INTERNATIONAL COUNCIL FOR
THE EXPLORATION OF THE SEA

C.M. 1985/H : 40
Pelagic Fish Committee

RESULTS OF HORSE MACKEREL (TRACHURUS TRACHURUS L.) OTOLITH EXCHANGE PROGRAM.

by

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P.O. Box 68, 1970 AB IJmuiden
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Abstract

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.

Résumé

Un échantillon d´otolithes de chinchard a été soumis à 8 lecteurs de 7 pays. Les résultats ont montré une variabilité inacceptable de la détermination de l´age du chinchard selon les différents lecteurs, en particulier pour les plus grands (vieux) poissons. Un groupe évaluait pour ces poissons des ages doubles de ceux attribués par les autres lecteurs et ce de façon consistante, cela a été attribué à une mauvaise interprétation des otolithes des grands poissons chez lesquels il se forme plus d´un anneau hyalin par période de croissance annuelle.
Quand les lecteurs utilisaient la même interprétation de la structure de l´otolithe (des anneaux secondaires a l´intérieur des zones annuelles de croissance) l´écart type par age pour les otolithes sectionnés était inférieur à celui des otolithes examinés entiers ou après brisure et brûlage. Dans ce groupe les lecteurs attribuaient des âges similaires jusqu´à 5 ans et au dela de cet age les différences devenaient plus marquées comme cela apparait au vu de l´augmentation des écarts types.

Introduction

At the ICES Mackerel Working Group meeting growth curves were fitted using Dutch, English and Spanish data for horse mackerel. Observed differences between the growth curves were considered to be due partly to differences in the aging techniques used. It was therefore agreed that before publishing comparative growth data, those involved should participate in an otolith exchange program (Anon., 1984).

The participating otolith readers are:

Derek Eaton, MAFF, Fisheries Laboratories, Lowestoft	England
Philippe Dechamps and J. Labastie, ISTPM, La Rochelle	France
Maria de Lourdes Marecos, INIP, Lisbon	Portugal
Antonio Celso Fariña Pérez, Instituto Español de Oceanografia, La Coruña	Spain
Martin Walsh, DAFS, Marine Laboratory, Aberdeen	Scotland
Douglas Beveridge, DAFS, Marine Laboratory, Aberdeen	Scotland
Michael Kerstan, Bundesforschungsanstalt für Fischerei, Hamburg	Fed. Rep. Germany
Kees Kuiter, RIVO, IJmuiden	the Netherlands

A total of 219 otoliths were send around the participants and the resulting ages using sectioned, whole and broken/burnt otoliths were compared.

Material and methods

A sample of 94 horse mackerel otoliths sectioned and embedded in resin (Bedford, 1983) was provided by the Fisheries Laboratory Lowestoft (date caught 16-6-1983 Bay of Biscay).
Five samples were from the Netherlands Institute for Fishery Investigations in IJmuiden and consisted, when possible, of one whole and one broken/burnt otolith:

Sample 82-002 (25 fish)	date caught: 24- 4-1982	Great Sole Bank	VIIj
Sample 82-003 (25 fish)	date caught: 8- 5-1982	Great Sole Bank	VIIj
Sample 82-005 (25 fish)	date caught: 16- 6-1982	Great Sole Bank	VIIj
Sample 82-006 (25 fish)	date caught: 29- 8-1982	Cornwall	VIIe
Sample 82-012 (25 fish)	date caught: 29-10-1982	Cornwall	VIIe

The otolith readings by the participants are listed in table 1. All doubtfull agings (listed in table 1 as "?" or "-" or alternative ages as for example 6/7) were omitted from analyses. Where ages were marked with a "+", (used to denote aging based upon time of spawning), the "birth-date" was taken as January 1st and the sign ignored.
The data were treated in three subsets: A) sectioned, B) whole and broken/burnt otoliths and C) sectioned, and whole and broken/burnt otoliths combined.
Differences in aging between each possible pairing of otolith readers

were analysed using regression techniques (tables 2 a-c). In a predictive regression of the form (Y = a + bX), Y is dependent upon X. This was evidently not the case in this study, and therefore the functional regression (Y = u + vX) was used (Ricker, 1973), although both the correlation (r) and the regression (v) coefficients are listed in table 2. Readers using similar methods of interpreting the otoliths and arriving at similar ages, will generate values of v and r which tend towards one, and values for the intercept (u) approaching zero. Where dissimilar methods are used, but which contain a constant bias, the value of r will still approximate to 1.0, but v will not be equal to 1.0.
The mean length at age of horse mackerel was estimated per otolith reader to show the differences in the growth curves obtained by each (table 3 and figure 1).
The variation in aging has been demonstrated by plotting the mean ages and the corresponding standard deviations obtained from the readings from each otolith read by only England, France, Spain and the Federal Republic of Germany (figures 2 a-c).

Results

The results of the otolith readings are listed in table 1.
Table 2 shows the GM regressions (Y = u + vX), the number of compared otoliths (n), the correlation coefficient (r) and the mean ages arrived at by compared otolith readers (mean X and Y).
Table 3 and figure 1 show the mean length at age estimated from the age readings by each otolith reader. It can be seen that the readers fall into two groups. Those from England, France, Spain and the Federal Republic of Germany consistently assigned younger ages than did the readers from Scotland and the Netherlands.
The Portugese reader was not aware of the catch dates of the otolith samples, which could only cause differences of not more than one year in the age readings. Their aging seems to be intermediate between the two groups, according to the regression techniques (tables 2 a-c), although the mean length at age data show a great similarity with those of England, France, Spain and the Federal Republic of Germany (figure 1 and table 3).
Figure 2 shows the mean age plotted against the standard deviation of otoliths read by England, France, Spain and the Federal Republic of Germany. Low standard deviations were estimated up to age 5, after which they started increasing. The low standard deviations for ages 3 and 4 obtained using sections show greater similarity, compared with the ages obtained using whole and broken/burnt otoliths (figures 2a and 2b).

Discussion

Only the otoliths and the corresponding catch dates were sent to the otolith readers, but not the lengths of the fish, because the given lengths could influence the outcome of the otolith readings.
The closer the regression and correlation coefficients (v and r) approximate to 1.0 and the intercept (u) to zero, the greater is the agreement between otolith readers. Readers from England, France, Spain and the Federal Republic of Germany use similar techniques for

interpreting the otoliths, and comparison of their agings show values of v close to 1.0. Readers from the Netherlands and Scotland tended to assign one years growth to each ring visible on the otolith, and in general their aging was approximately a factor of 2 greater than those of the first group, especially for larger fish (table 2). This clearly raises the problem of whether all rings visible are annual rings, or do the annual growth zones contain secondary rings. The phenomenom of secondary rings is described by Macer (1977), Farina Pérez (1983) and Kerstan (1984). Studies on light and scanning electrom microscopy have shown the relation between annual growth zones and the otolith surface structures, whilst measurements of postrostral otolith radii and measurement comparisons have shown that these criteria can be used to age the otoliths (Kerstan, 1984). The method of aging horse mackerel otoliths as decribed by Farina Pérez (1983) and Kerstan (1984) might be the right method to use, but it is still to be proved; e.g. by following exceptionally good year classes in data sets covering several years.

Experience of the species concerned is essential for anyone attempting to age fish reliably. In this study the participants from the Netherlands and Scotland had little or no experience in interpreting horse mackerel otoliths. This was evident not only in the way in which their aging differed from the other readers who were regularly examining horse mackerel otoliths, (and who accepted the phenomenom of secondary rings in the annual growth zones), but also in the way in which they aged the fish differently according to which technique was used: sections (table 2a) or whole and broken/burnt otoliths (table 2b).

In this study, the lower estimates of age (England, France, Spain, the Federal Republic of Germany) were thought to be more accurate. The aging by the Portugese otolith reader was fully in agreement with this reading method up to age 6, but above this age the otoliths were aged relatively older by Portugal, which caused a divergence in the regression coefficient v (table 2) and made it look like an intermediate method. The Portugese aging method should therefore be aspected as being a different technique for only the ages 6 and older. However, there is reasonable agreement between all participants on the age of the smaller fish, although France seems to age them younger (figure 1).

The standard deviation per age for sectioned otoliths was lower than for those otoliths examined whole or by breaking and burning. This, however, does not imply that the aging of sectioned otoliths is more accurate. It only shows less variability in the readings.

It is concluded that:

Consistent, comparable interpretation of horse mackerel otoliths, up to about 5 years old, is probably achievable amongst all participants.

A more detailed study is necessary to improve the method of aging of fish above 5 years of age.

Those countries having long time series of horse mackerel otolith readings should try and see whether it is possible to follow good or bad year classes to test the method of aging for especially the older age groups.

ERRATUM

Page numbering error: Page 5 is not missing.

Aknowledgement

The author would like to thank all participants for their cooperation in this horse mackerel otolith exchange program. Especially Derek Eaton for also correcting the manuscript and Jaques Gueguen for the French translation of the abstract.

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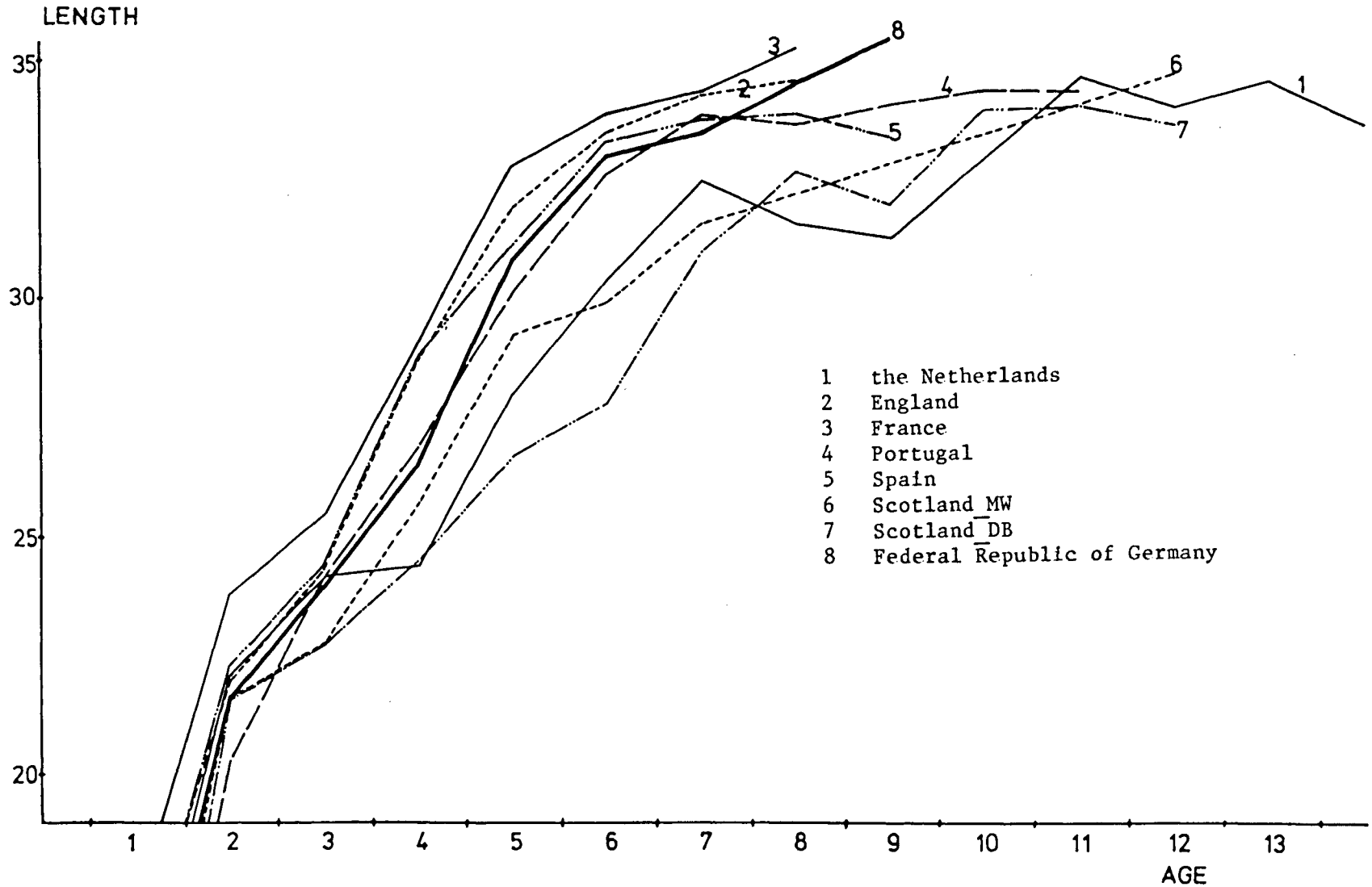

Figure 1: The mean length at age of horse mackerel as estimated from otolith readings by country using sectioned, and whole and broken/burnt otoliths (tables 1a and 1b).

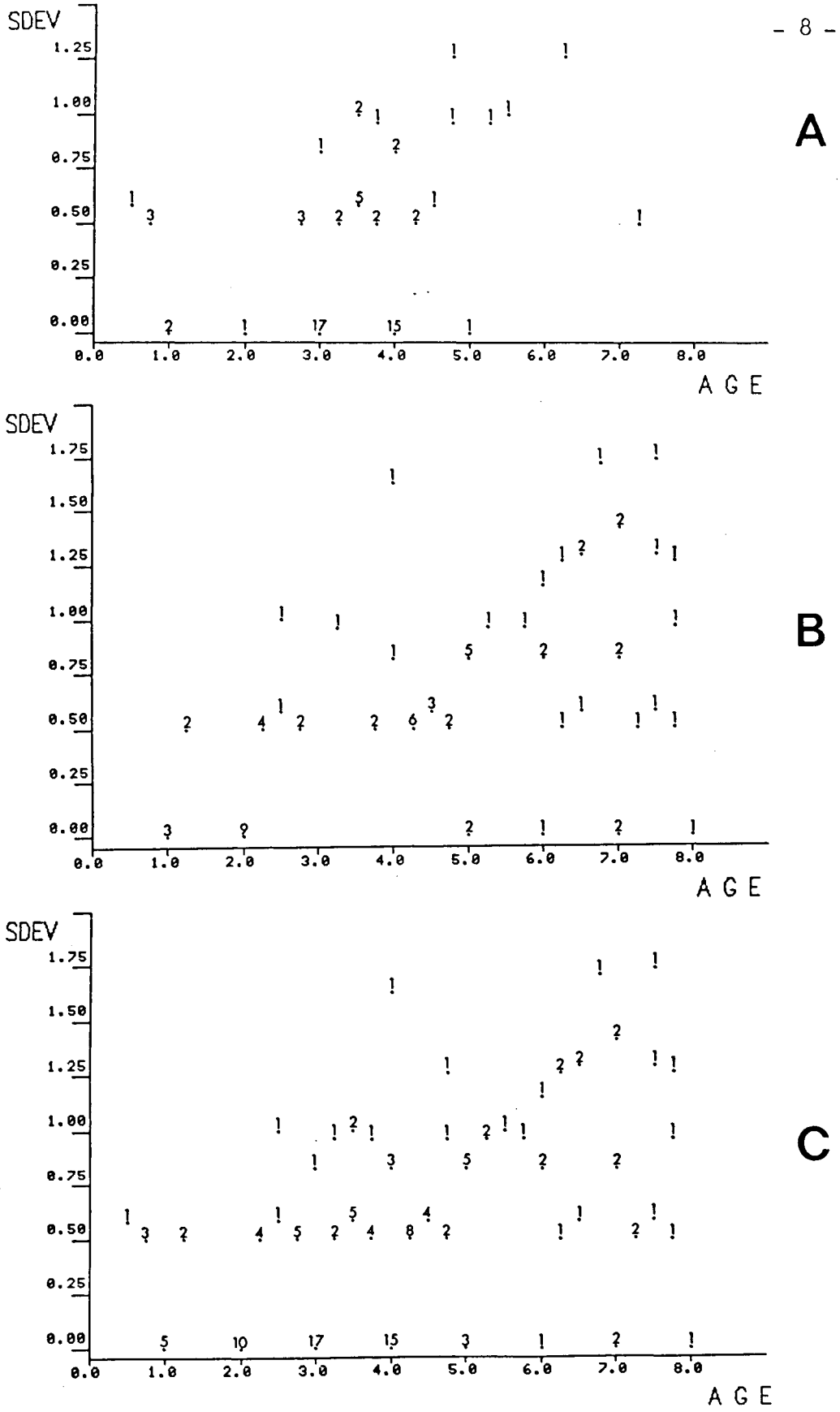

Figure 2: The mean ages plotted against the standard deviations of each otolith as read by otolith readers from England, France, Spain and the Federal Republic of Germany, together with the number of observations.
A = Sectioned otoliths
B = Whole and broken/burnt otoliths
C = Both A and B

Table 1a: Otolith readings by country of sectioned horse mackerel otoliths.

DATE CAUGHT: 16-6-83 NORTH BISCAY

COUNTRY		NETH	ENGL	FRANCE	PORT	SPAIN	SCOTL	SCOTL	GERM
OTOLITH	READER	CK	DE	PD	MdLM	ACFP	MW	DB	MK
otolith	length (cm)	age	age	age	age	age	age	age	age
SLIDE 1	FIRST ROW								
1	32.6	15	7	8	9(10)	8+	16	17?13-17	9?
2	22.7	4	3	3	3	3+	4?	3	3
3	28.3	4	3	3	5	4/3+	7?	4	4
4	23.1	4	3	2	3	3?	-	2	-
5	31.6	6	4	3	6	4+	-	6	-
6	26.3	5	4	4	4	4+	4	4	4
7	26.5	4	4	4	4	4+	4	4	4
8	27.1	6	5	5	5	5+	6(5)	5	5
9	29.2	6	4	5	5	4+	5?	5	5
10	28.0	5	4	4	5	4+	?	7	4+
11	30.7	15	7	7	16(17)	8+	15	14	7
12	28.3	5	3	3	4	3/4	4?	4	5?
13	24.9	5	3	3	4	4+	4?	3	4
14	33.2	15	7	6	13(?)	6/7+	13	15	8+
SLIDE 1	SECOND ROW								
15	26.6	4	4	3	4	3+	5?	4	4
16	29.5	6	5	3	5	3+	6?	6	4
17	33.4	8	5	3	7	5+	7	8	6
18	32.5	8	6	4	8	5+	8?	7	6
19	27.2	5	3	2	4	4+	7	8	3?
20	31.2	14	6	5	?	6+	14	13	8
21	33.5	9	4?	2	?	?	12	9???	-
22	30.6	6	6	4	5	6+	7	7	6
23	27.9	5	4	3	4	4+	5(6)	3	4+
24	10.7	1	1	0	1	1+	1	1	1
25	11.7	1	1	0	1	1+	1	2	1+
26	22.1	4	3	3	2	3+	4	4	3
27	25.7	5	4	4	3	4+	6	5	4
28	24.2	4	3	3	3	3+	4	2	3
29	24.8	4	3	3	3	3+	4	4	3+
30	27.6	5	4	4	3	4+	4(5)	3	4
SLIDE 1	THIRD ROW								
31	23.6	5	4	4	4	4+	4	4	4
32	13.1	1	1	0	0	1+	1	1	1
33	24.4	5	4	4	3	4+	5?	4	4
34	26.5	9	4	4	3	5+	9?	9?	4
35	21.5	4	3	3	3	3+	3	3	4
36	28.2	4	3/4?	3	3	4+	7?	9	5
37	22.3	4	3	3	3	3+	5?	4	4
38	24.1	5	4	4	4	4+	5(4)	4	4
39	23.4	4	3	3	3(4)	3+	6	3	4+
40	26.8	5	4	3	4	4+	6	4	5
41	33.8	15	7	5	14(15)	8+	15	15	-
42	22.3	4	3	3	3	3+	3	6	3+
43	30.5	9	5	4	6	5+	9?	7(6)	6?
44	22.3	4	3	3	3	3+	4	4	3+
45	23.2	4	3	3	3	3+	4	4	3
46	22.6	4	3	3	3	3+	4(3)	3	3

Table 1a (continued)

COUNTRY		NETH	ENGL	FRANCE	PORT	SPAIN	SCOTL	SCOTL	GERM
OTOLITH	READER	CK	DE	PD	MdLM	ACFP	MW	DB	MK
otolith	length (cm)	age	age	age	age	age	age	age	age
SLIDE 2	FIRST ROW								
47	31.2	9	6?	4	?	7+	9(8)	7	5
48	32.1	16	7	6	14+	7+	17	15	-
49	28.3	5	4	4	4	4+	4(5)	4	4
50	30.2	8	4	3	3+	5+	4	8	4
51	31.6	?	?	?	?	-	-	-	-
52	31.5	15	6	6	13+	7+	15	14	-
53	29.7	5	4	4	4	4+	4	4	4
54	26.8	4	3	3	4	4+(3)	5?	12	4
55	23.1	4	3	3	3	3+	4	6????	3+
56	23.1	4	3	3	3	3+	4(3)	3	3
57	22.6	4	3	3	3	3+	3	3	3
58	23.5	4	3	3	3	4+(3)	3	5	3
59	24.8	5	4	4	4	4+	4	4	4
60	22.9	5	3	3	4	4+	4	4	4
61	24.3	4	3	3	3+	3+	4(3)	6	3+
62	26.5	4	3	3	4	4+	4	3	4
SLIDE 2	SECOND ROW								
63	10.1	1	0/1?	0	1	0+	1	1	1
64	14.1	1	1	1	2	1+	1(2)	3	1+
65	11.8	1	1	0	1	0+	1(2)	3	1
66	23.9	4	3	3	3	3+	4	4	3
67	26.4	5	4	4	4+	4+	5	4	4+
68	26.8	5	4	4	4	4+	5?	3	4+
69	20.5	3	2	2	2+(3)	2+	3	2	2+
70	24.7	4	3	2	3+	3+	4	3	3
71	24.8	5	3/4?	3	4	4+	5	4	4
72	30.5	8	4	3	6?	5+	7	7	4+
73	25.6	4	3	3	3	3+	4	3	3+
74	21.5	4	3	3	4(3)	3+	6?	4	3+
75	24.1	4	3	3	3	3+	4	3	3
76	25.1	5	3	3	4	4/5+	5?	4	4
77	22.5	4	3	2	3	3+	5?	3	3
78	12.6	1	1	1	1	1+	1	1	1
79	33.1	14	8	5	?	7+	14?	13/14	8?
SLIDE 2	THIRD ROW								
80	29.7	5	4	2	4	4+	5	5	4
81	28.2	5	4	3	4	4+	6?	9???	4+
82	31.6	15	6	5-6	?	7+(8?)	15(16)	15	9?
83	27.8	8	?	4	8	6+	8	8	6?
84	30.8	4	5	3	3	3+	4	7	3+
85	25.8	5	3	2	4	3+	3(4)	6	3
86	29.8	15	3	5	?	8+	15	15	-
87	32.9	6	6	4	5(4)	4+	6	5	5+
88	31.6	5	4	4	4	4+	4	4	4+
89	27.0	5	4	4	4	4+	4(5)	4	4
90	26.5	5	4	4	4	5+	5(4)	3	4+
91	27.5	4	4	2	3	3+	4	2	3
92	20.5	6	3	3	4(3)	4+	6	6	4
93	20.0	4	2	1	?	2+	2	4	-
94	22.1	6	3	3	3	3+	5(4)	5	3

Table 1b: Otolith readings by country and by sample of whole and broken/burnt horse mackerel otoliths.

SAMPLE 82-002			DATE CAUGHT: 24-4-82 GREAT SOLE BANK						
COUNTRY OTOLITH READER		NETH CK	ENGL DE	FRANCE PD	PORT MdLM	SPAIN ACFP	SCOTL MW	SCOTL DB	GERM MK
otolith	length (cm)	age	age	age	age	age	age	age	age
26	32.6	8	6	6	6	7+	8(7)	9	7
27	33.7	7	5	4	6	6+	8(7)	7	6
28	33.8	14	8	7	?	9+	13?	11	7+
29	33.9	15	7	7	13(?)	7+	12	10	7+
30	33.3	8	6?	4-5	6	-	7	8	5+
31	33.3	7	5	5	6	4+	6?	7	6
32	34.2	14	6?	6	9	?	12?	8/9	6
33	34.0	7	6	6	6	6+	7(6)	7	6
34	34.6	13	8	6	8(7)	7+?	12?	11	8?
35	34.5	9	5	?	6	5+	6	-	5+
36	34.0	7	4	4	6	4/5	9?	7??	-
37	34.0	6	5	5	5(6)	4+	6	5	5+
38	35.9	11	7	7	?	?	13(14)	12	7+
39	35.4	13	8	7-8	10	5+?	12	11	9?
40	35.8	10	7	7	8+	6+	11	9	8
41	35.4	14	7	7	8(?)	6+	10?	8	-
42	35.5	13	8	8	11	6+	13	9	9+
43	35.5	12	6	7	8	6+	12	11	9
44	35.0	13	7	6	?	8+	14	12(13)	9
45	36.5	20	9?	8	14+?	8+	15?	16	8
46	36.1	14	6	5	10+	7+	12	10	8
47	36.2	13	8	8	11	8+	13(12)	10(9)	8
48	36.5	11	8?	6-7	8	7+?	12	8	9
49	37.6	12	7	6	?	7+	12	8	10
50	37.2	13	7	7	9(10)	7+	11?	12	8
SAMPLE 82-003			DATE CAUGHT: 8-5-82 GREAT SOLE BANK						
1	27.9	5	3?	3-4	5	6+	8?	7	4
2	28.3	5	4	3	5	4+	6	9	5
3	29.4	5	4	4	5	4+	8?	5-12	5
4	29.9	6	4	4	5	3+	6	5	4+
5	29.9	7	5	3-4	5	4+?	?	6	-
6	30.3	5	4	4	5	5+	6?	8	5
7	30.6	6	4	3-4	4	?	6	8	5+
8	30.6	6	5	5	6	4+	6?	9	5+
9	30.5	5	4	4	5	4+	7	5	5
10	30.3	6	5	4	5	4+	6	7	5
11	30.8	5	4	4	5	4+	5	9	5
12	30.6	7	5	5	5	5+	8(7)	7	5+
13	30.8	5	4	4	5	4+	?	6	-
14	30.7	5	4	4	5	4/5+	8?	8	-
15	31.0	6	5	5	5	4+	?	5	-
16	31.8	7	5	4	5	4+	7	7	6+
17	31.0	5	5	4	6(5)	6+	8??	11??	5+
18	31.2	6	4?	3	5	-	?	5	-
19	31.3	7	5	3	?	5+	6	8	5+?
20	31.2	6	5	4	?	4+	7	12(10)	5+
21	32.2	11	8	5-6	9	9+	12?	13	7?
22	32.3	12	6?	5	13	-	13(14)	11	-
23	33.2	7	6	6	7	7+	7	6	6+
24	34.2	12	8	6	12(13)	9+	12	12	10?
25	36.1	13	8	7	9	8+	11?	12(11)	8+

Table 1b (continued)

SAMPLE 82-005 DATE CAUGHT: 16-6-82 GREAT SOLE BANK

COUNTRY		NETH	ENGL	FRANCE	PORT	SPAIN	SCOTL	SCOTL	GERM
OTOLITH	READER	CK	DE	PD	MdLM	ACFP	MW	DB	MK
otolith	length (cm)	age	age	age	age	age	age	age	age
1	29.2	4	3	3	?	-	6?	13??	4+
2	30.2	6	?	4	?	-	6?	6/7	-
3	30.2	5	4	4	5	4	5?	15?	5
4	31.5	5	4	4	5	4	5	6	5
5	31.9	8	5	5	6	4	7	8	6+
6	31.7	5	4	4	5	4	6	10	5
7	31.4	5	4	4	6	4(3)	5?	7	5
8	31.7	5	4	?	5	4	5	5(4)	5
9	32.8	12	6?7	4	11	6/7	9?	9	7
10	32.8	14	7?	7	10+	7/8	10?	11	9?
11	32.5	6	5	5	6	5	6	7	5+
12	32.2	6	5?	4	6	-	6?	6	6
13	32.5	6	5	5	6	4	6?	14	6
14	32.7	13	7?	7	?	8	11?	11	7+
15	33.1	13	6?	5	8	9	12?	13	7?
16	33.5	16	8?	5	?	7	7(8)	5/6??	6+
17	33.5	13	7	5	10+(?)	5	10(9)	9	7
18	33.7	12	7	5-6	11	8/7	13?	9/10	8
19	33.3	12	6	5	10+	5	13?	8	7
20	34.9	13	6	5	11	7	9(9+)	11	9+
21	34.1	11	6	6	9	?	?	10??	7
22	34.2	13	6	5	12	7	11(12-14)	12/13	8
23	34.6	11	6	5	10	6	10?	9	8
24	35.2	13	7	6	12	6	13?	10	9+
25	35.0	13	5	5	?	6	13??	8	7+?
SAMPLE 82-006			DATE CAUGHT: 29-8-82 CORNWALL						
1	32.9	12	6	5-6	9	6(5)	9?	10(9)	8
2	32.9	6	4	5	8	5	7?	8	6+?
3	32.9	13	5?	6	7+	7	10(9)	9	9?
4	32.8	14	6	6	12+	7	13?	14	10?
5	32.4	14	7?	6	12	-	12??	10	-
6	33.6	12	6	6-7	12	7(6)	12	11	-
7	33.7	12	5	6	?	6	7?	6??	7+
8	33.4	14	6	7	?	7	15?	11	8
9	33.2	13	6	5	11	6	12	7	7
10	33.4	15	7	6	?	7(6)	11	10	8
11	33.6	19	7	7	12	7(8)	19	12-14	-
12	33.8	13	7?	?	11	7	10?	7?	8?
13	33.7	12	7	?	10+	6	12	9(10)	8
14	33.7	13	6?	6	9	7(6)	7	9(9+)	7
15	34.9	12	7	7	9	8	10(10+)	11	8
16	34.6	6	5	5	9	4	6	8	6
17	34.2	16	6	6	?	-	10+	10	-
18	34.3	14	6	6	8	8(7)	12?	13(14)	8
19	34.3	12	6	6	8	6	11(11+)	10	6+?
20	34.5	13	6?7	6	9(10)	-	9?	9	-
21	34.9	13	6	6	7	6?	10?	8	-
22	34.1	13	6	7	11(?)	7/8	13	11	8
23	34.6	13	7	5	7	-	13(12)	11	7+?
24	34.1	14	6?	6	?	8	12	10(11)	8+?
25	34.2	14	7	7	8	7	10	12	7

Table 1b (continued)

SAMPLE 82-012 DATE CAUGHT: 29-10-82 CORNWALL

COUNTRY		NETH	ENGL	FRANCE	PORT	SPAIN	SCOTL	SCOTL	GERM
OTOLITH	READER	CK	DE	PD	MdLM	ACFP	MW	DB	MK
otolith	length (cm)	age	age	age	age	age	age	age	age
1	17.9	1	1	1	1?	1	1(2)	4	1+
2	18.3	1	1	1	2	1	2(1)	4	2
3	18.9	1	1	1	2	1	2(1)	3	1+
4	18.5	1	1	1	2	1	1	5	1+
5	19.3	1	1	1	2	1	1(2)	5	2
6	20.6	2	2	2	2(3)	2	3(4)	3	2
7	21.7	2	2	2	2(3)	2	2	6	3
8	21.1	2	2	2	2(3)	2	3?	5	2+
9	21.1	2	2	2	3	2	3?	3	2+
10	21.2	2	2	2	3	2	2(3)	4	2+
11	21.7	2	2	2	2(3)	2	2(3)	3	2+
12	22.8	2	2	2	2(3)	2	3(2)	5	2+
13	22.2	2	2	2	2	2	2	3	2+
14	22.2	2	2	3	2	2	2	6??	2+
15	22.0	2	1	2	2	2	2??	2	-
16	22.2	2	2	3	2(3)	2	2(3)	4	2+
17	22.1	2	2	2	3	2	2(3)	3	2+
18	22.5	2	2	4	3	2	3?	3	2+
19	23.6	2	2	3	3	2	?	3	2+
20	23.1	2	2	2	?	2	4?	4	2+
21	23.9	3	2	3	3	2	4?	5	3
22	24.7	3	3	2	2+	3	4??	9	3+
23	24.5	3	3	3	3+	2	6?	7	3+
24	25.9	3	3	4	?	3	3	5?	3+
25	25.1	3	4	4	3	2	6??	7?	3

Table 2a: GM regressions from readings of SECTIONED horse mackerel otoliths.

X \ Y		ENGLAND	FRANCE	PORT	SPAIN	SCO_MW	SCO_DB	GERM
NETHERLANDS	v	0.40	0.40	0.87	0.48	1.04	1.03	0.53
	u	1.43	0.97	-0.41	1.13	-0.39	-0.43	1.07
	r	0.82	0.79	0.91	0.91	0.97	0.90	0.87
	n	87	92	76	84	54	86	78
mean age	X	5.80	5.72	4.87	5.67	6.06	5.53	4.95
mean age	Y	3.76	3.25	3.84	3.86	5.91	5.28	3.71
ENGLAND	v	----	0.96	1.80	1.11	2.70	2.60	1.08
	u	----	-0.28	-2.51	-0.32	-4.35	-3.08	-0.14
	r	----	0.84	0.79	0.86	0.81	0.70	0.91
	n	----	86	72	79	50	81	74
mean age	X	----	3.73	3.51	3.75	3.78	3.65	3.55
mean age	Y	----	3.29	3.83	3.84	5.86	5.25	3.70
FRANCE	v	----	----	1.76	1.18	2.66	2.56	1.11
	u	----	----	-1.57	-0.01	-2.71	-2.98	0.26
	r	----	----	0.70	0.87	0.79	0.65	0.84
	n	----	----	76	84	54	85	78
mean age	X	----	----	3.07	3.26	3.24	3.18	3.12
mean age	Y	----	----	3.84	3.86	5.91	5.16	3.71
PORTUGAL	v	----	----	----	0.61	1.16	1.22	0.89
	u	----	----	----	1.22	0.18	-0.09	0.44
	r	----	----	----	0.81	0.96	0.78	0.88
	n	----	----	----	70	41	72	68
mean age	X	----	----	----	3.84	3.80	3.83	3.44
mean age	Y	----	----	----	3.56	4.61	4.57	3.51
SPAIN	v	----	----	----	----	2.25	2.01	0.96
	u	----	----	----	----	-3.09	-2.48	0.24
	r	----	----	----	----	0.91	0.81	0.90
	n	----	----	----	----	51	78	73
mean age	X	----	----	----	----	3.90	3.74	3.53
mean age	Y	----	----	----	----	5.71	5.04	3.64
SCOTLAND_MW	v	----	----	----	----	----	0.99	0.54
	u	----	----	----	----	----	0.00	1.13
	r	----	----	----	----	----	0.95	0.91
	n	----	----	----	----	----	51	45
mean age	X	----	----	----	----	----	5.63	4.71
mean age	Y	----	----	----	----	----	5.55	3.67
SCOTLAND_DB	v	----	----	----	----	----	----	0.51
	u	----	----	----	----	----	----	1.34
	r	----	----	----	----	----	----	0.75
	n	----	----	----	----	----	----	75
mean age	X	----	----	----	----	----	----	4.64
mean age	Y	----	----	----	----	----	----	3.71

Table 2b: GM regressions from readings of WHOLE AND BROKEN/BURNT horse mackerel otoliths.

X \ Y		ENGLAND	FRANCE	PORT	SPAIN	SCO_MW	SCO_DB	GERM
NETHERLANDS	v	0.40	0.36	0.70	0.47	0.88	0.63	0.50
	u	1.42	1.65	1.10	1.16	0.51	2.79	1.57
	r	0.91	0.87	0.91	0.90	0.92	0.82	0.90
	n	105	111	89	93	44	97	94
mean age	X	7.90	8.38	8.15	7.70	8.95	8.16	7.74
mean age	Y	4.83	4.68	6.78	4.80	8.34	7.94	5.45
ENGLAND	v	----	0.89	1.59	1.06	2.30	1.41	1.21
	u	----	0.33	-1.13	-0.33	-3.79	1.01	-0.25
	r	----	0.93	0.86	0.94	0.89	0.82	0.94
	n	----	95	75	85	40	83	84
mean age	X	----	4.71	4.77	4.59	5.23	4.71	4.61
mean age	Y	----	4.54	6.44	4.54	8.23	7.94	5.32
FRANCE	v	----	----	1.84	1.22	2.46	1.64	1.28
	u	----	----	-1.84	-0.80	-3.98	0.36	-0.45
	r	----	----	0.78	0.88	0.84	0.77	0.89
	n	----	----	75	87	36	89	85
mean age	X	----	----	4.57	4.49	4.94	4.57	4.52
mean age	Y	----	----	6.56	4.70	8.19	7.84	5.35
PORTUGAL	v	----	----	----	0.71	1.37	0.95	0.77
	u	----	----	----	0.25	-1.39	1.68	0.62
	r	----	----	----	0.84	0.89	0.72	0.91
	n	----	----	----	65	31	70	67
mean age	X	----	----	----	6.20	6.84	6.44	6.33
mean age	Y	----	----	----	4.63	7.97	7.77	5.48
SPAIN	v	----	----	----	----	1.92	1.38	1.11
	u	----	----	----	----	-1.77	1.21	-2.63
	r	----	----	----	----	0.90	0.82	0.90
	n	----	----	----	----	34	75	78
mean age	X	----	----	----	----	4.88	4.63	4.51
mean age	Y	----	----	----	----	7.59	7.59	5.18
SCOTLAND_MW	v	----	----	----	----	----	0.65	0.60
	u	----	----	----	----	----	2.86	1.30
	r	----	----	----	----	----	0.72	0.95
	n	----	----	----	----	----	34	37
mean age	X	----	----	----	----	----	8.24	7.68
mean age	Y	----	----	----	----	----	8.21	5.89
SCOTLAND_DB	v	----	----	----	----	----	----	0.84
	u	----	----	----	----	----	----	-1.04
	r	----	----	----	----	----	----	0.80
	n	----	----	----	----	----	----	71
mean age	X	----	----	----	----	----	----	7.49
mean age	Y	----	----	----	----	----	----	5.24

Table 2c: GM regressions from readings of SECTIONED, WHOLE AND BROKEN/BURNT horse mackerel otoliths.

X	Y	ENGLAND	FRANCE	PORT	SPAIN	SCO_MW	SCO_DB	GERM
NETHERLANDS	v	0.43	0.39	0.77	0.47	0.95	0.80	0.52
	u	1.38	1.24	0.34	1.15	0.00	1.12	1.28
	r	0.89	0.85	0.92	0.91	0.95	0.85	0.91
	n	192	203	165	177	98	183	172
mean age	X	6.95	7.17	6.64	6.73	7.36	6.93	6.48
mean age	Y	4.34	4.03	5.42	4.35	7.00	6.69	4.66
ENGLAND	v	----	0.95	1.71	1.07	2.39	1.89	1.21
	u	----	-0.07	-1.95	-0.26	-3.67	-1.44	-0.43
	r	----	0.90	0.87	0.91	0.85	0.76	0.94
	n	----	181	147	164	90	164	158
mean age	X	----	4.24	4.16	4.18	4.42	4.19	4.11
mean age	Y	----	3.94	5.16	4.20	6.91	6.48	4.56
FRANCE	v	----	----	1.81	1.16	2.37	1.98	1.23
	u	----	----	-1.71	-0.22	-2.48	-1.16	-0.15
	r	----	----	0.81	0.87	0.81	0.75	0.89
	n	----	----	151	171	90	174	163
mean age	X	----	----	3.81	3.89	3.92	3.89	3.85
mean age	Y	----	----	5.19	4.29	6.82	6.53	4.56
PORTUGAL	v	----	----	----	0.64	1.23	1.09	0.76
	u	----	----	----	0.89	-0.22	0.59	0.79
	r	----	----	----	0.84	0.94	0.80	0.93
	n	----	----	----	135	72	142	135
mean age	X	----	----	----	4.98	5.11	5.12	4.87
mean age	Y	----	----	----	4.07	6.06	6.15	4.49
SPAIN	v	----	----	----	----	2.11	1.70	1.11
	u	----	----	----	----	-2.60	-0.83	-0.06
	r	----	----	----	----	0.91	0.81	0.91
	n	----	----	----	----	85	153	151
mean age	X	----	----	----	----	4.29	4.18	4.04
mean age	Y	----	----	----	----	6.46	6.29	4.44
SCOTLAND_MW	v	----	----	----	----	----	0.90	0.61
	u	----	----	----	----	----	0.58	1.00
	r	----	----	----	----	----	0.89	0.94
	n	----	----	----	----	----	85	82
mean age	X	----	----	----	----	----	6.67	6.05
mean age	Y	----	----	----	----	----	6.61	4.67
SCOTLAND_DB	v	----	----	----	----	----	----	0.67
	u	----	----	----	----	----	----	0.40
	r	----	----	----	----	----	----	0.79
	n	----	----	----	----	----	----	146
mean age	X	----	----	----	----	----	----	6.03
mean age	Y	----	----	----	----	----	----	4.45

Table 3: Mean length at age (cm) and number of fish (otoliths) by country using sectioned, whole and broken/burnt otoliths.

AGE COUNTRY	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
NETH	14.8	22.1	24.2	24.4	28.0	30.4	32.5	31.6	31.3	35.9	34.7	34.1	34.6	33.7	-
n	12	15	6	33	40	22	9	8	5	1	5	13	22	13	-
ENGL	15.8	22.0	24.3	28.7	31.9	33.5	34.3	34.6	-	-	-	-	-	-	-
n	12	17	39	44	24	26	21	9	-	-	-	-	-	-	-
FRANCE	17.5	23.8	25.5	29.1	32.8	33.9	34.4	35.3	-	-	-	-	-	-	-
n	8	21	50	46	28	25	16	4	-	-	-	-	-	-	-
PORT	11.4	20.3	24.2	26.9	30.1	32.6	33.9	33.7	34.1	34.4	34.4	33.7	32.0	32.2	-
n	5	10	37	27	25	15	5	10	8	6	7	6	2	1	-
SPAIN	15.6	22.3	24.4	28.8	31.1	33.3	33.8	33.9	33.4	-	-	-	-	-	-
n	10	20	30	48	16	18	18	11	4	-	-	-	-	-	-
SCOT_MW	12.8	21.6	22.8	25.7	29.2	29.9	31.6	27.9	-	34.3	34.7	34.8	34.3	33.2	31.5
n	6	4	6	21	6	15	11	1	-	2	2	12	3	2	4
SCOT_DB	11.7	21.6	22.8	24.5	26.7	27.8	31.0	32.7	32.0	34.0	34.1	33.7	32.2	31.9	32.2
n	4	6	26	31	17	12	17	18	13	8	13	5	3	4	5
GERM	14.0	21.6	24.0	26.6	30.8	33.0	33.5	34.6	35.5	37.7	-	-	-	-	-
n	10	16	29	38	26	14	14	18	6	1	-	-	-	-	-