REPORT OF THE HORSE MACKEREL (SCAD) AGE DETERMINATION WORKSHOP
Lowestoft 9-14 April 1987 -

1. INTRODUCTION

In accordance with the terms of a contract with the Commission of the European Communities, the United Kingdom Ministry of Agriculture, Fisheries and Food (the Contractor) convened a Horse Mackerel (Scad) Age Determination Workshop at the Fisheries Laboratory, Lowestoft, during the period 9-14 April 1987. The objectives of the Workshop were:

To compare otolith interpretation methods used by different workers involved in horse mackerel age determination in the north-east Atlantic.

To relate growth rates based on age determinations from otoliths to growth rates based on length composition analyses, and examine whether length composition analyses can be used as a basis for age validation.

To attempt to reach agreement on a standard method of otolith interpretation.

2. PARTICIPANTS

D Beveridge	(UK Scotland)
K Bhatnagar	(Ireland)
J Casey	(UK England)
J Dardignac	(France)
D Eaton	(UK England)
C Farina	(Spain)
H Isidro	(Portugal)
B W Jones	(UK England)
M Kerstan	(Federal Republic of Germany)
K Kuiter	(Netherlands)
M Marcecos	(Portugal)
J Martinez Portela	(Spain)

The following staff of the Fisheries Laboratory also assisted in the work of the Study Group.

J Barry

W A Dawson

S Warnes

3. SUMMARY OF METHODS FOR EXAMINING OTOLITHS

At the commencement of the meeting participants described the techniques they normally used for examining otoliths.

England Whole otoliths are examined against a dark background for the smaller fish, but for the larger fish transverse sections are cut and are examined by reflected light. Where necessary to supplement these techniques, the second otolith may be broken and burned.

France Length composition analyses (NORMSEP) have been made and growth rates so determined have been related to age determinations from scales but at present only length composition analyses are being made. For seven age groups which have been identified by length composition analysis agreement with age determinations is reported to be good.

Federal Republic of Germany Whole otoliths are examined first by reflected light against a black background. If this is not successful the otoliths are viewed by transmitted light. For difficult otoliths longitudinal sections of burnt otoliths are cut.

Ireland Only limited experience with horse mackerel age determination at present.

Netherlands One otolith is kept whole and the other is broken, polished and burnt. Otoliths are examined in alcohol against a black background. Some shading of the otolith from the light source sometimes improves the clarity.

Portugal Whole otoliths are used, immersed in alcohol or water and

viewed against a dark background using reflected light.

Scotland Only very limited experience with horse mackerel age determination to date using whole otoliths.

Spain For the smaller fish (less than 25 cm) whole otoliths are used but transverse sections are prepared for the larger fish. Examination is by reflected light with the otoliths or sections immersed in alcohol.

4. BACKGROUND

Eltink (1985) reported on the results of a horse mackerel otolith exchange which was arranged to investigate possible differences in ageing technique which were believed to be the cause of differences in growth curves produced by different workers. This report concluded:

"A sample of horse mackerel otoliths was circulated amongst 8 readers from 7 countries. The results demonstrated an unacceptable variability in age determination of horse mackerel between readers from different countries, especially for larger (older) fish. One group consistently arrived at ages for these fish which were approximately a factor 2 greater than those ages assigned by other readers. This was assumed to be caused by misinterpretation of otoliths of larger fish, where more than one hyaline ring is laid down in an annual growth period. Where readers used the same interpretation of otolith structure (secondary rings within annual growth zones) the standard deviation per age for sectioned otoliths was lower than for those otoliths examined whole or by breaking and burning. Readers in this group assigned similar ages up to 5 years, beyond which point differences become more pronounced as shown by increasing standard deviations."

The objective of the present Workshop was to reduce the amount of disagreement resulting from different age interpretations.

Of the ten otolith readers participating in the present Workshop six had also participated in the otolith exchange.

5. METHODS

Initially the ten otolith readers in the Workshop worked with three samples of otoliths representing three different methods of examining otoliths. Ages were given as age groups rather than true biological ages. For this purpose the convention of a "birthdate" of 1 January was adopted. Sample 1 consisted of transverse sections mounted on glass slides. Sample 2 consisted of whole otoliths which, unknown to the readers, were taken from the same fish as Sample 1. For Sample 3, otoliths of Sample 2 were broken and burnt. Readers were not able to refer to their age determinations for Sample 2 when reading Sample 3. The lengths of the fish from which the otoliths were taken were not disclosed to the readers until after they had made their age determinations. All otoliths were taken from fish caught in March in ICES Division VIIj.

The age determinations for the three samples were tabulated and then analysed to assess differences between the three methods and also for differences between readers.

Two participants undertook an exercise to compare age determinations from scales and otoliths taken from the same fish.

Results of modal analyses of length compositions were discussed at the Workshop.

6. RESULTS OF COMPARATIVE AGE DETERMINATIONS

The results of the age determinations of the three samples of otoliths are given in Table 1. It should be noted that in some cases the three chosen methods were not the normal method that would be used by the reader. For example one reader preferred to work with longitudinal sections rather than transverse sections. Another preferred to work with whole otoliths in combination with broken, polished and burnt otoliths.

The first ten otoliths in each sub-sample, 50 otoliths in total, were used in the statistical analysis. For analysis of differences between methods

the otoliths were grouped by length. For all readers combined the highest ages were, in nearly all length groups given by Method 1 (transverse sections) with the lowest ages given by Method 3 (broken and burnt). (Table 2, Figure 1).

Figures 2-4 show for each method the age determinations for each otolith. For the illustration the otoliths have been arranged in order of increasing length but it should be noted that the abscissa is not linear in length. An age value of -1 indicates no age determination. These figures clearly show the range in age determination recorded by the different readers and that the range of ages increases with increasing fish length.

Table 3 gives the results of analysis of variance of log transformed age determinations. There are significant differences between methods and a greater difference between readers. There is also a significant interaction between the effects of methods and readers suggesting that the age differences for the methods are not the same for all readers. However this interaction effect is small compared to the main effects of reader and method.

For each reader the mean length of each age group was calculated from the sample of otoliths used for age determination in this study. These are given in Table 4, and for whole otoliths (Method 2) are plotted graphically in Figure 5. No attempt was made to derive von Bertalanffy growth parameters from these data since the value of K would be largely determined by the mean length of 1 group individuals, which in this data set, is based on only 2 observations.

7. RESULTS OF SCALE AND OTOLITH AGE DETERMINATION COMPARISONS

This exercise was undertaken by two participants (numbers 3 and 7) using a sample of 20 scales and otoliths taken from the same fish. The otoliths were prepared as transverse sections mounted on glass slides. Each reader made three replicate readings of each scale and otolith. The results are given in Table 5 and show that otoliths tended to be aged older than scales but there is no systematic difference between readers. The analysis of

variance table (Table 6) shows the difference between methods to be significant.

8. LENGTH COMPOSITION MODAL ANALYSIS

Data of horse mackerel length compositions were available for ICES Sub-area VII from twelve English research vessel groundfish trawl surveys. The surveys covered the period 1983 to 1987 and were carried out in the months of March, July and December. For each survey, sample length compositions for each haul were raised to the total catch for the haul and the haul length compositions were then summed for all hauls in Sub-area VII.

The method of analysis used was one developed by Shepherd (unpublished). Given a range of values for growth parameters K and $L\infty$ and length compositions obtained at different times, this program tests the goodness of fit using a score system and calculates values of parameter t_o for each K and $L\infty$ combination. Values of K and $L\infty$ are selected for a data set on the basis of the goodness of fit criterion. The survey data were analysed in four ways: using the March, July and December length compositions separately and also using all data combined. The results indicated von Bertalanffy growth parameters as follows:

ANALYSIS	MONTH	L	K	t
1	March	58	.20	.11
2	July	52	.14	.56
3	December	57	.22	.15
4	Combined	56	.22	.18

Using these parameters growth curves were calculated and plotted in Figure 6. Although the separate March and December analyses and that for all months combined give results in close agreement, the growth curve based on the July samples is quite different. Furthermore, additional exploratory analyses have indicated that different methods of aggregating sample data to give cruise total length compositions could affect the result of the analyses. It was considered that the results of these analyses were not sufficiently conclusive to provide a basis for age determination

validation.

9. A STANDARD METHOD OF OTOLITH INTERPRETATION

The results of comparative age determinations showed that there were differences in interpretation which resulted in different ages being given to an otolith by the various readers. The range of ages given to an otolith by the ten readers increased with length. Up to about 30cm in length there was relatively good agreement in age determination and to a large degree the deviations from the modal value were the readings of relatively inexperienced readers. On the first readings there was some disagreement resulting from different interpretations of the nucleus. Difficulties with the nucleus arise particularly with young fish with few rings outside the nucleus. In older fish the nucleus can be seen relative to a series of outer rings and can be identified with more confidence. Differences in nucleus interpretation were largely resolved during the course of the Workshop and, despite the fact that horse mackerel have an extended spawning season resulting in variable nucleus size, nucleus interpretation is not now considered to be a major problem. The main source of disagreement was associated with the interpretation of the outer rings of the larger/older fish. Of the experienced readers some consistently counted all rings as annual rings. Others interpreted some of the outer rings as splits or checks produced in the formation of annual rings and as a result gave lower ages than those who counted all rings. In addition to this systematic difference there was also some random variation between readers but some of this variation is due to the inexperience of some of the readers.

In order to obtain a standard method of interpretation it would be desirable to reduce between-reader random variation to a minimum level but, most important of all, it is necessary to resolve the problem of systematic differences in interpretation of the outer rings in the otoliths of older fish. There was no problem in seeing which rings were being counted by each reader but as both groups of readers were confident that their interpretation was correct some objective basis of validation was necessary to indicate which interpretation was the correct one. It had been hoped that length composition modal analysis would provide a means of validation

but as indicated in Section 8 the results were inconclusive. In the absence of any alternative means of validation there was no basis for making a decision as to which interpretation should be adopted as standard.

10. DISCUSSION

Apart from general biological studies the primary objective of age determination is to be able to age fish sufficiently reliably to enable catch age compositions for different countries to be added together for use in age based analytical assessments. For this purpose the requirement is that the national age compositions are compatible and that fish are correctly allocated to yearclasses with reasonable reliability.

If this primary objective cannot be achieved length based assessments could be attempted. For these, however, some age data are also required in order to determine growth rates in the form of growth parameters. If age data are not sufficiently good for the growth parameters to be defined within narrow limits the results of the assessments can be inconclusive.

For age based assessments it may not be necessary to have age compositions covering the complete range of ages in the population and satisfactory results might be achieved with truncated age compositions.

Results of the Workshop indicate that there are still differences in interpretation between readers. The extended spawning season of horse mackerel means that fish spawned at different times of year will be expected to lay down otolith nuclei of different sizes which could cause problems in interpreting the nucleus. However, the degree of agreement for younger fish is better than for the older fish and it appears that the identification of the nucleus is not the major problem. With the older fish there are obviously still differences in interpretation of the outer rings. The main problem is in deciding which are true annual zones and which are split rings.

Attempts to use length composition modal analysis to validate age

determinations have been inconclusive as the results obtained for growth rates have differed depending on how the length composition data were aggregated for use in the analysis. The view was also expressed that growth curves calculated from length composition analysis are determined primarily from identifiable modes which were normally restricted to the younger age groups. This being so they may be of limited value in validating the growth pattern of older fish.

No progress was made towards agreeing a standard method of otolith interpretation as no method of validation was found to resolve the main problem of the interpretation of the outer rings of the larger/older fish.

Age compositions of samples for the years 1981 to 1986 for the Netherlands from Division VIa and Sub area VII were available at the Workshop. The indications were that identifiable yearclasses could be followed through successive years' age compositions up to at least age 7. The 1982 year class appears as a particularly abundant one. Fish allocated to this yearclass in German samples are also abundant. This yearclass also appears as an abundant one in Portuguese sample age compositions from Sub-area IX in years 1984 to 1986. It would be more appropriate to make such comparisons using catch age composition data, rather than data from aged samples only. However, these data were not available at the Workshop, but such a comparison could be made by the ICES assessment working group.

The limited comparison between age determinations from otoliths and scales made during the Workshop indicated that it could be useful to extend this work. It would be useful to examine more older fish to ascertain whether it is possible to distinguish the older rings at the edges of the scales and whether the identification of the older annual rings on scales is less ambiguous than for otoliths.

It is recommended to the Commission of the European Communities that the report on this Workshop should be brought to the attention of the International Council for the Exploration of the Sea.

10. REFERENCE

Eltink, A. 1985. Results of Horse Mackerel (Trachurus trachurus L.) Otolith Exchange Program. ICES CM 1985/H:40, 17 pp.

Table 1. Ages assigned to each otolith by reader and method. Only the first 10 otoliths in each sub-sample were used in the statistical analysis

		SAMPLE 1 TRANSVERSE SECTIONS										SAMPLE 2 WHOLE OTOLITHS										SAMPLE 3 BROKEN AND BURNT									
LENGTH (mm)	SEX	READER										READER										READER									
		1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
Sub-sample 1																															
363	M	9	8		12	11	9		22	7	11	10	9		9	8	11	6	18	7	10	13	8	8	13	7	13	8	22	6	10
328	M	13	12		10	9	8	6	16	8	12	10	7		8	7	9	7	15	7	8	8	7	7	10	8	8	8	16	6	9
375	F	11	12		10	11	10	6	16	10	10	11	12		9	10	10	6	15	7	10	9	10		11	8	10	9	16	8	11
356	M	7	6	3	6	5	7	5	8	5	6	9	5	8	6	6	7	6	7	6	8	5	6	5	6	4	5	5	7	5	5
285	F	4	4	4	5	4	5	4	5	8	4	7	9	6	4	4	5	4	5	4	6	5	3	3	4	4	4	4	5	4	4
366	M	12	13		12	10	7	6	15	8	8	11	6		10	8	10	5	18	7	9	11	9		10	7	8	7	15	7	10
364	M	16	14		11	10	9	7	16	7	9	12	7	8	9	9	8	6	15	7	8	7	7	5	10	8	7	6	17	5	8
394	M	10	9		12	12	9		21	9	10	12	6		10	9	9	8	22	7	9	13	10	9	11		9	9	16	6	10
351	M	12	10		11	10	8		14		8	8	7		11		9		15			11	15		13	9	8	10	15	8	10
375	M	14	12		13	10	7	6	18	9	10	12	6	8	10	9	8	8	19	8	9	8	6	7	10	8	11	7	20	7	9
345	M	14			10	10	9	6			11	11		9	9	10	8	7						7			9	7			
267	M	4			5	6	5				5				4	4	6														
370	M	7			7	9	7				7				7	7	10							6			9	6			
Sub-sample 2																															
316	F	6	7	3	7	7	5	6	8	5	7	5	4	5	5	5	4	4	7	5	5	6	4	5	6	6	4	6	7	5	6
258	M	5	3	3	5	4	4	4	4	4	4	4	5	4	4	4	4	3	4	4	5	4	3	3	3	3	3	3	4	3	3
267	F	4	5	5	5	5	4	5	5	4	5	5	4	4	5	5	5	4	5	4	4	6	4	4	4	5	4	4	4	4	4
315	M	10	5		11	8	6	7	16	6	8	8	6		7	8	6	6	16	5	6	7	5	6	9	6	3	6	16	6	8
328	F	7	7		8	7	7	6	7	5	8	6	4	6	7	8	8	6	8	5	7	9	6	3	8	7	3	3	9	6	7
329	M	7	6		8	6	8	9	9	5	7																				
322	M	6	6	6	10	6	7	6	9	5	7	8	8	5	6	9	6	7	8	5	8	6	6	4	8	6	5	5	10	6	7
381	M	12	4		12	9	10		19	8	11	6	5	5	9		7	8	19		10	12	10	10	13	10	8	12	20	8	13
316	M	7	8	6	8	6	6	7	8	4	7	6	7	4	8	7	6	7	7	6	7	7	5	6	6	6	6	6	8	6	7
168	F	3	2	3	3	2	2	2	2	1	2	6	2	1	2	2	3	2	2	2	3	5	1	1	2	2	2	2	2	2	3
187	F	2			3	2	2			1	3	5	2	1	2	2	1	1	2	2	4	5	2		2		2		4	2	
188	M	3			4	2	2			1	3				3	2	3				3			3	3	2		3			3
184	F	3			4	2	2			1	2				2	2	2				3										
200	M	6			7		3			1	2				3	3	3				5										
Sub-sample 3																															
241	M	8	7	4	4	3	4	3	4	2	3	5	3	4	4	4	5	3	4	4	3	4	3	3	3	3	4	3	4	3	3
246	F	5	8	5	4	4	4	4	5	2	4	6	4	3	3	4	5	3	4	3	3	4	3	3	3	3	4	3	4	3	4
244	M	5	8	4	4	4	5	4	5	3	3	6	2	3	4	4	4	3	4	4	3	3	2	3	3	4	5	3	4	3	4
240	F	5	5	4	4	3	4	3	4	2	3																				
246	F	5	6	5	4	4	5	4	4	2	3	7	7	4	4	4	5	3	4	3	3	3	3	3	3	3	3	3	4	3	4
244	F	4	4	4	5	4	5	3	4	3	3	5	6	4	4	4	5	3	4	3	4	4	5		6	4	3	3	4	3	5
258	M	4	6	5	5	5	5	5	5	3	4	4	3	3	4	4	6	4	5	3	4	5	6	4	4	5	5	5	5	4	4
257	M	5	4	4	4	5	4	4	5	2	4	5	7	3	4		6	3	4	4	4	5	4	4	4	4	4	5	5	4	4
257	F	4	9	3	4	4	5	3	4	2	3	2	10	5	4	4	6	3	4	4	4	4	3	3	3	4	4	3	4	3	3
252	M	4	3	4	4	4	4	3	4	3	3	4	7	4	3	4	4	3	4	3	3	5	4	3	3	3	4	3	4	3	3
238	M	4			5	4	4			2	2	6	3	5	4	4	5	3	4	3	4	4	5	3	3	3	4	3	4	3	3
237	F	5			4	4	4				3				4		4				3										
408	F	12			11	12	11				11				9	10	10				7										
221	F	5			4	4	4				3				3		5				3										

Table 1. Continued

LENGTH (mm)	SEX	SAMPLE 1 TRANSVERSE SECTIONS READER										SAMPLE 2 WHOLE OTOLITHS READER										SAMPLE 3 BROKEN AND BURNT READER									
		1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
Sub-sample	4																														
266	M	5	3	5	5	5	5	4	5	5	5	7	4	4	4	6	4	4	5	4	5	4	3	3	4	4	3	4	5	4	4
274	M	5	4	3	4	4	4	4	4	4	5	5	3	2	4	4	3	3	3	4	3	3	4	2	3	3	3	3	4	3	3
290	F	4	8		5	5	4	4	4	4	5	5	3	4	5	5	5	4	5	3	4	4	3	2	4	4	3	4	5	5	4
278	M	6	5		5	6	3	5	5	5	4	7	4	4	4	4	4	4	5	4	4	4	3	4	4	4	3	4	5	4	4
291	F	5	3	4	5	5	4	5	5	5	5	4	3	4	4	5	4	4	5	4	3	5	5	2	4	4	4	4	5	5	4
273	F	6	4	4	5	5	4	4	5	4	6	5	2	3	5	4	4	4	5	4	3	6	5	2	4	4	3	3	5	4	5
310	F	5	5	4	5	6	3	5	5	5	6	5	6	3	4	4	5	4	5	4	3	6	7	2	4	5	3	3	5	4	6
283	M	5	4	3	5	6	4	5	5	4	7																				
262	M	5	7	3	5	5	3	5	5	4	6	8	2	3	5	5	4	4	5	5	4	4	4	2	4	5	3	3	5	4	4
303	M	8	5		6	6	3	7	7	5	8	8	9	4	6	6	6	5	7	5	4	7	5	2	5	5	3	3	7	5	5
286	M	8			6	6	5			5	8	8	4	5	6	8	7	5	10	4	5	5	5		7	6	5	5	9	6	6
243	M	4			4	5	4				4				4	4	5				3					4					3
274	F	5			5	5	4				6				5	5	7				4										
286	F				5	5	4				8				4	4	5				4										
Sub-sample	5																														
385	M	13	12	14	9	9	9	8	15	6	11	11	11		12		10	8	14	9	7	8	13		11	9	7	7	14	8	11
400	F	12	11		4	10	8	9	22	8	10	12	11		12		11	9	20	10	8	5	8	7	14	9	7	6	20	9	10
384	M	13	11		7	8	6	6	19	6	11		4		10		10	9	10			7	14		12	10	8	7	13		8
371	F	8	7	10	5	9	8	7	13	6	8	10	7	6	9	8	11	8	13	7	7	8	10	9	11	8	7	7	13	12	10
278	F	4	3	5	5	5	5	5	5	3	5	5	3	4	4	4	6	3	5	4	4	5	5	3	4	4	4	4	4	4	4
302	F	5	4	5	7	5	6	5	8	4	6	6	4	4	6	5	7	4	6	5	4	4	6	3	6	4	4	4	4	4	4
280	M	4	3	5	6	4	5	4	5	3	4	5	4	4	4	4	6	4	5	4	4	5	5	4	5	4	5	5	6	4	4
310	F	6	5	7	6	6	7	8	8	4	6	6	5	5	6	5	7	5	7	6	6	6	6	5	6	5	6	5	6	6	5
288	M	4	4	4	5	4	4	5	5	3	5	6	3	4	5	4	5	4	5	4	4	4	4	3	4	4	4	4	5	4	4
282	M	4	3	5	9	5	5	5	5	4	4	5	4	4	5	4	5	4	5	4	4	5	5	4	5	4	5	4	5	4	4
308	M	7			9	4	5			4	8				6	6	7				5										
253	F	4			12	6	3			2	4				3	3	4				3										
312	F	11			11		4			5	8				11	9	5				5										
–	–					7																									

Table 2

Age means by method and length group

Mid point of length Group	Method 1	2	3
170	2.2	2.5	2.2
230	3.7	-	-
250	4.2	4.1	3.6
270	4.6	4.3	4.0
290	4.7	4.5	4.1
310	6.3	5.7	5.4
330	7.8	7.3	7.0
350	7.7	7.9	8.0
370	10.3	9.4	9.5
390	10.5	10.0	10.2

Table 3

ANALYSIS OF VARIANCE OF $\log_e$ (age)

Source	d.f.	SS	MS	F
OTOLITH	49	205.8		
METHOD.OTOLITH	92	6.18	0.0672	0.97
METHOD	2	2.82	1.41	28.8**
READER	9	22.66	2.52	51.4**
METHOD.READER	18	3.95	0.22	4.5**
RESIDUAL	1216	59.54	0.049	
TOTAL	1386	300.9		

** Statistically significant at the 5% level

TABLE 4

MEAN LENGTHS (cm) OF EACH AGE GROUP FROM THE OTOLITH SAMPLE USED IN THE WORKSHOP

AGE GROUP	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
READER																						
Method 1 - Transverse sections																						
1		18.7	19.5	26.6	26.5	27.8	33.5	30.2	36.3	35.5	34.4	38.1	36.6	36.0								
2		16.8	27.2	28.7	28.9	30.2	30.4	29.2	32.6	36.3	39.2	36.3	36.6	36.4								
3			27.2	26.6	26.9	31.9	31.0			37.1												
4			17.8	24.9	27.8	30.7	31.4	32.4	32.5	34.3	35.0	35.1	37.5									
5		18.2	24.1	25.9	27.9	29.6	32.2	35.0	36.7	36.7	36.9	40.1										
6		18.2	26.8	26.4	27.3	32.8	35.1	35.6	37.0	37.8	40.8											
7		16.8	24.7	26.5	28.8	34.9	33.9	34.8	36.5													
8		16.8		25.6	27.3		31.6	32.0	32.6				37.1	35.1	37.6	34.6		37.5	38.3		39.4	38.2
9	16.8	24.8	26.3	28.3	31.0	36.4	36.5	40.7	38.5	37.5												
10		19.8	23.3	26.4	27.8	29.8	32.3	32.3	36.4	38.6	37.8	32.8										
Method 2 - Whole otoliths																						
1		25.7		26.5	26.9	28.2	26.9	30.7	35.6	35.4	36.8	38.3										
2		22.7	27.0	29.4	32.6	33.4	31.1	32.2	31.7	25.7	39.3	37.5										
3	17.8	27.4	26.4	27.5	30.1	32.8		36.5	34.5													
4		18.0	22.7	26.4	28.2	31.2	33.8	32.2	37.2	38.0	33.2	39.3										
5		18.2	22.7	26.5	28.9	30.8	33.8	33.8	35.3	37.6												
6	18.7	18.4	20.8	26.6	26.5	28.6	31.2	35.3	35.8	38.1	37.8											
7		16.8	25.3	28.3	31.6	35.1	32.8	38.1	39.2													
8		17.8	27.4	24.8	27.9	30.2	32.0	32.5		33.5			37.1	38.5	35.5	31.5		36.5	37.8	40.0		39.4
9		17.8	25.6	27.3	30.7	32.7	36.6	37.5	38.5	40.0												
10			24.2	26.8	27.8	30.3	36.2	35.4	37.8	37.3												
Method 3 - Broken and burnt otoliths																						
1			26.0	26.3	27.5	30.0	33.6	36.5	35.2		36.6		37.9									
2	16.8	21.6	26.9	27.4	27.7	32.2	33.4	38.2	36.6	38.0			38.5	38.4	35.1							
3	16.8	28.6	26.2	27.7	33.7	33.4	36.2	36.3	38.3	38.1												
4		17.8	34.4	27.7	28.8	30.7	28.6	32.5	31.5	35.8	38.1	38.4	36.5	40.0								
5		17.8	25.1	27.7	29.6	31.1	34.7	36.3	37.9	38.3												
6		17.8	28.1	27.1	29.0	31.3	38.0	36.2	37.0	37.5	37.5											
7		16.8	26.0	28.3	29.6	34.7	37.1	34.7	38.5	35.1		38.1										
8		16.8		25.2	27.8	29.5	32.5	31.6	30.7	32.2			37.8	38.5	35.9	35.3	36.4			38.5		36.3
9		17.8	25.4	27.8	33.1	33.5	37.1	38.0	40.0			37.1										
10			24.2	27.2	29.7	30.4	32.2	33.5	37.4	38.0		38.1										

Table 5

Comaprison of age determinations from Scales and Otolith Sections.

	SCALES						OTOLITH SECTIONS						
	READER 3			READER 7			READER 3			READER 7			
OTOLITH	REPLICATE			REPLICATE			REPLICATE			REPLICATE			LENGTH CM
	1	2	3	1	2	3	1	2	3	1	2	3	
1	8	6	6	6	6	6	9	9	10	9	8	7	33
2	4	7	7	9	8	7	7	8	10	8	9	8	35
3	6	6	6	8	7	7	8	10	9	8	7	8	34
4	3	7	6	8	9	8	8	9	9	9	8	9	35
5	–	9	9	8	7	7	8	8	8	8	8	7	33
6	7	8	8	8	7	7	6	6	7	8	8	8	43
7	5	5	5	5	5	5	7	4	5	5	5	5	26
8	6	6	7	7	5	6	7	8	8	11	8	9	33
9	3	4	4	4	4	4	6	4	4	4	4	4	26
10	7	8	7	9	7	7	–	5	9	9	7	9	34
1	7	8	7	8	8	7	9	10	11	8	9	8	32
2	8	8	9	7	8	7	9	10	10	9	9	8	33
3	9	9	9	9	7	7	9	10	11	10	9	10	33
4	10	10	8	7	7	7	9	6	9	9	8	9	35
15	7	7	5	6	7	6	9	9	9	10	9	9	35.5
6	–	–	–	–	–	–	9	8	9	7	9	8	35
7	4	4	4	5	6	4	5	5	5	5	5	5	30
8	2	2	2	2	2	2	3	2	2	2	2	2	16
9	4	4	4	4	4	4	4	5	5	5	5	5	23
20	7	7	7	10	7	9	–	9	11	–	7	9	35.5

Table 6

Analysis of variance of $\log_e$ (age) for otolith against scale readings

SOURCE	d.f.	S.S.	M.S.	F
Otolith	19	28.56		
Reader	1	0.006	0.006	1
Method	1	1.32	1.32	59.2**
Reader Method	1	0.057	0.057	2.6
Residual	207	4.62	0.022	
Total	229	34.56		

** Stat. significant at 5% level.

Figure 1. Comparison of mean age per length group for age determinations by three different methods: 1. Transverse sections, 2. Whole, 3. broken and burnt.

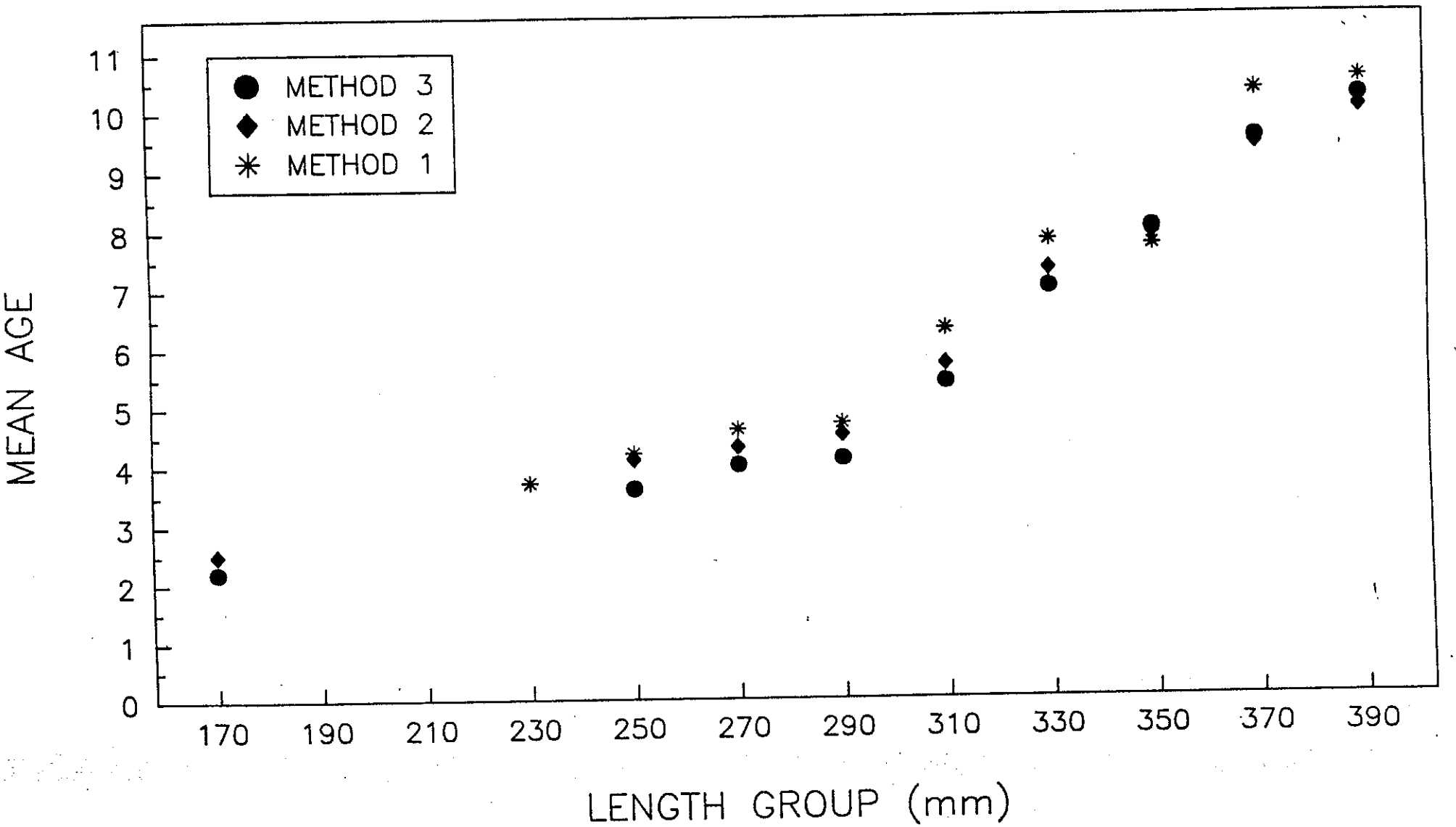

Figure 2. Age determinations of 50 otoliths by 10 readers. Method 1: transverse sections

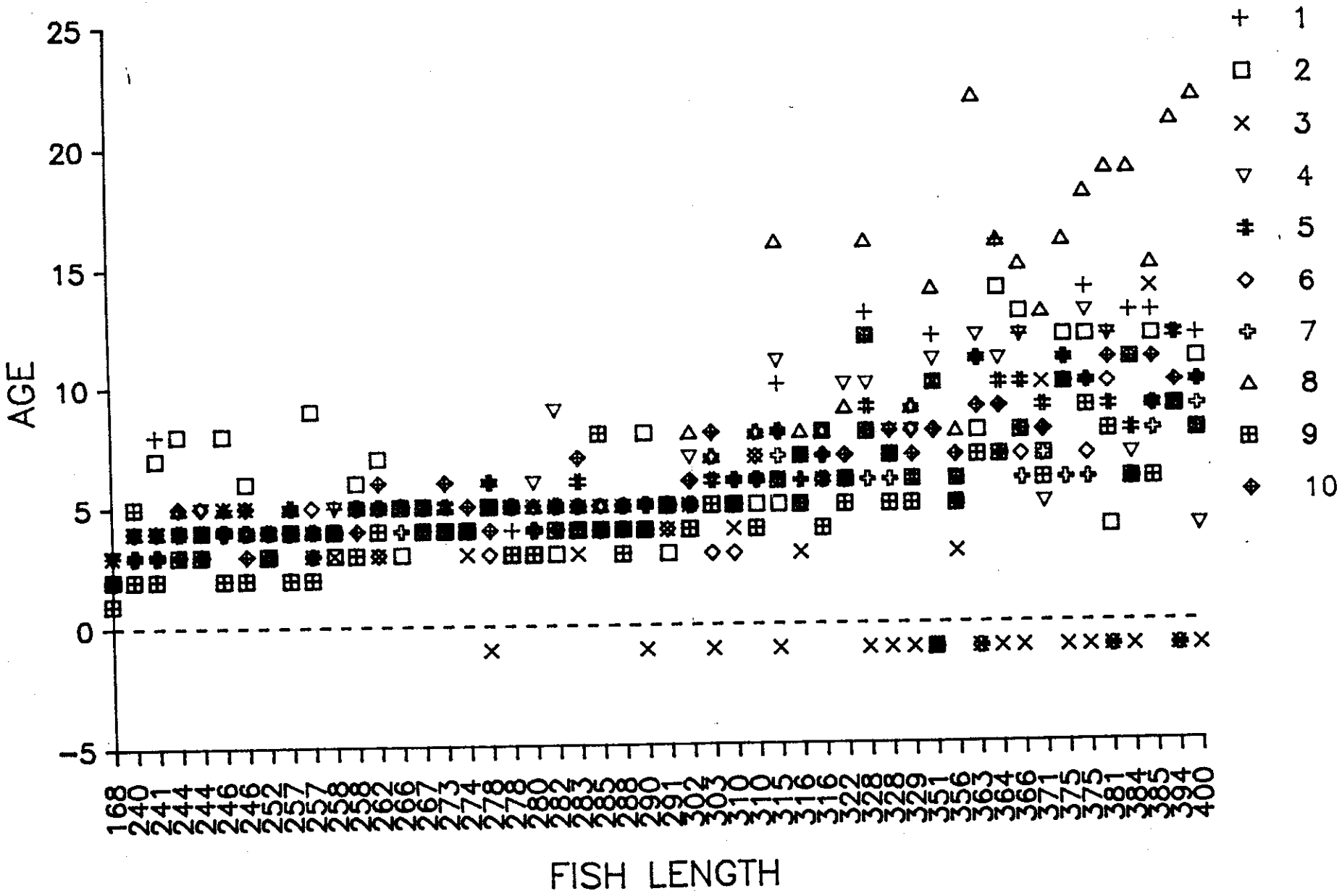

Figure 3. Age determinations of 50 otoliths by 10 readers. Method 2: Whole otoliths.

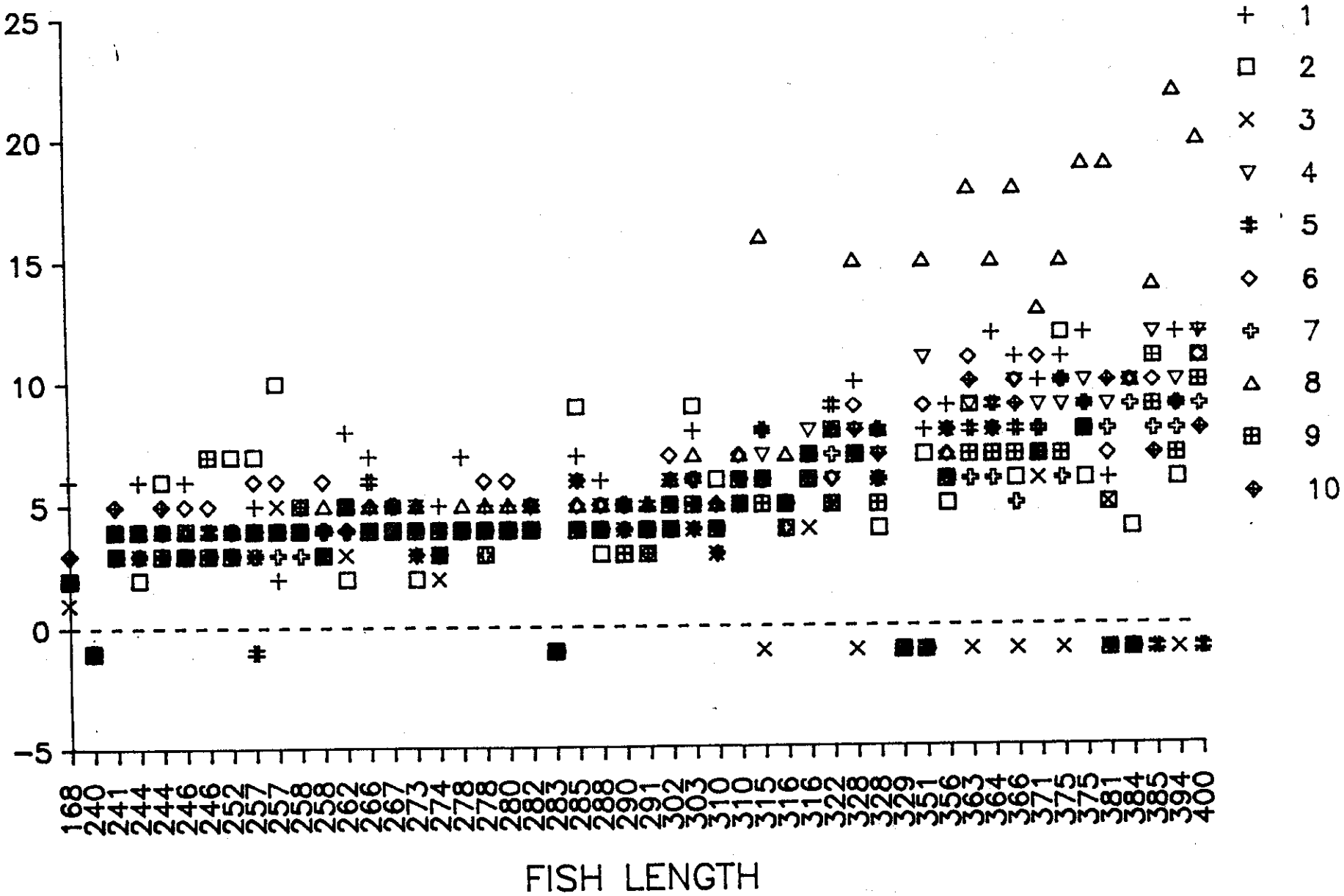

Figure 4. Age determinations of 50 otoliths by 10 readers. Method 3: Broken or burnt otoliths

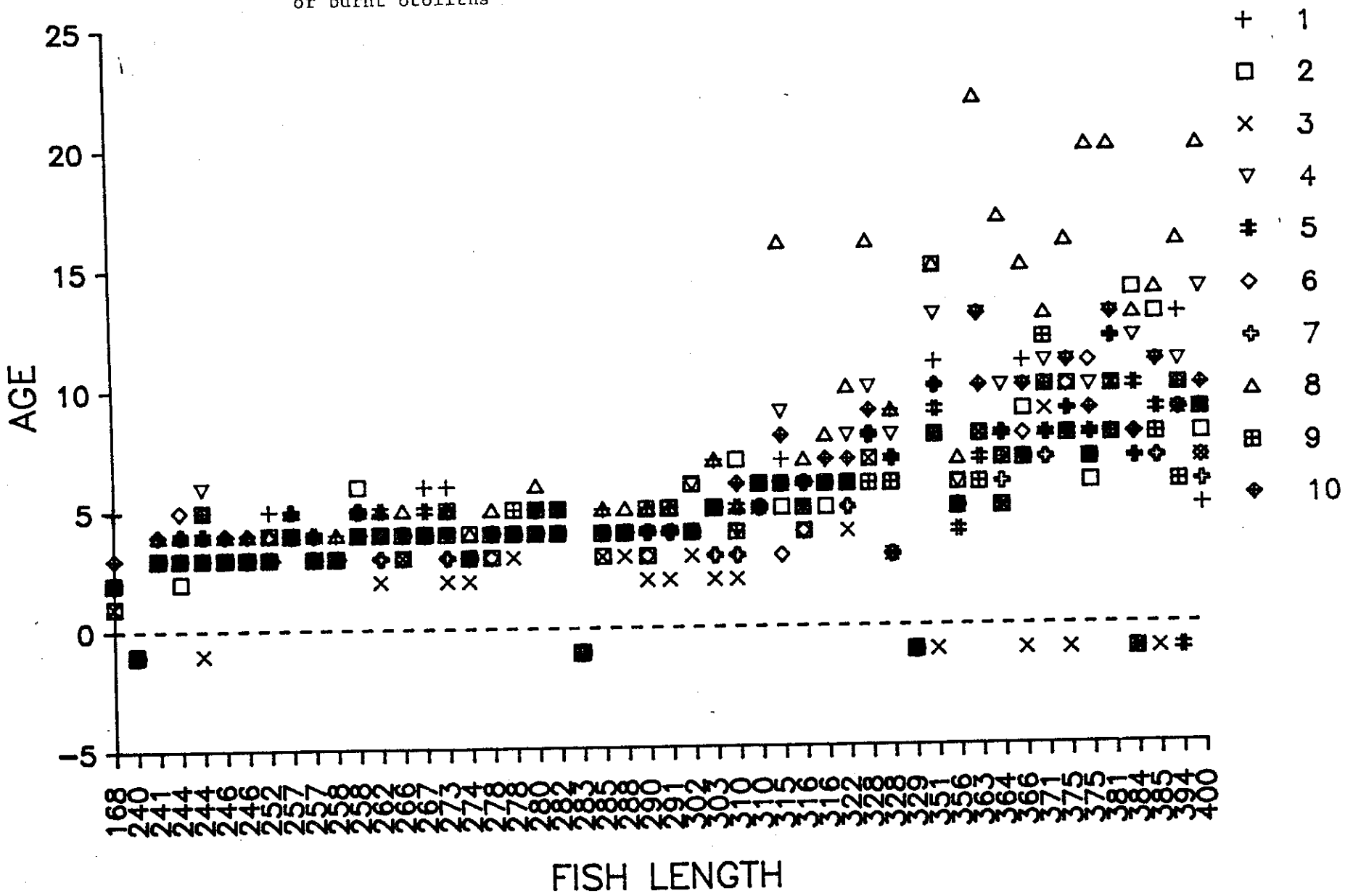

Figure 5. Mean length at age calcualted from 50 otoliths for each of ten readers. method 2: whole otoliths

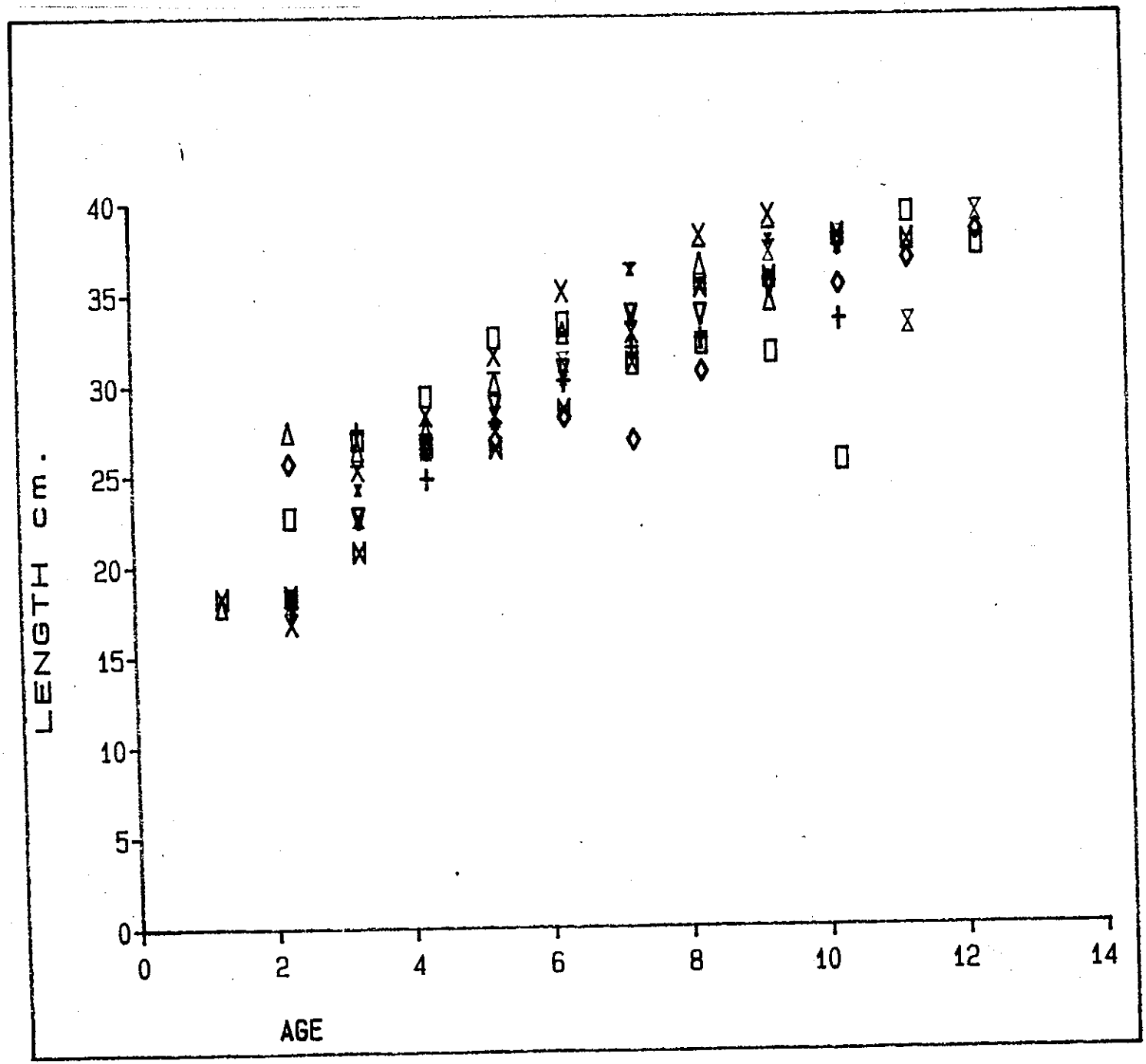

Figure 6. von Bertanlanffy growths based on growth parameters estimated by modal analysis of reasearch vessel survey length compositions. 1: March surveys, 2: July surveys, 3: December surveys, 4: all surveys combined.