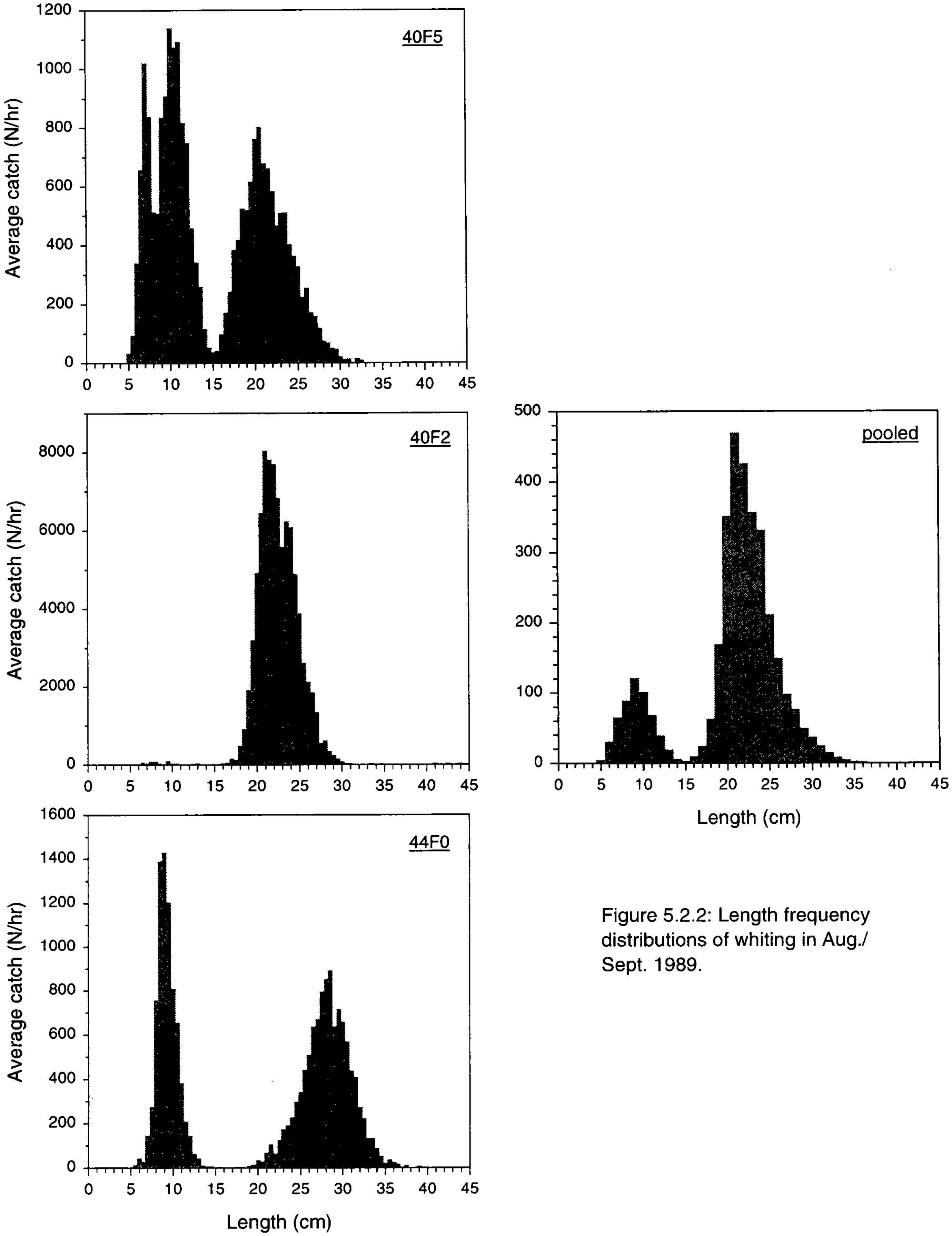


Figure 5.2.2: Length frequency distributions of whiting in Aug./ Sept. 1989.

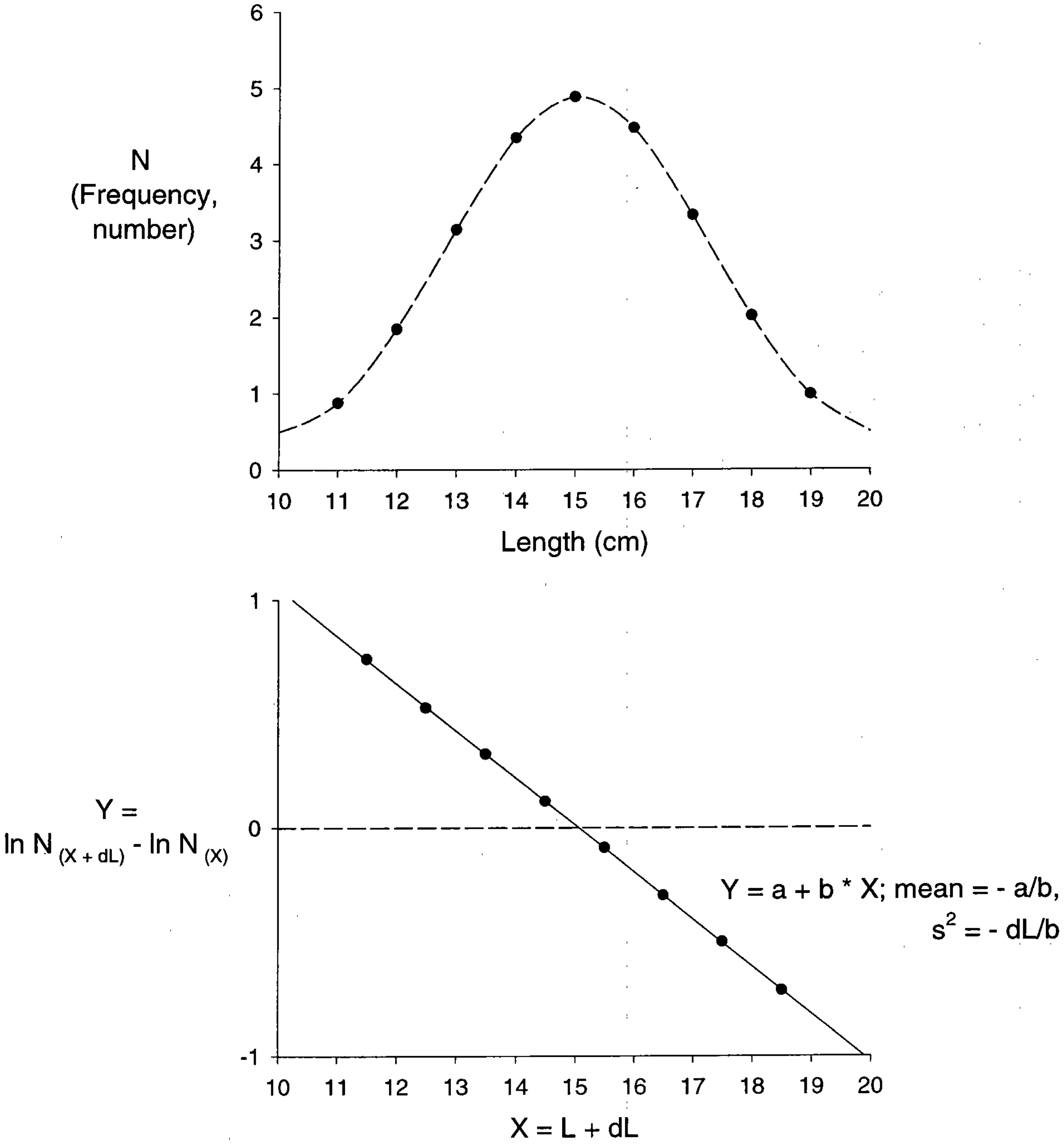
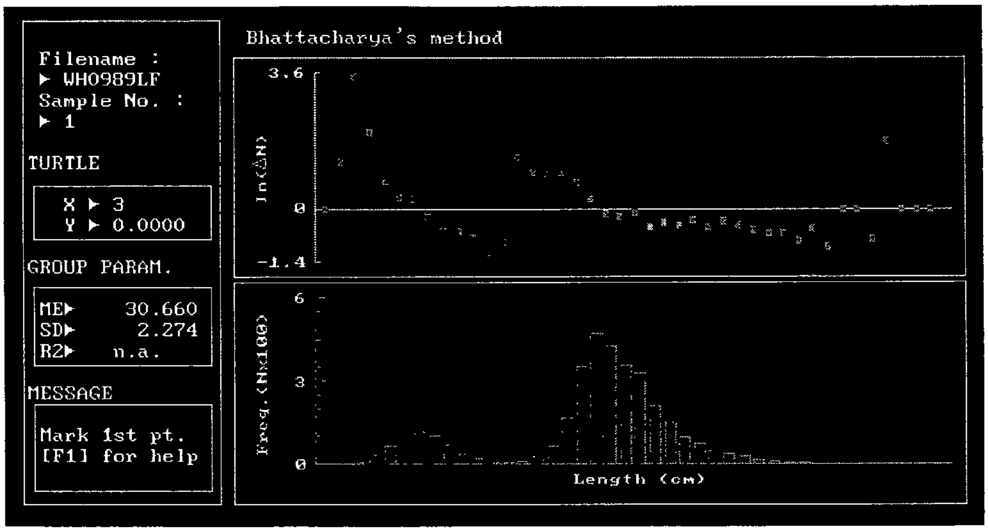
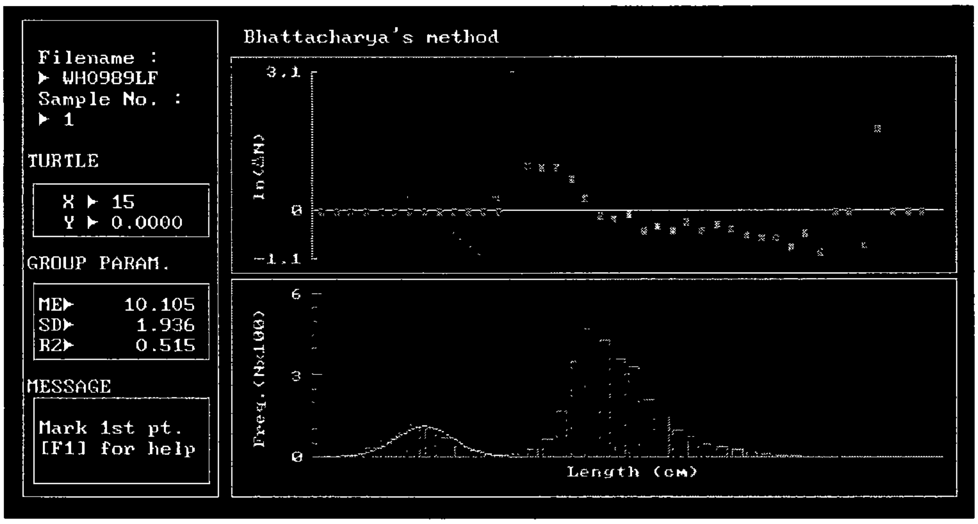


Figure 5.2.3. Converting a parabola into a straight line. dL: width of the length interval, e.g., 1 cm. Example from Sparre *et al.* (1989).



a)



b)

c)

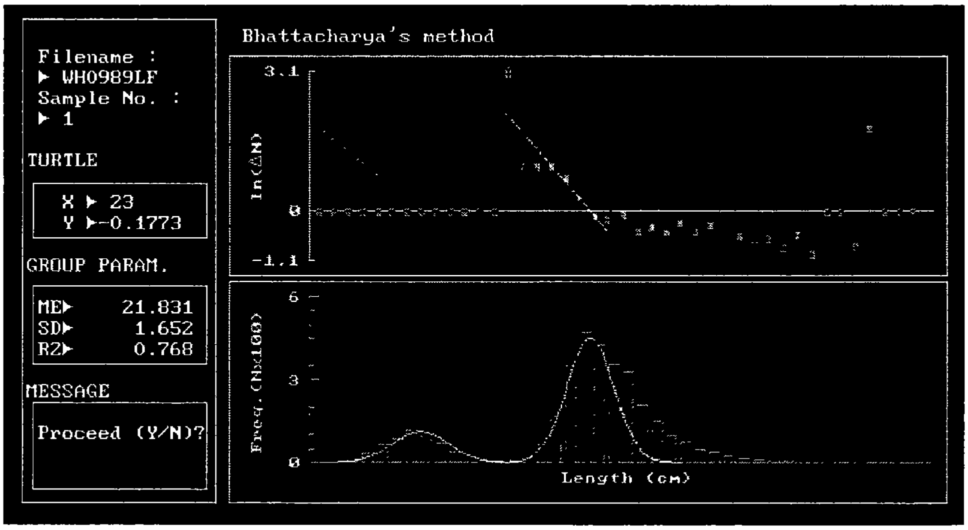
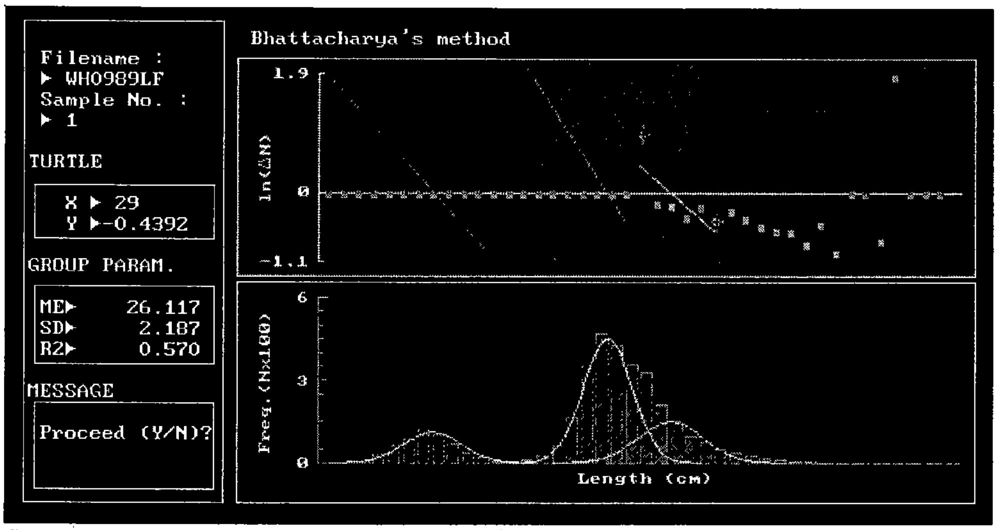
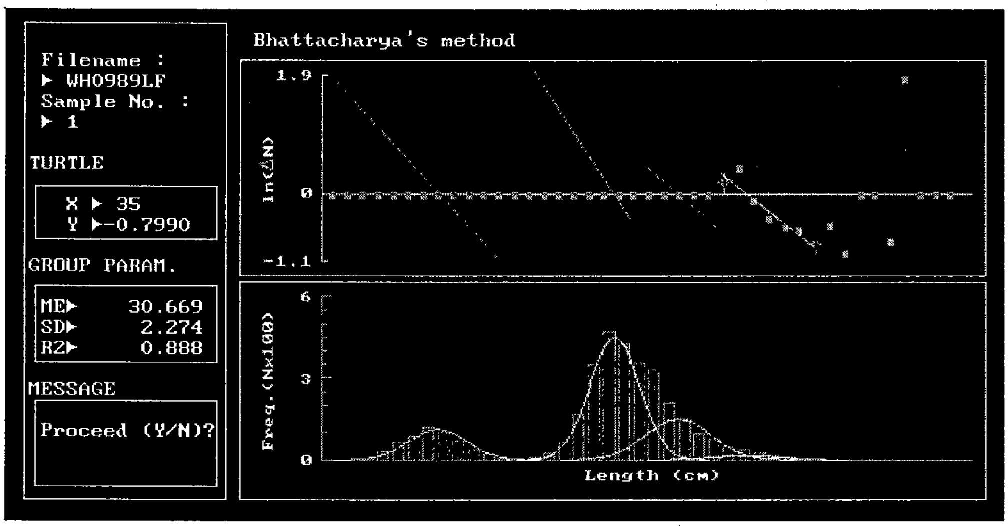


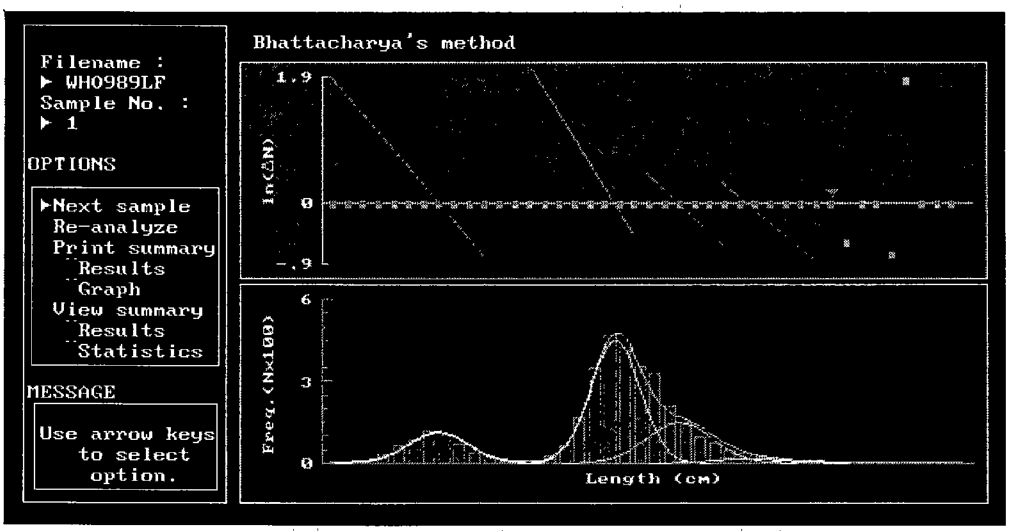
Figure 5.2.4. Length frequency decomposition a) start, b) 1st cohort, c) 2nd cohort.



d)

e)





f)

Figure 5.2.4 (cont.). Decomposition d) 3rd cohort, e) 4th cohort, f) final.

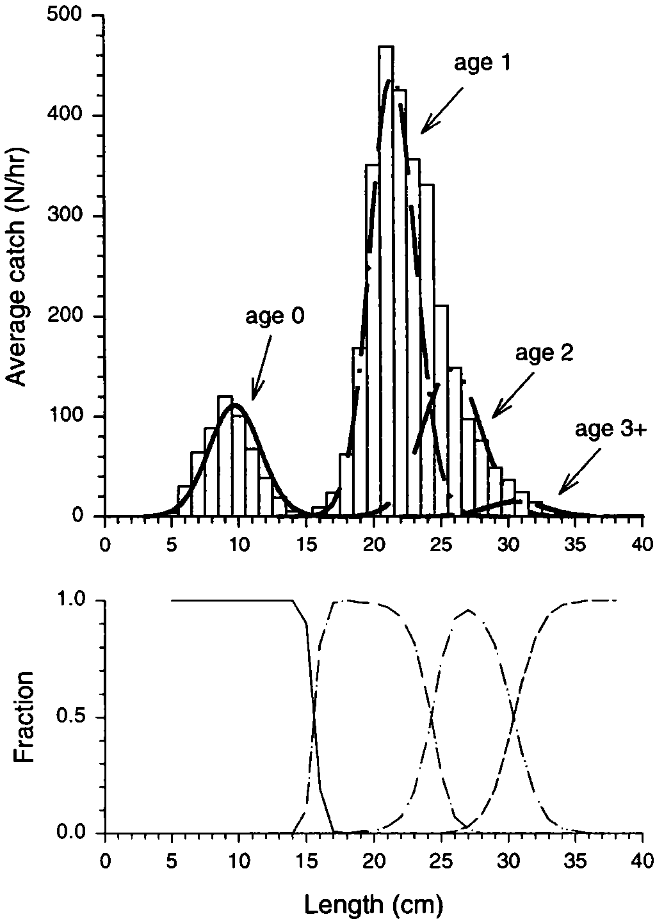


Fig. 5.2.5: Age decomposition of whiting catches from Aug./Sept. 1989 and resulting age length key based on Bhattacharya's method.

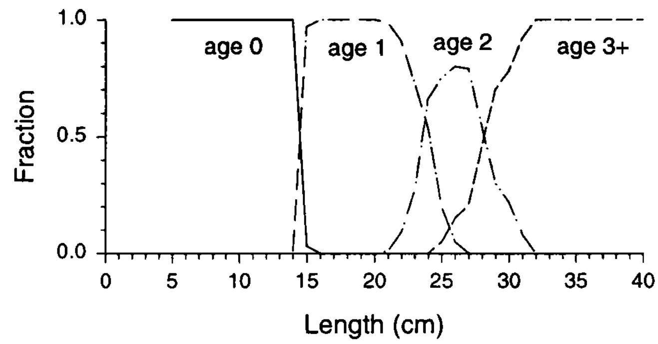


Fig. 5.2.6: Age length key of whiting for the 3rd quarter 1989. Roundfish areas 1 to 4 combined. Data from the Scottish Groundfish Survey in ICES Div. VIb.

5.3 Test of length decomposition of IBTS data from the Skagerrak

Results from the International Bottom Trawl Survey (IBTS) in the Skagerrak were used to derive age distributions from the observed length frequency distributions. Data included whiting catches in standard hauls taken at depths between 20–139 m during quarters I and III from 1991 to 1997.

Averages of number of whiting per standard haul and length group were pooled by quarter and year giving 14 distributions to analyse. Analysis was performed in a two step procedure. Firstly, the Bhattacharya technique was applied to decompose length distributions into approximate normal distributions (Bhattacharya, 1967). These approximations were taken as an input to a precise estimation of normal distributions using the method described by Hasselblad (1966). The predicted and observed length distributions were compared by a chi-square test. Both methods assume that the derived normal distributions can be interpreted as age group components.

All but one of the 14 estimated distributions were significantly different from the observed data (95% confidence level). Thus, the calculations did not describe the observed distributions and should not be used for further compilations.

However, results from the 1st quarters were used to illustrate the method. The predicted age composition and overall length frequency are compared with observed data in Figure 5.3.1. Only four modes in each length distribution could be recognised. The first mode for all years varied in mean lengths from 12.3 to 16.1 cm. These values were close to mean lengths of the second mode, which varied between 16.8 to 18.7 (excluding the mean of 24.9 cm in 1994). Traditional otolith analyses would include the variability in lengths of both the first and second mode as age group 1 (except for 1994). In addition, the third and fourth modes ranged between 19.5 to 26.0 cm and 27.3 to 33.2 cm, respectively. These ranges corroborate to the estimated growth of age groups 2 and 3 in the Skagerrak by traditional otolith analysis. Thus, the decomposition of length groups into normal distributions indicated bimodality in age group 1.

Figure 5.3.2 shows the relation between estimated number fishes in the decomposed length distributions and in traditionally aged data by otolith analysis. The relation indicates a correlation between the two methods. However the relation does not conform to unity; the decomposed data seem to overestimate older ages compared to the results from otolith analysis.

The applied method assumes that age distributions are normally distributed. The assumption requires a non-biased growth of all individual fish of a *year class* and no migration or mingling between stocks. However, skewed growth is observed regularly for young whiting in the Skagerrak. Furthermore, the Skagerrak is a transition area where whiting may spend only a part of their lifecycle as do other gadoid stocks (cod, haddock). Whiting in the Skagerrak may also belong to several stock units. Thus, the method can only be applied to the Skagerrak whiting when adequate biological knowledge on growth and stock structure become available.

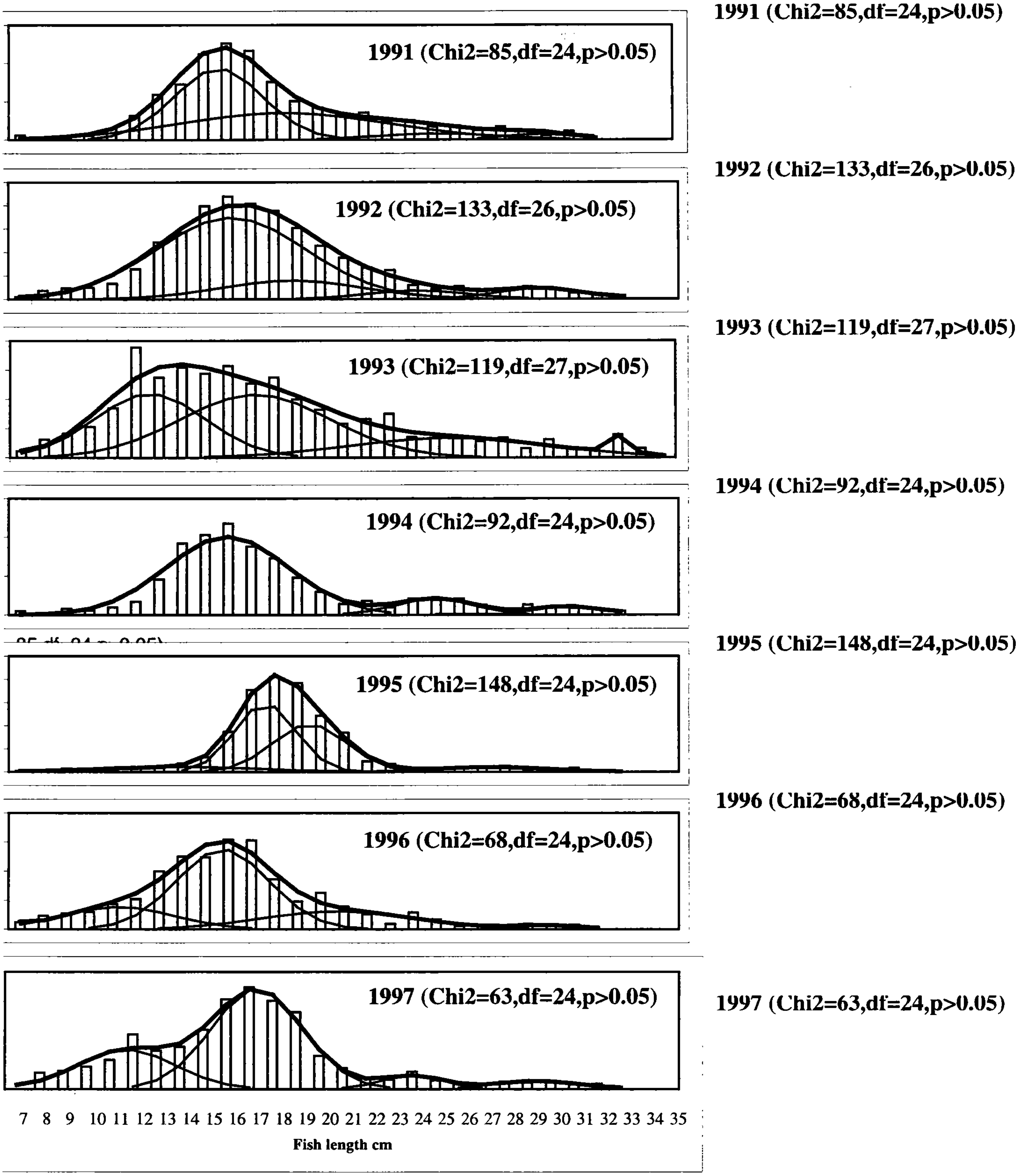
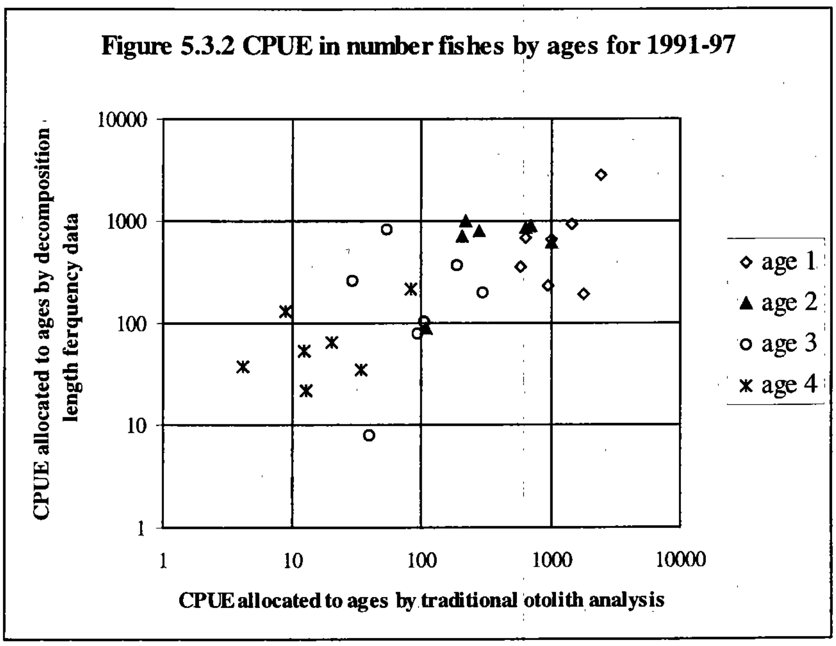


Figure 5.3.1. Length frequency data from IBTS in the Skagerrak, 1st quarter 1991 to 1997. Illustration of decomposed length distributions (columns) by normal distributions (lines). Overall fit indicated by thick line. Note that the overall fit is significantly different from observed data, i.e. results are not valid.



5.4 Length data available

Previous sub sections have investigated the reliability of deriving age data by decomposition of whiting length frequencies by statistical methods. The Workshop decided that there were still flaws in the methods employed and more detailed knowledge is required about whiting biology before this option becomes viable. However, in order to aid any future statistical investigation Table 5.4.1 lists the whiting length frequencies held by the participating institutes for the period 1977 – 1997.

Table 5.4.1 – Whiting Length Frequencies Available

Year/Stock	IIIa	IV	VIa	VIIa	VIIb	VIIg
1977		B,H,S	S			
1978		B,H,S	S			
1979		B,H,S	S			
1980		H,S	S			
1981		H,S	S	N		
1982		H,S	S	N		
1983		E,H,S	S	E,N		E
1984		E,H,S	E,S	E,N		E
1985		B,E,H,S	S	E,N		E
1986		B,E,H,S	E,S	E,N		E
1987		B,E,H,S	E,S	E,N,S		E
1988		B,E,H,S	E,S	E,N,S		E
1989		B,E,H,S	E,S	E,N,S		E
1990		B,E,H,S	S	E,NS		E
1991		B,E,H,S	E,S	E,N,S		E
1992		B,E,H,S	E,S	E,N,S		E
1993		B,E,H,S	S	E,N,S		E
1994		B,E,H,S	S	E,N,S		E
1995		B,E,H,S	S	E,N,S		E
1996		B,E,H,S	S	E,N,S		E
1997		B,E,H,S	E,S	E,N,S		E

B Belgium E England H Netherlands N Northern Ireland
S Scotland

No data available from: France, Ireland, Denmark and Sweden

6 RESULTS OF COMPARATIVE READINGS IN WORKSHOP

6.1 Methodology

Comparative readings were made during the workshop in order to further discuss and disentangle problems in the age estimation of whiting. Otoliths from the pre-meeting exchange programme were not used, instead the otolith reading representative from each country provided a sample of 10 otoliths from their own collection for reading by the other participants. As the otoliths came from existing collections, they were already prepared using the favoured method of the participant providing the sample. In total 97 new otoliths were made available from the workshop participants. The samples represented mainly younger age groups from all seasons in the Northeast Atlantic (Table 6.1.1). Almost half (48%) of the otoliths were presented as sectioned while the rest were broken.

Table 6.1.1 Otolith samples analysed during the comparative readings.

Country of origin	Sampled month	Min of fish length (cm)	Max of fish length (cm)	Sample size (n)
Belgium	MAR	29	35	10
Denmark	OCT	8	29	10
Denmark	SEP	15	21	10
England	DEC	25	31	10
France	OCT	34	34	7
Ireland	SEP	29	35	10
Northern Ireland	MAR	19	36	10
Netherlands	FEB	22	40	10
Scotland	JAN	24	30	3
Scotland	JUN	20	32	3
Scotland	NOV	15	27	4
Sweden	SEP	13	48	10
Grand Total		8	48	97

Accompanying data sheets containing information regarding date of collection and area of collection were provided for each otolith reader to record their findings. Several stereo binocular microscopes with both incidental illumination and transmitted illumination bases were provided along with additional lighting so that the readers could recreate their preferred set up for reading. The samples were then distributed so that each reader was allocated the otoliths supplied by one of the other readers. Once they had examined the otoliths provided and recorded their own findings the reader returned the completed data sheet for analysis and selected another sample and accompanying data sheet.

No discussion regarding the ageing of any samples took place between readers before they had an opportunity to complete that particular sample. In several cases difficulty was encountered when readers were working with material that was presented in a different way from that which they were used to. In these cases they were encouraged to seek help in adapting their set up so that clarification of the otolith surface could be obtained.

Although time was allocated for the otoliths to be read by each reader, this proved to be insufficient and several readers had to return to this task when breaks in the schedule allowed.

6.2 Results

Altogether 10 readers with varying degrees of experience participated in the age reading exercises. The analysis of results followed the recommendations by the Workshop on Sampling Strategies for Age and Maturity (ICES, 1994). Actual analysis were performed with a specially designed spreadsheet developed by Guus Eltink (Eltink, 1994). The spreadsheet calculates modal ages by each otolith from all readings. These overall modal ages are further related to the mean ages and confidence limits (approximated by 2 standard deviations) of the corresponding otoliths by each individual reader.

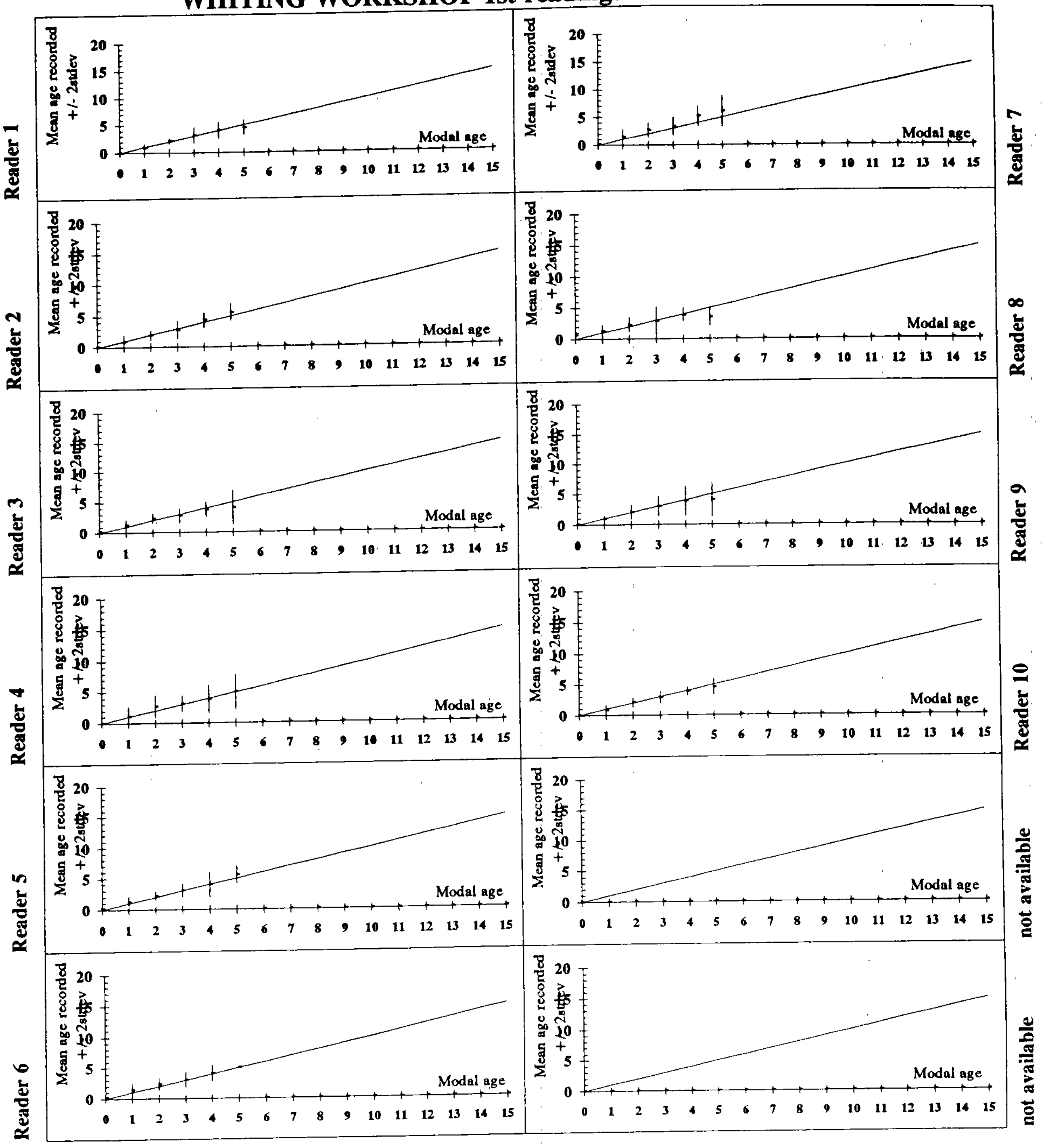
The otolith collection was read twice. The first comparative age reading was performed after a short presentation of the results from the exchange program but before problem otoliths from the exchange program had been demonstrated and thoroughly discussed (Section 4.3). These discussions and a presentation of the results from the first age reading exercise preceded the second age reading exercise of the same otolith collection.

Table 6.2.2 shows the detailed results from the first comparative age readings. The correspondence of the modal age of all readers to the estimated mean age of individual readers is presented in Table 6.2.3 and Figure 6.2.1. Results indicate a tendency by some readers to overestimate younger age groups and to underestimate older age groups. One reader overestimated all age groups. Agreement with modal age varied between readers (55–82%) and decreased by older age groups. Overall agreement was 69%. Variability (expressed as 2 standard deviations) was high, generally above one age unit (see Table 6.2.4).

Table 6.2.2 WHITING WORKSHOP 1st readings 24-25 Oct 1998

Sample origin	Fish no	Fish length	Landing month	Reader 1	Reader 2	Reader 3	Reader 4	Reader 5	Reader 6	Reader 7	Reader 8	Reader 9	Reader 10	MODAL AGE	Age difference	Average age
ENG	1		25 DEC	1	1	1	1	1	2	1	1	1	1	1	1	1.1
ENG	2		26 DEC	5	3	2	2	3	4	5	8	2	3	3	6	3.7
ENG	3		27 DEC	4	5	3	2	4	5	5	3	2	4	4	3	3.7
ENG	4		28 DEC	3	2	2	2	2	3	4	3	2	2	2	2	2.5
ENG	5		28 DEC	4	4	4	2	3	4	6	4	3	4	4	4	3.8
ENG	6		29 DEC	4	4	3	3	2	4	5	4	3	4	4	3	3.6
ENG	7		29 DEC	2	2	2	2	2	3	2	2	2	2	2	1	2.1
ENG	8		30 DEC	6	4	3	3	3	4	6	5	4	4	4	3	4.2
ENG	9		30 DEC	3	3	2	2	3	3	3	3	3	3	3	1	2.8
ENG	10		31 DEC	3	2	2	2	2	3	4	4	3	2	2	2	2.7
DEN1	11		8 OCT	0	0	0	0	0	0	0	1	0	0	0	1	0.1
DEN1	12		12 OCT	0	0	0	0	0	0	0	1	0	0	0	1	0.1
DEN1	13		10 OCT	0	0	0	0	0	0	0	1	0	0	0	1	0.1
DEN1	14		13 OCT	0	0	0	0	0	0	0	1	0	0	0	1	0.1
DEN1	15		18 OCT	0	0	0	0	0	1	0	0	1	0	0	1	0.2
DEN1	16		20 OCT	1	1	1	0	1	1	1	2	1	1	1	2	1.0
DEN1	17		24 OCT	1	2	1	1	1	1	2	2	1	1	1	1	1.3
DEN1	18		22 OCT	1	1	1	1	1	1	1	2	1	1	1	1	1.1
DEN1	19		28 OCT	2	1	3	3	2	1	3	3	1	2	3	2	2.1
DEN1	20		29 OCT	2	1	2	2	2	1	2	2	1	2	2	1	1.7
BEL	21		35 MAR	5	3	3	3	2	2	4	3	4	2	3	3	3.1
BEL	22		29 MAR	4	3	3	4	3	3	5	3	3	3	3	2	3.4
BEL	23		32 MAR	3	3	3	3	3	3	4	3	3	3	3	1	3.1
BEL	24		32 MAR	4	5	4	4	4	4	5	4	4	4	4	1	4.2
BEL	25		35 MAR	4	3	4	3 -		3	4	2	3	2	3	2	3.1
BEL	26		33 MAR	3	3	2	4	3	4	3	2	3	2	3	2	2.9
BEL	27		31 MAR	4	3	3	4	3	3	1	3	4	3	3	3	3.1
BEL	28		32 MAR	3	3	3	4	4	3	4	3	3	3	3	1	3.3
BEL	29		31 MAR	4	4	4	5	4	3	5	3	4	4	4	2	4.0
BEL	30		34 MAR	3	3	3	4	3	3	4	2	4	3	3	2	3.2
SWE	31		28 SEP	3	1	2	3	3	4	2	3	1	2	3	3	2.4
SWE	32		30 SEP	3	1	1	4	4	3	3	2	2	3	3	3	2.6
SWE	33		29 SEP	2	1	2	4	3	2	3	3	1	2	2	3	2.3
SWE	34		27 SEP	2	1	2	4	2	2	3	3	1	2	2	3	2.2
SWE	35		32 SEP	2	1	2	3	2	2	3	2	2	2	2	2	2.1
SWE	36		23 SEP	1	1	2	2	2	2	2	1	1	1	1	1	1.5
SWE	37		21 SEP	1	1	1	1	1	2	1	1	1	1	1	1	1.1
SWE	38		13 SEP	0	0	0	0	0	1	0	0	0	0	0	1	0.1
SWE	39		48 SEP	4	5	4	5	5	5	7	4	7	4	4	3	5.0
SWE	40		34 SEP	3	2	2	3	3	3	3	2	3	3	3	1	2.7
N.IRE	41		24 MAR	2	2	2	2	2	2	2	2	2	2	2	0	2.0
N.IRE	42		22 MAR	2	2	2	2	3	3	3	2	2	2	2	1	2.3
N.IRE	43		22 MAR	2	2	2	3	2	2	2	3	2	2	2	1	2.2
N.IRE	44		18.5 MAR	1	1	1	1	1	1	2	2	1	1	1	1	1.2
N.IRE	45		20.4 MAR	2	2	2	2	2	2	2	3	2	2	2	1	2.1
N.IRE	46		33.8 MAR	3	4	3	4	4	4	4	4	4	4	4	1	3.8
N.IRE	47		34.4 MAR	3	3	3	3	3	3	3	3	4	3	3	1	3.1
N.IRE	48		33.2 MAR	3	3	3	4	4	3	3	3	4	3	3	1	3.3
N.IRE	49		36 MAR	3	3	4	4	4	4	5	3	4	3	4	2	3.7
N.IRE	50		32.6 MAR	5	6	5	6	6	5	7	4	5	5	5	3	5.4
DEN2	51		15 SEP	0	0	0	0	0	0	0	1	0	0	0	1	0.1
DEN2	52		15 SEP	0	0	1	0	1	0	0	1	0	0	0	1	0.3
DEN2	53		15 SEP	0	0	0	0	0	0	0	0	0	0	0	0	0.0
DEN2	54		16 SEP	0	0	0	0	0	0	0	0	0	0	0	0	0 0
DEN2	55		18 SEP	0	0	0	0	0	0	1	1	0	0	0	1	0.2
DEN2	56		19 SEP	1	0	1	0	1	1	1	1	1	0	1	1	0.7
DEN2	57		19 SEP	0	1	1	0	1	0	1	1	0	0	0	1	0 5
DEN2	58		21 SEP	0	0	1	1	1	1	1	1	0	0	1	1	0.6
DEN2	59		21 SEP	0	0	2	1	2	1	1	1	1	0	1	2	0.9
DEN2	60		21 SEP	1	1	2	1	2	1	1	1	1	1	1	1	1.2
NETH	61		34 FEB	3	3	3	4	3	3	4	3	3	3	3	1	3.2
NETH	62		30 FEB	2	2	3	3	3	3	3	2	2	2	2	1	2.5
NETH	63		30 FEB	2	2	3	3	2	3	3	2	3	3	3	1	2.6
NETH	64		33 FEB	3	3	3	3	3	4	4	3	3	3	3	1	3.2
NETH	65		27 FEB	2	2	3	2	2	2	3	2	2	2	2	1	2.2
NETH	66		40 FEB	4	4	4	4	4	4	4	4	4	4	4	0	4.0
NETH	67		27 FEB	2	3	3	3	3	3	3	2	3	3	3	1	2.8
NETH	68		24 FEB	2	2	2	2	2	2	3	2	1	2	2	2	2.0
NETH	69		29 FEB	2	2	3	3	2	3	3	2	2	1	2	2	2 3
NETH	70		22 FEB	2	2	3	1	2	2	4	1	1	1	2	3	1.9
FRA	71		34 OCT	3	3	3	3	3	3	4	3	3	3	3	1	3.1
FRA	72		34 OCT	2	2	2	2	2	2	2	2	2	3	2	1	2.1
FRA	73		34 OCT	2	2	2	2	2	3	2	2	3	3	2	1	2.3
FRA	74		34 OCT	2	2	2	2	2	3	2	2	3	2	2	1	2.2
FRA	75		34 OCT	2	2	2	2	3	3	3	3	3	3	3	1	2.6
FRA	76		34 OCT	3	3	3	3	4	4	3	3	3	4	3	1	3.3
FRA	77		34 OCT	3	3	2	2	3	3	3	2	4	3	3	2	2.8
IRE	78		32 SEP	4	5	4	6	6	5	5	4	3	4	4	3	4 6
IRE	79		33 SEP	2	2	2	3	2	3	2	2	2	3	2	1	2.3
IRE	80		34 SEP	3	3	2	3	2	3	2	2	3	3	3	1	2.6
IRE	81		32 SEP	3	3	3	3	3	3	3	3	3	3	3	0	3.0
IRE	82		35 SEP	3	4	3	3	3	4	3	3	2	3	3	2	3.1
IRE	83		31 SEP	2	2	3	2	2	2	2	2	2	2	2	1	2.1
IRE	84		30 SEP	2	2	2	2	2	3	2	3	2	2	2	1	2.2
IRE	85		31 SEP	2	2	2	5	2	2	2	2	3	2	2	3	2.4
IRE	86		32 SEP	2	2	2	3	2	2	2	3	2	2	2	1	2.2
IRE	87		29 SEP	2	2	2	2	2	2	2	2	2	2	2	0	2.0
SCOT	88		24 JAN	2	2	2	4	2	2	3	2	2	2	2	2	2.3
SCOT	89		26 JAN	3	3	3	3	3	2	3	2	2	2	3	1	2.6
SCOT	90		30 JAN	4	4	3	4	3	3	4	4	3	3	4	1	3.5
SCOT	91		20 JUN	1	1	1	1	1	2	1	1	1	1	1	1	1 1
SCOT	92		25 JUN	2	3	3	4	2	2	3	2	3	2	2	2	2.6
SCOT	93		32 JUN	4	5	5	4	5	4	6	4	5	4	4	2	4.6
SCOT	94		15 NOV	0	0	0	0	0	1	1	0	0	0	0	1	0 2
SCOT	95		22 NOV	1	1	1	3	1	2	3	1	1	1	1	2	1.5
SCOT	96		27 NOV	4	5	3	4	5	5	5	3	3	4	5	2	4.1
SCOT	97		27 NOV	2	2	3	4	3	2	2	2	2	2	2	2	2.4

WHITING WORKSHOP 1st readings 24-25 Oct 1998



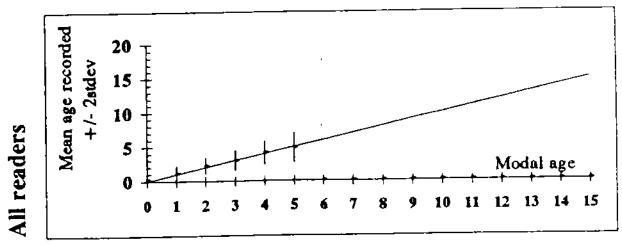


Figure 6.2.1 In above age bias plots the mean age recorded +/- 2stdev of each age reader and all readers combined is plotted against the modal age.

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WHITING WORKSHOP 2nd readings 27 Oct 1998

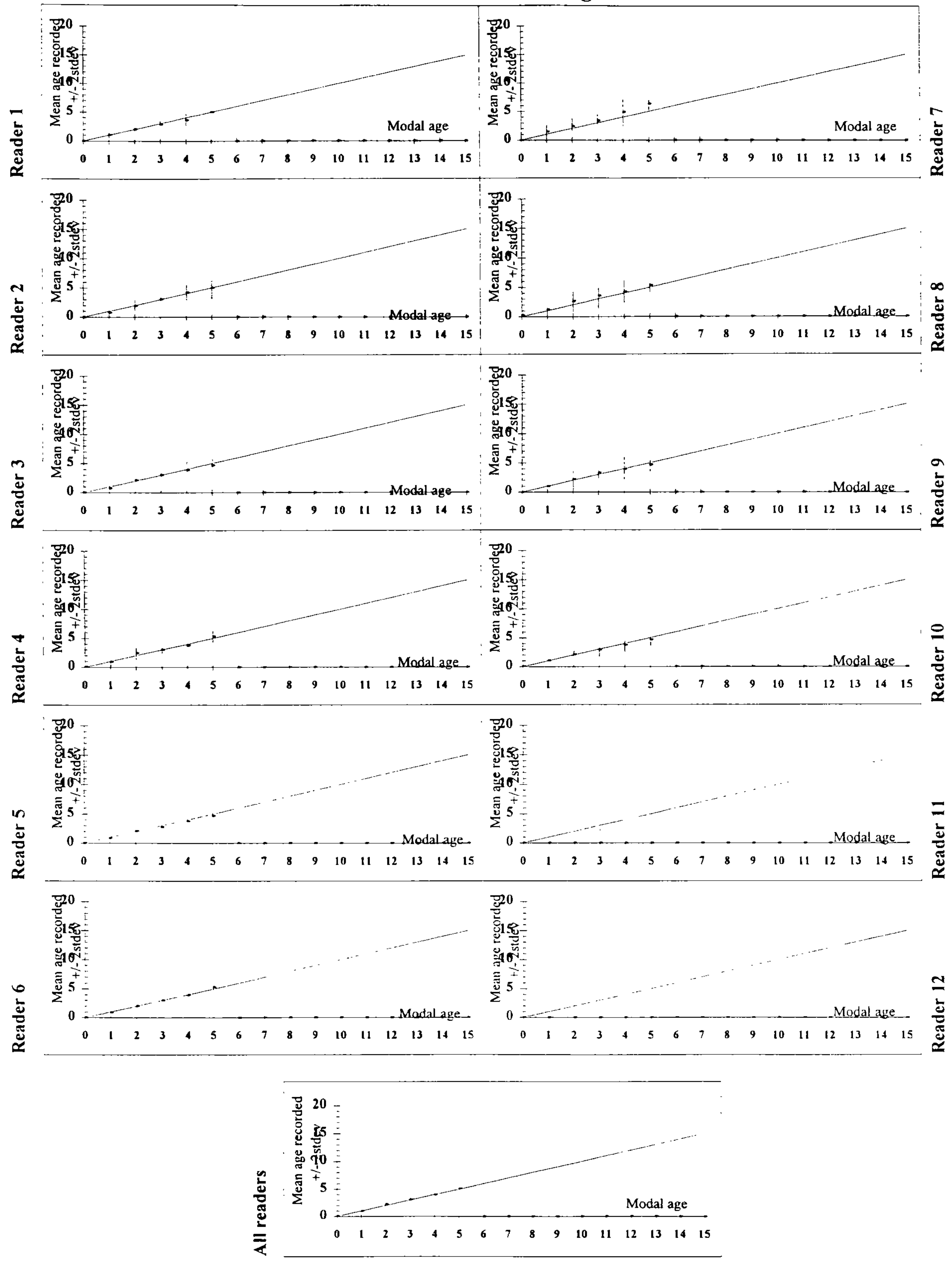

Figure 6.2.2 In above age bias plots the mean age recorded +/- 2stdev of each age reader and all readers combined is plotted against the modal age.

WHITING WORKSHOP 1st readings 24-25 Oct 1998

Table 6.2.3 The mean age recorded, 2stdev, the number of age readings and the agreement with modal age are presented by modal age for each reader and for all readers combined. The number of age readings and the agreement is given for age groups 0-15 combined.

Reader 1

Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	0.00	0.85	2.07	3.11	4.00	4.50	-	-	-	-	-	-	-	-	-	-	
2stdev	0.00	0.75	0.52	1.47	1.41	1.41	-	-	-	-	-	-	-	-	-	-	
Number of age readings	13	13	28	28	13	2	-	-	-	-	-	-	-	-	-	-	97
Agreement with modal age	100%	85%	93%	68%	77%	50%	-	-	-	-	-	-	-	-	-	-	82%

Reader 2

Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	0.08	0.85	1.89	2.71	4.31	5.50	-	-	-	-	-	-	-	-	-	-	
2stdev	0.55	1.11	0.83	1.43	1.26	1.41	-	-	-	-	-	-	-	-	-	-	
Number of age readings	13	13	28	28	13	2	-	-	-	-	-	-	-	-	-	-	97
Agreement with modal age	92%	69%	82%	75%	54%	50%	-	-	-	-	-	-	-	-	-	-	75%

Reader 3

Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	0.15	1.23	2.25	2.88	3.69	4.00	-	-	-	-	-	-	-	-	-	-	
2stdev	0.75	0.88	0.88	1.22	1.26	2.83	-	-	-	-	-	-	-	-	-	-	
Number of age readings	13	13	28	28	13	2	-	-	-	-	-	-	-	-	-	-	97
Agreement with modal age	85%	77%	75%	64%	54%	50%	-	-	-	-	-	-	-	-	-	-	70%

Reader 4

Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	0.00	1.08	2.64	3.14	3.85	5.00	-	-	-	-	-	-	-	-	-	-	
2stdev	0.00	1.52	1.90	1.30	2.29	2.83	-	-	-	-	-	-	-	-	-	-	
Number of age readings	13	13	28	28	13	2	-	-	-	-	-	-	-	-	-	-	97
Agreement with modal age	100%	69%	54%	57%	46%	0%	-	-	-	-	-	-	-	-	-	-	61%

Reader 5

Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	0.15	1.23	2.14	3.00	3.92	5.50	-	-	-	-	-	-	-	-	-	-	
2stdev	0.75	0.88	0.71	1.11	2.08	1.41	-	-	-	-	-	-	-	-	-	-	
Number of age readings	13	13	28	27	13	2	-	-	-	-	-	-	-	-	-	-	96
Agreement with modal age	85%	77%	86%	70%	46%	50%	-	-	-	-	-	-	-	-	-	-	74%

Reader 6

Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	0.23	1.38	2.32	3.07	4.08	5.00	-	-	-	-	-	-	-	-	-	-	
2stdev	0.88	1.01	1.10	1.33	1.28	0.00	-	-	-	-	-	-	-	-	-	-	
Number of age readings	13	13	28	28	13	2	-	-	-	-	-	-	-	-	-	-	97
Agreement with modal age	77%	62%	61%	68%	62%	100%	-	-	-	-	-	-	-	-	-	-	66%

Reader 7

Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	0.23	1.38	2.57	3.29	5.15	6.00	-	-	-	-	-	-	-	-	-	-	
2stdev	0.88	1.30	1.38	1.71	1.80	2.83	-	-	-	-	-	-	-	-	-	-	
Number of age readings	13	13	28	28	13	2	-	-	-	-	-	-	-	-	-	-	97
Agreement with modal age	77%	69%	54%	54%	23%	50%	-	-	-	-	-	-	-	-	-	-	56%

Reader 8

Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	0.62	1.31	2.29	2.82	3.85	3.50	-	-	-	-	-	-	-	-	-	-	
2stdev	1.01	0.96	1.20	2.25	1.11	1.41	-	-	-	-	-	-	-	-	-	-	
Number of age readings	13	13	28	28	13	2	-	-	-	-	-	-	-	-	-	-	97
Agreement with modal age	38%	69%	68%	61%	69%	0%	-	-	-	-	-	-	-	-	-	-	61%

Reader 9

Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	0.08	0.92	2.00	2.93	3.85	4.00	-	-	-	-	-	-	-	-	-	-	
2stdev	0.55	0.55	1.22	1.63	2.43	2.83	-	-	-	-	-	-	-	-	-	-	
Number of age readings	13	13	28	28	13	2	-	-	-	-	-	-	-	-	-	-	97
Agreement with modal age	92%	92%	64%	57%	46%	50%	-	-	-	-	-	-	-	-	-	-	67%

Reader 10

Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	0.00	0.77	2.04	2.82	3.85	4.50	-	-	-	-	-	-	-	-	-	-	
2stdev	0.00	0.88	0.86	0.95	0.75	1.41	-	-	-	-	-	-	-	-	-	-	
Number of age readings	13	13	28	28	13	2	-	-	-	-	-	-	-	-	-	-	97
Agreement with modal age	100%	77%	82%	75%	85%	50%	-	-	-	-	-	-	-	-	-	-	81%

not available

Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
2stdev	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Number of age readings	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Agreement with modal age	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	#####

not available

Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
2stdev	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Number of age readings	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Agreement with modal age	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	#####

ALL READERS

Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	0.15	1.10	2.22	2.96	4.05	4.75	-	-	-	-	-	-	-	-	-	-	
2stdev	0.72	1.08	1.20	1.51	1.78	2.14	-	-	-	-	-	-	-	-	-	-	
Number of age readings	130	130	280	279	130	20	-	-	-	-	-	-	-	-	-	-	969
Agreement with modal age	85%	75%	72%	65%	56%	45%	-	-	-	-	-	-	-	-	-	-	69%

Table 6.2.4 First comparative readings - Agreement and variability of readers by modal age. Note the low number otoliths representing modal age 5.

Modal age	number otoliths	range of agreement (%)	Range of variability (age unit)
0	13	38 – 100%	0.00 – 1.01
1	13	62 – 92%	0.55 – 1.11
2	28	54 – 93%	0.52 – 1.90
3	28	54 – 75%	0.95 – 2.25
4	13	23 – 85%	0.75 – 2.43
5	2	0 - 100%	0.00 – 2.83

Detailed results from the second comparative readings are shown in Table 6.2.5. Table 6.2.6 and Figure 6.2.2 show the calculated agreement between modal age and means of individual readers. Overall agreement with modal ages increased by 3% to 72% compared to the first comparative readings. Agreement for all individual readings increased substantially for age group 0 to 1 but the relatively high variability between examined otoliths remained for older modal ages. However, most readers scored less variability for all modal ages compared to the first reading experiment (see Table 6.2.7).

Table 6.2.5 WHITING WORKSHOP 2nd readings 27 Oct 1998

Sample origin	Fish no	Fish length	Landing month	Reader 1	Reader 2	Reader 3	Reader 4	Reader 5	Reader 6	Reader 7	Reader 8	Reader 9	Reader 10	MODAL AGE	Age difference	Average
ENG	1	25	DEC	1	1	1	1	1	1	1	2	1	1	1	1	1.1
ENG	2	26	DEC	3	3	2	3	2	3	5	8	3	3	3	6	3.5
ENG	3	27	DEC	3	5	4	4	3	4	6	5	4	4	4	3	4.2
ENG	4	28	DEC	2	2	3	4	2	1	3	4	3	2	2	3	2.6
ENG	5	28	DEC	4	4	3	3	4	3	4	6	2	4	4	4	3.7
ENG	6	29	DEC	3	3	3	3	2	3	5	4	3	3	3	3	3.2
ENG	7	29	DEC	2	2	2	2	2	2	2	3	2	2	2	1	2.1
ENG	8	30	DEC	4	4	5	4	4	5	6	6	4	4	4	2	4.6
ENG	9	30	DEC	3	3	3	3	3	3	3	3	3	3	3	0	3
ENG	10	31	DEC	3	2	3	2	2	2	3	3	3	3	3	1	2.6
DEN1	1	8	OCT	0	0	0	0	0	0	0	0	0	0	0	0	0
DEN1	2	12	OCT	0	0	0	0	0	0	0	0	0	0	0	0	0
DEN1	3	10	OCT	0	0	0	0	0	0	0	0	0	0	0	0	0
DEN1	4	13	OCT	0	0	0	0	0	0	0	1	0	0	0	1	0.1
DEN1	5	18	OCT	0	0	0	0	0	0	0	1	0	0	0	1	0.1
DEN1	6	20	OCT	1	0	1	0	1	1	1	1	1	1	1	1	0.8
DEN1	7	24	OCT	1	1	1	1	1	1	2	1	1	1	1	1	1.1
DEN1	8	22	OCT	1	1	1	1	1	1	1	1	1	1	1	0	1
DEN1	9	28	OCT	2	1	1	2	2	1	2	2	2	2	2	1	1.7
DEN1	10	29	OCT	2	1	1	1	2	1	2	1	1	1	1	1	1.3
BEL	1	35	MAR	3	3	4	3	2	3	3	4	4	3	3	2	3.2
BEL	2	29	MAR	3	3	3	4	3	4	2	5	3	3	3	3	3.3
BEL	3	32	MAR	2	3	3	3	2	3	2	5	4	2	2	3	2.9
BEL	4	32	MAR	4	4	4	4	4	3	5	4	4	4	4	2	4
BEL	5	35	MAR	4	4	3	2	3	3	5	3	4	2	3	3	3.3
BEL	6	33	MAR	3	5	3	3	3	4	3	4	3	3	3	2	3.4
BEL	7	31	MAR	3	3	3	3	3	3	3	4	4	3	3	1	3.2
BEL	8	32	MAR	3	4	4	3	3	3	3	3	3	3	3	1	3.2
BEL	9	31	MAR	4	6	4	4	4	4	4	4	4	4	4	2	4.2
BEL	10	34	MAR	3	4	3	3	2	3	3	4	4	3	3	2	3.2
SWE	1	28	SEP	2	1	4	3	2	3	3	3	1	2	3	3	2.4
SWE	2	30	SEP	2	1	3	3	2	2	3	4	1	2	2	3	2.3
SWE	3	29	SEP	2	1	1	3	2	2	2	2	1	2	2	2	1.8
SWE	4	27	SEP	3	1	2	2	1	2	2	4	1	2	2	3	2
SWE	5	32	SEP	2	1	1	2	2	2	2	1	1	2	2	1	1.6
SWE	6	23	SEP	1	1	1	1	1	1	2	1	1	2	1	1	1.2
SWE	7	21	SEP	1	1	1	1	1	1	1	1	1	2	1	1	1.1
SWE	8	13	SEP	0	0	0	0	0	0	0	0	0	1	0	1	0.1
SWE	9	48	SEP	4	4	4	4	5	4	8	5	7	5	4	4	5
SWE	10	34	SEP	2	2	2	3	2	3	3	2	3	3	2	1	2.5
N.IRE	1	24	MAR	2	2	2	2	2	3	2	3	2	2	2	1	2.2
N.IRE	2	22	MAR	2	2	2	3	3	4	3	3	3	2	3	2	2.7
N.IRE	3	22	MAR	2	2	2	3	2	2	2	3	2	2	2	1	2.2
N.IRE	4	18.5	MAR	1	1	1	1	1	1	2	2	1	1	1	1	1.2
N.IRE	5	20.4	MAR	2	2	2	3	2	2	2	2	2	2	2	1	2.1
N.IRE	6	33.8	MAR	4	4	4	4	4	5	5	4	4	4	4	1	4.2
N.IRE	7	34.4	MAR	3	3	4	3	3	4	4	4	4	4	4	1	3.6
N.IRE	8	33.2	MAR	3	3	3	4	4	4	4	3	4	3	3	1	3.5
N.IRE	9	36	MAR	3	4	5	4	4	5	4	3	4	3	4	2	3.9
N.IRE	10	32.6	MAR	5	6	5	6	6	7	6	5	5	5	5	2	5.6
DEN2	1	15	SEP	0	0	0	0	0	0	0	0	0	0	0	0	0
DEN2	2	15	SEP	0	0	0	1	0	0	0	0	0	0	0	1	0.1
DEN2	3	15	SEP	0	0	0	0	0	0	0	1	0	0	0	1	0.1
DEN2	4	16	SEP	0	0	0	0	0	0	0	0	0	0	0	0	0
DEN2	5	18	SEP	0	0	0	0	0	0	0	0	0	0	0	0	0
DEN2	6	19	SEP	1	0	0	1	0	1	1	1	1	1	1	1	0.7
DEN2	7	19	SEP	1	0	0	0	0	0	1	1	1	1	1	1	0.5
DEN2	8	21	SEP	1	0	0	1	0	1	1	0	1	0	1	1	0.5
DEN2	9	21	SEP	1	0	0	1	0	1	1	1	1	1	1	1	0.7
DEN2	10	21	SEP	1	1	1	1	1	1	1	1	1	1	1	0	1
NETH	1	34	FEB	3	3	4	4	3	3	3	4	4	4	3	1	3.5
NETH	2	30	FEB	2	2	3	3	3	2	3	3	3	2	3	1	2.6
NETH	3	30	FEB	2	2	3	3	2	3	3	3	3	3	3	1	2.7
NETH	4	33	FEB	3	3	3	3	3	4	4	3	4	3	3	1	3.3
NETH	5	27	FEB	2	2	3	2	2	2	2	3	3	2	2	1	2.3
NETH	6	40	FEB	4	4	4	4	4	4	4	4	4	4	4	0	4
NETH	7	27	FEB	3	3	4	3	3	3	3	3	4	4	3	1	3.3
NETH	8	24	FEB	1	2	1	2	2	1	2	2	1	1	1	1	1.5
NETH	9	29	FEB	2	3	2	2	3	2	3	3	3	2	2	1	2.5
NETH	10	22	FEB	2	2	2	2	2	1	4	3	1	2	2	3	2.1
FRA	1	34	OCT	3	3	3	3	3	3	3	4	4	4	3	1	3.3
FRA	2	34	OCT	2	2	3	2	2	2	2	3	3	3	2	1	2.4
FRA	3	34	OCT	2	2	2	2	2	2	2	2	3	2	2	1	2.1
FRA	4	34	OCT	2	2	2	3	2	2	2	3	3	2	2	1	2.3
FRA	5	34	OCT	2	4	3	4	3	2	4	3	4	3	4	2	3.2
FRA	6	34	OCT	3	4	3	3	4	3	4	3	4	4	3	1	3.5
FRA	7	34	OCT	3	3	3	3	3	2	3	3	3	3	3	1	2.9
IRE	1	32	SEP	5	4	4	5	4	5	6	6	5	5	5	2	4.9
IRE	2	33	SEP	2	2	2	2	2	2	2	2	2	2	2	0	2
IRE	3	34	SEP	3	3	2	3	3	3	3	3	3	2	3	1	2.8
IRE	4	32	SEP	3	4	2	3	4	4	4	4	3	3	4	2	3.4
IRE	5	35	SEP	3	4	3	2	3	3	3	3	4	3	3	2	3.1
IRE	6	31	SEP	2	2	2	2	2	2	2	2	2	2	2	0	2
IRE	7	30	SEP	2	2	2	2	2	2	2	2	2	3	2	1	2.1
IRE	8	31	SEP	3	3	2	3	2	2	4	3	3	3	3	2	2.8
IRE	9	32	SEP	2	2	2	3	3	2	2	3	3	2	2	1	2.4
IRE	10	29	SEP	2	2	2	2	2	2	2	2	2	2	2	0	2
SCOT	1	24	JAN	2	2	2	2	2	2	2	2	2	2	2	0	2
SCOT	2	26	JAN	3	3	3	3	3	3	3	3	2	2	3	1	2.8
SCOT	3	30	JAN	4	4	4	4	3	4	4	3	3	3	4	1	3.6
SCOT	4	20	JUN	1	1	1	1	1	1	1	1	1	1	1	0	1
SCOT	5	25	JUN	2	3	3	3	2	2	4	3	2	2	2	2	2.6
SCOT	6	32	JUN	5	5	5	5	4	4	7	5	4	4	5	3	4.8
SCOT	7	15	NOV	0	0	0	0	0	0	0	0	0	0	0	0	0
SCOT	8	22	NOV	1	1	1	1	1	1	3	2	1	1	1	2	1.3
SCOT	9	27	NOV	4	5	4	4	4	4	6	4	4	3	4	3	4.2
SCOT	10	27	NOV	2	2	2	2	3	2	4	1	2	1	2	3	2.1

WHITING WORKSHOP 2nd readings 27 Oct 1998

Table 6.2.6 The mean age recorded, 2stdev, the number of age readings and the agreement with modal age are presented by modal age for each reader and for all readers combined. The number of age readings and the agreement is given for age groups 0-15 combined.

Reader 1

Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	0.00	1.06	2.04	2.88	3.57	5.00	-	-	-	-	-	-	-	-	-	-	
2stdev	0.00	0.50	0.39	0.86	1.29	0.00	-	-	-	-	-	-	-	-	-	-	
Number of age readings	12	16	26	26	14	3	-	-	-	-	-	-	-	-	-	-	97
Agreement with modal age	100%	94%	96%	81%	64%	100%	-	-	-	-	-	-	-	-	-	-	88%

Reader 2

Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	0.00	0.75	1.92	3.04	4.21	5.00	-	-	-	-	-	-	-	-	-	-	
2stdev	0.00	1.15	1.12	1.65	1.40	2.00	-	-	-	-	-	-	-	-	-	-	
Number of age readings	12	16	26	26	14	3	-	-	-	-	-	-	-	-	-	-	97
Agreement with modal age	100%	63%	69%	58%	71%	33%	-	-	-	-	-	-	-	-	-	-	68%

Reader 3

Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	0.00	0.75	2.12	3.04	3.86	4.67	-	-	-	-	-	-	-	-	-	-	
2stdev	0.00	0.89	1.18	1.20	1.54	1.15	-	-	-	-	-	-	-	-	-	-	
Number of age readings	12	16	26	26	14	3	-	-	-	-	-	-	-	-	-	-	97
Agreement with modal age	100%	75%	65%	65%	64%	67%	-	-	-	-	-	-	-	-	-	-	71%

Reader 4

Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	0.08	0.94	2.42	3.00	3.79	5.33	-	-	-	-	-	-	-	-	-	-	
2stdev	0.58	0.89	1.16	0.98	0.85	1.15	-	-	-	-	-	-	-	-	-	-	
Number of age readings	12	16	26	26	14	3	-	-	-	-	-	-	-	-	-	-	97
Agreement with modal age	92%	81%	62%	77%	79%	67%	-	-	-	-	-	-	-	-	-	-	76%

Reader 5

Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	0.00	0.88	2.08	2.77	3.79	4.67	-	-	-	-	-	-	-	-	-	-	
2stdev	0.00	1.24	0.78	1.17	1.16	2.31	-	-	-	-	-	-	-	-	-	-	
Number of age readings	12	16	26	26	14	3	-	-	-	-	-	-	-	-	-	-	97
Agreement with modal age	100%	63%	85%	62%	64%	0%	-	-	-	-	-	-	-	-	-	-	71%

Reader 6

Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	0.00	0.94	2.00	3.04	3.93	5.33	-	-	-	-	-	-	-	-	-	-	
2stdev	0.00	0.50	0.98	1.20	1.66	3.06	-	-	-	-	-	-	-	-	-	-	
Number of age readings	12	16	26	26	14	3	-	-	-	-	-	-	-	-	-	-	97
Agreement with modal age	100%	94%	77%	65%	57%	33%	-	-	-	-	-	-	-	-	-	-	75%

Reader 7

Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	0.00	1.44	2.38	3.35	4.86	6.33	-	-	-	-	-	-	-	-	-	-	
2stdev	0.00	1.26	1.39	1.49	2.46	1.15	-	-	-	-	-	-	-	-	-	-	
Number of age readings	12	16	26	26	14	3	-	-	-	-	-	-	-	-	-	-	97
Agreement with modal age	100%	63%	73%	69%	57%	0%	-	-	-	-	-	-	-	-	-	-	69%

Reader 8

Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	0.25	1.19	2.65	3.54	4.21	5.33	-	-	-	-	-	-	-	-	-	-	
2stdev	0.90	1.09	1.87	2.13	1.95	1.15	-	-	-	-	-	-	-	-	-	-	
Number of age readings	12	16	26	26	14	3	-	-	-	-	-	-	-	-	-	-	97
Agreement with modal age	75%	69%	38%	65%	50%	67%	-	-	-	-	-	-	-	-	-	-	58%

Reader 9

Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	0.00	1.00	2.19	3.31	3.93	4.67	-	-	-	-	-	-	-	-	-	-	
2stdev	0.00	0.00	1.60	1.47	2.14	1.15	-	-	-	-	-	-	-	-	-	-	
Number of age readings	12	16	26	26	14	3	-	-	-	-	-	-	-	-	-	-	97
Agreement with modal age	100%	100%	46%	50%	71%	67%	-	-	-	-	-	-	-	-	-	-	67%

Reader 10

Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	0.08	1.06	2.08	2.92	3.71	4.67	-	-	-	-	-	-	-	-	-	-	
2stdev	0.58	0.89	0.78	1.26	1.22	1.15	-	-	-	-	-	-	-	-	-	-	
Number of age readings	12	16	26	26	14	3	-	-	-	-	-	-	-	-	-	-	97
Agreement with modal age	92%	81%	85%	62%	57%	67%	-	-	-	-	-	-	-	-	-	-	74%

Reader 11

Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
2stdev	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Number of age readings	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Agreement with modal age	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	#####

Reader 12

Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
2stdev	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Number of age readings	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Agreement with modal age	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	#####

ALL READERS

Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	0.04	1.00	2.19	3.09	3.99	5.10	-	-	-	-	-	-	-	-	-	-	
2stdev	0.40	0.98	1.25	1.43	1.73	1.69	-	-	-	-	-	-	-	-	-	-	
Number of age readings	120	160	260	260	140	30	-	-	-	-	-	-	-	-	-	-	970
Agreement with modal age	96%	78%	70%	65%	64%	50%	-	-	-	-	-	-	-	-	-	-	72%

Table 6.2.7 Second comparative readings - Agreement and variability of readers by modal age. Observe that the number of otoliths have been reallocated between modal ages.

Modal age	number otoliths	range of agreement(%)	range of variability (age units)
0	12	92 – 100%	0.00 – 0.90
1	16	63 – 100%	0.00 – 1.26
2	26	38 – 96%	0.39 – 1.87
3	26	50 – 81%	0.86 – 2.13
4	14	50 – 71%	0.85 – 2.46
5	3	0 – 100%	0.00 – 3.06

Results from both readings should be interpreted with caution due to the low sample number. In addition the same sample was used in both reading experiments, which might have confounded the results of the second reading experiment. However, the apparent increase between experiments in reader agreement with modal age and precision (lower variability) among younger age groups indicate a higher consensus among readers. The remaining high and even increased variability for some readers may also be interpreted as an effort by individual readers to adopt to a new common standard, outlined between the experiments. It should be noted that modal age might not represent true age; results only indicate a better precision between readers.

Several readers expressed concern over unaccustomed working conditions. Besides unfamiliar working tools, many readers experienced problems with otoliths that had not been prepared according to the favoured standard. Readers used to sectioned otoliths had troubles with broken otoliths and vice versa. However, results from the second reading experiment indicated that the coefficient of variance for both broken and sectioned otoliths decreased by half from 38–30% to 19–15% for readers preferring broken and sectioned otoliths, respectively. Thus, sectioned otoliths seemed to be easier to analyse regardless of preference (Table 6.2.8). The slightly lower coefficient of variance (30% and 15%) for readers preferring sectioned otoliths might suggest that these readers had a higher experience in otolith readings. All participants recommended further analyses of the effects of preparation techniques and reader experience.

Table 6.2.8 – Preferences

	Preparation technique	
Reader preference	broken otolith	sectioned otolith
prefers sectioned	30% C.V.	15% C.V.
prefers broken	38% C.V.	19% C.V.

Despite the unaccustomed working conditions during the workshop, both comparative readings resulted in better agreement and precision than from the pre-meeting exchange program (Section 4.1). One obvious reason was that the participants in the exchange programs were not identical to the participants in the comparative readings. Another reason was that otoliths had been damaged during transport and handling during the exchange program and were thus in a less optimal condition for analysis. However, the most important reason was considered to be the exchange of experience between readers during the workshop. It was concluded that exchange programs can be used to monitor precision between readers or laboratories. However, substantial improvements in precision can only be achieved by personal discussions on common otolith samples.

7 TECHNIQUES AND GUIDELINES

7.1 Methodologies of age determinations for whiting

The participants at the workshop used a range of methods for the determination of whiting ages by visual interpretation of the opaque and translucent growth zones that are found within whiting otoliths.

The basic principle of exposing the growth zones along the transverse line through the nucleus of the otolith for visual inspection was common to all methods.

Although two basic methods, thin sectioning and otolith breaking were used, a diverse range of variations existed for each method.

7.1.1 Preparation of the otoliths

1. Otolith thin-section methods

Transverse thin sections were prepared from otoliths using a variety of techniques and principal variations are summarised in the table below. All of these techniques are essentially variations of the method described by Bedford and Williams to embed the otoliths in resin blocks prior to sectioning. The various combinations of type of cutting blade, the number of cutting blades and the cutting speed employed to produce the otolith thin sections, are not thought to affect the readability of the otolith growth zones in these cases and have been excluded from the table.

Institute	Section Thickness	Colour of Embedding Resin	Un-mounted Sections	Sections Mounted on Glass Microscope Slides		
				Mounted with Cover Slip	Fixed to Slide	
					Un-coated	Protective Coating
RIVO	0.8 mm	black			Yes	
FRC	0.4 – 0.5 mm	black				yes
CEFAS	0.3 – 0.4 mm	black		yes		
AESD	0.3 – 0.4 mm	black		yes		
IFREMER	0.3 mm	clear	Yes			

2. Otolith Breaking methods.

The participants who employ the otolith breaking method use a variety of techniques and the principal variations are summarised in the table below. If the otolith breaking method is used, it is essential that the otoliths are broken cleanly and in the correct place, to ensure the broken face of the otolith is complete and in alignment with the transverse line through the nucleus of the otolith.

3. Otolith breaking methods.

Institute	Otolith Breaking Method		Grinding of the Broken Surface
	Small Otoliths	Large otoliths	
DSF	By hand	Scalpel	Difficult otoliths
DIFR	By hand	wire cutters	
IMR, Sweden	Fine wire cutters	piano wire cutters	
MLA	By hand	by hand or scalpel	

7.1.2 Viewing the Otoliths

1. Otolith thin sections

The methods used by participants to view otolith thin sections include:

- Incident light (I)
- 'Ring Illumination´ (RI)
- Transmitted light (T)
- 'Bright Field' transmitted light (BFT)

It is necessary to control certain aspects of the light used to view the otolith thin sections in order to ensure that translucent and opaque growth zone are observation conditions within the optimum range for the interpretation of these zones. These include:

- Light intensity (I, RI, T, BFT)
- The degree of focussing of the light source (I)
- The angle of the incident light (I)
- The orientation of the otolith to the direction of the illumination (I)

2. Broken otoliths

The majority of the methods used by participants to view broken otoliths were based on the principle, that otolith growth zones are best observed by directing light against the distal and/or proximal surface(s) of the otolith and then observing the light transmitted through the broken surface of the otolith. These methods included:

- Viewing broken otoliths immersed in water with bi-directional transmitted light.
- Viewing broken otoliths immersed in 100% alcohol with bi-directional transmitted light.
- Viewing broken otoliths mounted in modelling clay with directional transmitted light and shading the broken surface. The surface of the otolith is coated with baby oil.
- Viewing broken otoliths mounted in modelling clay using incident light directed against the broken surface and observing the light reflected from the broken surface.
  (This method is only used occasionally).

It is necessary to control certain aspects of the light used to view the broken otoliths in order to ensure that translucent and opaque growth zone are within the optimum range for the interpretation of these zones. These include:

- Light intensity
- The degree of focussing used
- The angle of the incident light
- The orientation of the otolith to the direction(s) of the illumination

3. Otolith viewing magnification.

Participants routinely use magnifications in the following ranges to view whiting otolith growth zones.

- 5x to 10x
- 10x to 15x
- 15x to 20x

7.2 Interpretation of the Otoliths

Suggested guidelines for the interpretation of whiting otolith growth zones include:

- Use a low magnification for the initial observation of each otolith and then increase the magnification if this is necessary to resolve any aspects of the growth zones that are difficult to interpret.
- In general both otolith sections and broken otoliths should be illuminated by using the lowest light intensity necessary to show the translucent and opaque growth zones with the best clarity.
- When observing otolith thin sections, both incident and transmitted light should be used to interpret the growth zones.
- The use of incident light often provides better definition to the otolith edge type (opaque or translucent) when observing otolith thin sections.

The advantages and disadvantages the various methods are set out in the following table.

METHOD	ADVANTAGES	DISADVANTAGES
Thin Section Methods	More efficient training.	Longer preparation time.
	More efficient archiving of material.	More expensive.
	More efficient re-reading of otoliths.	The otolith orientation within the light path cannot be manipulated.
	Material is less likely to suffer degradation during otolith exchanges.	
Otolith Breaking Methods	Easier to locate the nucleus by grinding if necessary.	The breaking method requires a greater degree of skill.
	The otolith orientation within the light path can be manipulated.	
	Shorter Preparation time.	Longer training times for new readers.
	Less expensive	

7.3 Future Whiting Otolith Exchanges

In order to maintain consistency between experienced readers there should be regular exchanges of ageing material and these exchanges should occur at least every two years. These exchanges can demonstrate substantial bias or disagreements between readers; in such events it may be necessary to convene a workshop to review the age determination of a particular species. In recent years the number and frequency of exchanges has not reach the prescribed level but nevertheless some exchanges have occurred and for gadoid species there appear to be some common problems.

There are two entirely different methods of viewing the otolith viz. thin sectioned and broken. Both techniques have their advantages and disadvantages and it is highly unlikely that a standard technique is going to emerge in Europe within the foreseeable future and all future exchange schemes should make provision for the dual methods of age determination. In addition, by nature of their composition, broken otoliths are fragile and frequent handling causes a rapid deterioration in their integrity resulting in material which is difficult, and in some cases, impossible to interpret. This is a manifestly unfair system which penalises readers who are well down the circulation list. Subsequent analysis will probably under estimate the level of precision between readers due to the inadequate material presented to later readers.

Establishing an exchange scheme which meets all the necessary criteria should not be undertaken lightly and preparing the otoliths for exchange will cause a considerable amount of work for the co-ordinator. However, the steps outlined below will produce a scheme that should produce an accurate estimate of precision between readers and institutes.

Step 1 Obtain fish. Determine required parameters e.g., capture date, length, weight, sex

Step 2 Remove the pair of sagittae otoliths

Step 3 Take one otolith from the pair and thin section to an agreed standard

Step 4 Photograph thin section by a) transmitted light
b) reflected light

Step 5 Digitise photographs

Step 6 Take remaining whole otolith from pair and break in the appropriate plane

Steps 1 to 6 should be repeated for the number of fish that are going to constitute the exchange.

Step 7 — Assemble the material. For each fish there should now exist:
1 thin section otolith
1 broken otolith
2 digitised images – 1 of thin section by transmitted light
1 of thin section by reflected light
Associated documentation e.g., length etc

Step 8 — The number of participants in the scheme should be divided into two groups and material from half the fish sent to the first reader in each group.

Step 9 — The material should be circulated within each sub-group until completed.

Step 10 — The material should be transferred from each sub-group to the other and circulated within the new sub-group.

The co-ordinator must be kept informed at all stages of the progress of the exchange material and age determinations should be passed directly to him/her as soon as possible. Although for some fish the possibility will exist for a range of ages depending on the viewing method the reader should only submit one age.

The above method still prevents readers from undertaking detailed investigations on difficult otoliths e.g., grinding, polishing etc. and it is still a compromise for the preparation of thin sections (see 7.1.1). However, it does provide the individual reader with a number of options and at least one should be close to their accustomed style of reading. The digitised images can be annotated for subsequent discussion (see also Section 8.1).

7.4 Future whiting workshops

Otolith exchanges can highlight particular problems with age determination but the only practical way of attempting to resolve conflicts, is via a workshop. Within such an environment discussion on problem otoliths is invaluable, especially when the group can view the otoliths concerned. One of the features noted at the Hirtshals Workshop were the different requirements by individual readers for illumination (power and style), microscopes (magnification) and prepared material (these are listed at length in Sections 7.1.1 and 7.1.2). Despite the use of a well-equipped laboratory not all preferences could be catered for and the participants felt 'uncomfortable' when viewing some otoliths with unfamiliar equipment. Participants in future workshops should be encouraged to travel with as much personal reading equipment as possible.

Whiting otoliths are relatively easy to view, the problem arises in the interpretation of the macrostructure displayed. These problems over interpretation were first expounded in 1960 (Gamble *et al*, 1960) and in the intervening 39 years the problems have remained basically the same but with the additional discovery of crescent shaped translucent zones (Section 4.3). Many of these problems could be solved by age validation but work prior to the Workshop failed to find any comprehensive collection of validated otoliths. Institutes should give serious consideration to building collections of validating ages from reared or tagged whiting – this should be started immediately so that the participants in any future Workshop have a firm foundation on which to re-interpret the otoliths.

A novel feature for the established readers at the present Workshop was the impressive strides made in the use of microstructures, e.g., daily rings, as an aid to interpretation of the macrostructures, i.e., annuli and the tentative confirmation of false checks, e.g., Bowers' Zone. Further work should be encouraged in this area and a future Workshop should include a major section where scientists from both disciplines can pool their knowledge.

8 FUTURE INTERCALIBRATION

8.1 Digitised Images

The Workshop was concerned that the experience assembled at the meeting should be conveyed to other interested parties, e.g., current whiting otolith readers who were unable to attend the meeting and any future readers. Discussion focused on the best method to communicate this knowledge with reference to modern technology.

Eventually it was decided to produce material for a CD-ROM during the meeting with the intention of providing a collection of interpretations that could be used by any institute as a familiarisation or training package. It must be emphasised that this collection of otoliths could not be classified as a reference collection (the otoliths were not validated for age) nor as a control collection of agreed determinations. The collection was built in Hirtshals by readers viewing projections of digitised sections; most of the readers felt constrained by having to use unfamiliar equipment and photographs created using lighting techniques that frequently varied from that practised at individual institutes. In addition many of the images proved difficult to interpret and under normal circumstances the individual readers would have made more intensive investigations involving fine focusing, different illumination, additional polishing etc. For all these reasons the group of readers could not put 100% confidence on their age estimations and thus the collective age estimates should be viewed as probably correct but not definitive.

The Marine Laboratory, Aberdeen obtained otoliths from whiting caught in April and May 1998 at several locations off the northeast coast of Scotland. The fish were measured for total length and the otoliths extracted. Subsequently the otoliths were sent to the Fisheries Research Centre, Dublin where they were sectioned. The sections were viewed under an Olympus SZH 10 Research Stereo microscope, using transmitted light, and photographed via a JVC TK-C 1380 colour video camera. The images were digitised by Leica Q500MC software and stored as TIF files.

There are a number of software packages that could be used to store annotated digitised images but the preferred choice was Paint Shop Pro Version 5 which was selected for a number of reasons.

1. It is easily obtainable

2. It is relatively inexpensive

3. It allows files to be saved in approximately 44 different formats which include PNG so images can be included in HTML documents or published on the Web.

4. The preferred format PSP is completely lossless for all compression methods.

5. Version 5 contains the option to include layering; thus images can hold a large amount of information in various layers and these can be 'switched off' or 'switched on' as required by individual viewers.

Coincidentally, within the European Fish Ageing Network (EFAN) there are a group of developers, based at LASAA in Brest, who wish to obtain a reference database of otoliths in order to test their ageing algorithms. Joint discussions prior to the Hirtshals Workshop produced some simple protocols which satisfied both the algorithm developers and also those scientists who wish to use such images for training etc.

It was decided that four layers would be laid on top of a digitised image, the latter acting as the background image.

Layer 1	Labelled as 'Nucleus' and this identifies the position of the nucleus with either a dot or a ring.
Layer 2	The second layer, called 'Rings', contains the agreed annuli interpretation. Each annuli is identified by a green coloured dot.
Layer 3	The third layer, identified as 'Doubts', highlights those areas which some or all the readers thought could be false rings/checks or, indeed, further annuli.
Layer 4	The last layer is called 'Text' and contains some simple information on the image together with condensed comments from a group of very experienced readers.

The procedure involved was to project the basic digitised image on to a screen and build the four layers using the comments from all 10 readers that attended the Workshop. The revised images were stored in a computer with the intention that these new images should be eventually put onto a CD-ROM. All institutes participating in the Hirtshals Workshop will receive a copy to enable training of future readers and to provide an electronic collection which can be used to re-confirm the confidence of existing readers. Additional copies of the CD-ROM will be made available to other interested parties at a future date.

8.2 Reader Exchange

Over the last 20 years there has been a large increase in the co-operation between individual institutes concerning age determination. This co-operation is mainly seen by postal exchange of otoliths and by workshops. Previous sections (4.3 and 7.3) have highlighted the difficulties associated with exchange schemes although modern technology should increase their effectiveness. Workshops play a major role in promoting a consensual understanding of the interpretation of otoliths but by their very nature they are expensive to run and complex to organise. Understandably they occur only infrequently. A major feature that emerged from the current workshop was the creation of the opportunity for experts to meet and discuss in great detail individual reading problems. This opportunity was much appreciated. Participation in the Hirtshals Workshop has created an informal network of whiting otolith readers who envisage exchanging ideas and problems in the future. However, this is probably insufficient for resolving all problems and given that Workshops are rarely occurring events some alternative mechanism should be put in place. Consequently institutes should try and build on the formal and informal links created and consider sending individual readers to other institutes for further training on whiting age determination.

9 SUMMARY AND CONCLUSIONS

Acting on resolution 1997/2:29 which was passed at the 1997 Statutory Meeting the Workshop covered the following points:

a) A review of the biology and ageing problems of whiting. The problems that had been identified by Gamble *et al* in 1960 still existed and these generated much debate within the Workshop.

b) Microstructures as an aid to age determination. There were extensive sessions on this aspect and all the participants recognised that this was an interesting and fruitful area which could resolve many of the difficulties highlighted in previous years.

c) Age determination exercises. An exchange scheme was undertaken prior to the Workshop and two further exercises were performed during the meeting. The overall initial agreement with the modal age ranged from 58% - 67% (depending on otolith preparation) but after discussions the final agreement rose to 72%. Further improvement in precision will probably be aided by the use of validated otoliths, either by viewing otoliths from fish of known age or using microstructure techniques.

d) Age determination from length frequencies. Statistical methods (Bhattacharya's and Hassleblad) were used to decompose length frequency distributions. These methods were only found to be reliable for juvenile fish and more knowledge is required on whiting biology before these methods could be used on mature stocks.

e) Guidelines and intercalibration. Simple guidelines were established for viewing and interpreting whiting otoliths but the participants felt that more extensive guidelines could be created at a subsequent workshop after further work on validation, e.g., microstructure work. At the Workshop material was processed to create a CD-ROM of otoliths with agreed age determinations. This method will form the basis of a collection that can be used by all interested parties to standardise interpretations of whiting otoliths.

The Workshop was hampered by the lack of validated material and was unable to fulfil the term of reference relating to growth rates from individuals of known age. All institutes should be encouraged to improve this serious deficiency.

In conclusion all the participants benefited from the meeting and have now established close links for future problems on whiting otoliths. By the end of the Workshop a much greater awareness of the otolith structure had emerged and it was felt that a further Workshop in approximately two year's time would resolve many of the outstanding difficulties. However, this was dependent on the sourcing of validated otoliths and further developments in microstructure research.

10 RECOMMENDATIONS

The Workshop recommends that:

1. because microstructure analysis appears to be a useful tool to verify false rings, checks etc. more work should be encouraged in this direction.

2. further efforts should be made to source otoliths from whiting of validated age, especially from older fish.

3. all national institutes should be encouraged to formalise and write up their procedures for the preparation and reading of whiting otoliths in order to increase internal quality control.

4. that there should be more exchange of readers between institutes in order to transfer knowledge from experienced to less experienced readers.

5. statistical methods can be employed to decompose observed length frequencies into an estimated age composition. The present knowledge of whiting distributions and growth rates in the North Sea is not yet sufficient to derive precise age compositions from these methods alone, especially for ages two and older.

6. because there are two fundamentally different ways of reading otoliths the method of conducting whiting otolith exchanges should be reviewed. Serious consideration should be given to the method outlined in Section 7.3.

7. due to the wide spread demand for a training package the possibilities of producing such material on a CD-rom should be investigated.

8. that a further Workshop should be held in 2 years time to review developments in microstructure work, verify ageing on validated otoliths and produce an introductory guide to whiting otolith age determination.

11 GLOSSARY FOR OTOLITH STUDIES

The terminology used in this report comes from the glossary of the first "Fish Otolith Research and Application" symposium presented in Secor, D.H., J.M. Dean and S.E. Campana (Eds.) Recent developments in fish otolith research. University of South Carolina Press. Columbia, South Carolina, USA, 723–729. Additional terms (highlighted in bold) have also been included which describe specific macroscopic features discussed in this report.

Accessory growth centre - a growth centre formed beyond the otolith core that leads to a new plane of growth and from which a new series of growth increments appears to emanate. Formation of these structures is often associated with life-history transitions such as metamorphosis. Accessory growth centres are often referred to as accessory primordia; however, the term accessory growth centre is preferred because these features are different structurally from primordia (e.g., they do not contain primordial granules).

Accuracy - the closeness of a measures or computed value to its true value.

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

Age group - the cohort of fish that have a given age (e.g., the 5-year-old age group). The term is not synonymous with year class or day-class. All ages are assumed to begin on January 1st.

Annulus (pl. annuli) - one of a series of concentric zones on a structure that may be interpreted in terms of age. The annulus is defined as either a continuous translucent or opaque zone that can be seen along the entire structure or as a ridge or a groove in or on the structure. In some cases, an annulus may not be continuous or obviously concentric. The optical appearance of these marks depends on the otolith structure and the species and should be defined in terms of specific characteristics on the structure. This term has traditionally been used to designate year marks even though the term is derived from Latin "anus" meaning ring; not from "annus" which means year. The variations in microstructure that make an annulus a distinctive region of an otolith are not well understood.

Check - a discontinuity (e.g., a stress-induced mark) in a zone, or in a pattern of opaque and translucent zones, or microincrements. Microstructural checks (e.g., hatching checks) often appear as high-contrast microincrements with a deeply etched D-zone or an abrupt change in the microstructural growth pattern. If the term is used, it requires precise definition.

Cohort - group of fish of a similar age that were spawned during the same time interval. Used with age group, *year class*, and day class.

Core - the area or areas surrounding one or more primordia and bounded by the first prominent D-zone. Some fishes (e.g., salmonids) possess multiple primordia and multiple cores.

Corroboration - a measure of the consistency or repeatability of an age determination method. For example, if two different readers agree on the number of zones present in a hard part, or if two different age estimation structures are interpreted as having the same number of zones, corroboration (but not validation) has been accomplished. The term verification has been used in a similar sense; however, the term corroboration is preferred as verification implies that the age estimates were confirmed as true.

D-zone - that portion of a microincrement that appears dark when viewed with transmitted light, and appears as a depressed region when acid-etched and viewed with a scanning electron microscope. This component of a microincrement contains a greater amount of organic matrix and a lesser amount of calcium carbonate than the L-zone. Referred to as discontinuous zone in earlier works on daily increments; D-zone is the preferred term. See L-zone.

Daily increment - an increment formed over a 24-hour period. In its general form, a daily increment consists of a D-zone and an L-zone. The term is synonymous with "daily growth increment" and "daily ring". The term daily ring is misleading and inaccurate and should not be used. The term daily increment is preferred. See increment.

Discontinued ring - A ring read as an annulus but which cannot be followed over the entire otolith. These rings often appear to be fused to the preceding annulus and in whiting are restricted to fish > 3 years old.

Distal surface- opposite surface of the otolith from the sulcus acusticus.

Hyaline zone - a zone that allows the passage of greater quantities of light than an opaque zone. The term hyaline zone should be avoided; the preferred term is translucent zone.

Increment - a reference to the region between similar zones on a structure used for age estimation. The term refers to a structure, but it may be qualified to refer to portions of the otolith formed over a specified time interval (e.g., subdaily, daily, annual). Depending on the portion of the otolith considered, the dimensions, chemistry, and period of formation can vary widely. A daily increment consists of a D-zone and an L-zone, whereas an annual increment comprises an opaque zone and a translucent zone. Both daily and annual increments can be complex structures, comprising multiple D-zones and L-zones or opaque and translucent zones, respectively.

L-zone - that portion of a microincrement that appears light when viewed with transmitted light, and appears as an elevated region when acid etched and viewed with a scanning electron microscope. The component of a microincrement that contains a lesser amount of organic matrix and a greater amount of calcium carbonate than the D-zone. Referred to as incremental zone in earlier works on daily increments: L-zone is the preferred term. See D-zone.

Lapillus (pl. lapilli) - one of the three otolith pairs found in the membranous labyrinth of osteichthyan fishes. The most dorsal of the otoliths, it lies within the utriculus ("little pouch") of the pars superior. In most fishes, this otolith is shaped like an oblate sphere and it is smaller than the sagitta.

Marginal increment - the region beyond the last identifiable mark at the margin of a structure used for age estimation. Quantitatively, this increment is usually expressed in relative terms, that is, as a fraction or proportion of the last complete annual or daily increment.

Microincrement - increments that are typically less than 50 μm in width; the prefix "micro" serves to indicate that the object denoted is of relatively small size and that it may be observed only with a microscope. Often used to describe daily and subdaily increments. See increment.

Microstructural growth interruption - a discontinuity in crystallite growth marked by the deposition of an organic zone. It may be localised or a complete concentric feature. See check.

Nucleus - in this report the term is used to denote the early part of the sagitta otolith formed prior to any accessory growth centres. This part of the otolith approximately corresponds to the otolith formed during the larval phase.

Opaque zone - a zone that restricts the passage of light when compared with a translucent zone. The term is a relative one because a zone is determined to be opaque on the basis of the appearance of adjacent zones in the otolith (see translucent zone). In untreated otoliths under transmitted light, the opaque zone appears dark and the translucent zone appears bright. Under reflected light the opaque zone appears bright and the translucent zone appears dark. An absolute value for the optical density of such a zone is not implied. See translucent zone.

Precision - the closeness of repeated measurements of the same quantity. For a measurement technique that is free of bias, precision implies accuracy.

Primordium (pl. primordia) - the initial complex structure of an otolith, it consists of granular or fibrillar material surrounding one or more optically dense nuclei from 0.5 μm to1.0 μm in diameter. In the early stages of otolith growth, if several primordia are present, they generally fuse to form the otolith core.

Proximal surface - sagitta surface facing the sensory macula, distinguished by having a sulcus acusticus.

Sagitta (pl. sagittae) - one of the three otolith pairs found in the membranous labyrinth of osteichthyan fishes. It lies within the sacculus ("little sack") of the pars inferior. It is usually compressed laterally and is elliptical in shape; however, the shape of the sagitta varies considerably among species. In non-ostariophysan fishes, the sagitta is much larger than the asteriscus and lapillus. The sagitta is the otolith used most frequently in otolith studies..

Sulcus acusticus (commonly shortened to sulcus) - a groove along the medial surface of the sagitta. A thickened portion of the otolithic membrane lies within the sulcus acusticus. The sulcus acusticus is frequently referred to in otolith studies because of the clarity of increments near the sulcus in transverse sections of sagittae.

Transitions zone - a region of change in otolith structure between two similar or dissimilar regions. In some cases, a transition zone is recognised due to its lack of structure or increments, or it may be recognised as a region of abrupt change in the form (e.g., width or contrast) of the increments. Transition zones are often formed in otoliths during metamorphosis from larval to juvenile stages or during significant habitat changes such as the movement from a pelagic to a demersal habitat or a marine to freshwater habitat. If the term is used, it requires precise definition.

Translucent zone - a zone that allows the passage of greater quantities of light than an opaque zone. The term is a relative one because a zone is determined to be translucent on the basis of the appearance of adjacent zones in the otolith (see opaque zone). An absolute value for the optical density of such a zone is not implied. In untreated otoliths under transmitted light, the translucent zone appears bright and the opaque zone appears dark. Under reflected light the translucent zone appears dark and the opaque zone appears bright. The term hyaline has been used, but translucent is the preferred term.

Transverse section- section through the proximal-distal axis

Validation - the process of estimating the accuracy of an age estimation method. The concept of validation is one of degree and should not be considered in absolute terms. If the method involves counting zones, then part of the validation process involves confirming the temporal meaning of the zones being counted. Validation of an age estimation procedure indicates that the method is sound and based on fact.

Vateritic – term used to describe otoliths in which all or part of the calcium carbonate has been deposited in the vaterite rather than the more typical aragonite form. Vateritic sagittae appear 'glassy', making it difficult to differentiate incremental structures. The cause of vateritic replacement is unknown but has been found to be common in fish kept under hatchery, and therefore perhaps stressed, conditions.

Verification - the process of establishing that something is true. Individual age estimates can be verified if a validated age estimation method has been employed. Verification implies the testing of something, such as a hypothesis, that can be determined in absolute terms to be either true or false.

Year class - the cohort of fish that were spawned or hatched in a given year (e.g., the 1990 *year class*). Whether this term is used to refer to the date of spawning or hatching must be specified as some high-latitude fish species have long developmental time prior to hatching.

Zone - region of similar structure or optical density. Synonymous with ring, band and mark. The term zone is preferred.

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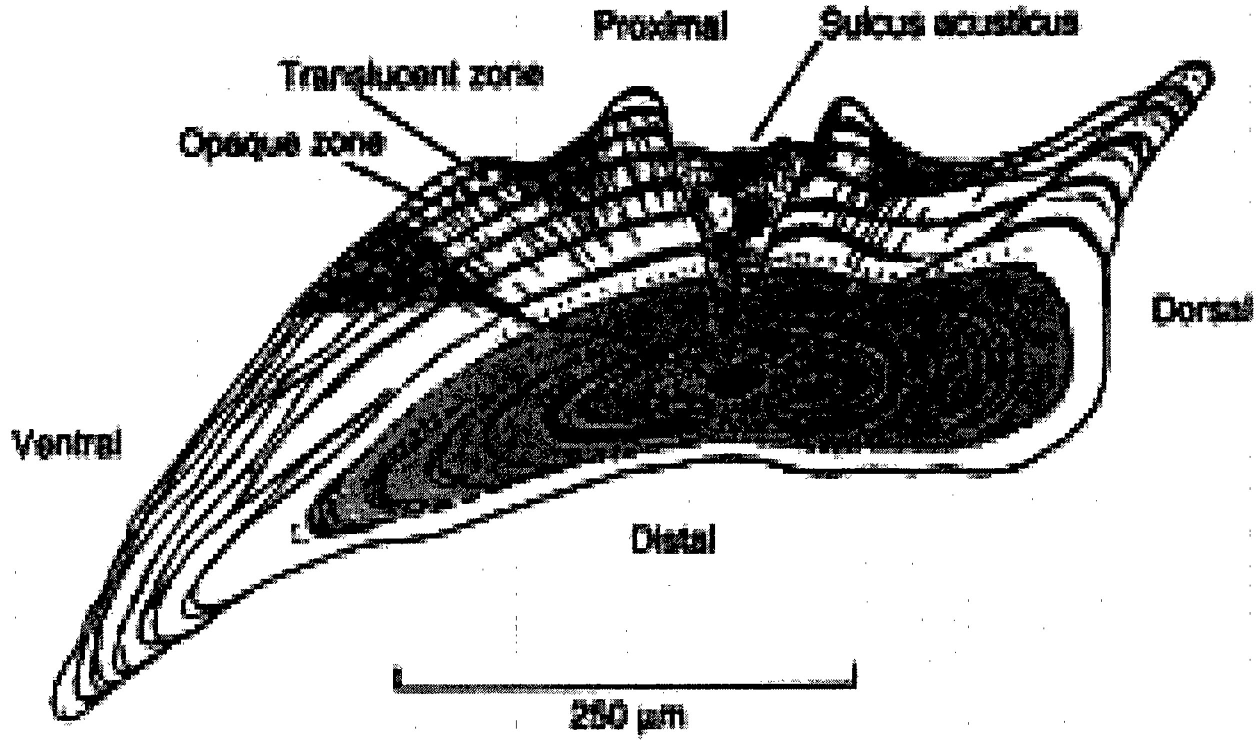

Figure 11.1

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