REPORT OF THE MACKEREL AGE DETERMINATION {.¡QRKSHOP,
LO\ffiSTOFT, 1-6 JUNE 1987

1. INTRODUCTION

In accordance with the terms of a contract with the Commission of
the European Economic Community, the United Kingdom Ministry of
Agriculture, Fisheries and Food (the Contractor) convened a Mackerel Age
Determination Workshop at the Fisheries Laboratory, Lowestoft, during the
period 1-6 June 1987. The objectives of the Workshop were:

"To assess the consistency of age determination of older mackerel by
otolith readers for the main countries exploiting mackerel in the
north-east Atlantic. In the event of an unacceptable level of
disagreement in age determination of older mackerel, to attempt to
identify the source of differences and to attempt to agree on a standard
method of interpretation.

To recommend whether or not the upper limit of the age range used in
mackerel assessments should be extended from 10 to 15 years."

2. PARTICIPANTS

Participants taking part in comparative age determination:

E Barnwall	Ireland
J Beintema	Netherlands
D Beveridge	UK (Scotland)
W A Dawson	UK (England)
H Gill	Norway
H lbsen	Denmark
K Kuiter	Netherlands
I Reinholtz	Federal Republic of Germany
M Walsh	UK (Scotland)

Other participants

J Barry	Fisheries Laboratory, Lowestoft
J Casey	" " "
B l¡ Jones	" " "

3. BACKGROUND

It is generally accepted that age determination of mackerel of the
main stocks in the ICES area (the Western and the North Sea stocks)by
the various otolith readers is sufficiently consistent and reliable for
assessment purposes up to the age of ten. Up to the present time it has
been the normal practice of the ICES Mackerel Working Group to make age
structured analytical assessments based on ages 1 to 10 with the older
fish grouped as an 11+ group. It could be an advantage for Virtual
Population Analyses to work with an extended age range. Consequently at
the 1984 meeting of the ICES Mackerel Working Group it was agreed that an
otolith exchange should be organised and the results examined befare
extending the range of ages used in the assessments. The results of this
otolith exchange were reported by Dawson (1986)and it was concluded that
the level of agreement of fish older than 10 years was not satisfactory

and it was suggested that convening an age determination workshop would be beneficial and hopefully would help to reduce the differences in otolith interpretation. Seven otolith readers from seven countries participated in the otolith exchange and five of these readers were able to attend the age determination workshop.

4.   GENERAL CONSIDERATIONS

4.1 Mounting otoliths

     The basic method used by most readers is to mount whole otoliths on black slides and to view them under a microscope by reflected light. Two countries routinely viewed unmounted otoliths submerged in alcohol. There were, however differences in detail of the mounting techniques which are summarised in the text table below:-

Summary of the mackerel otolith preparation techniques used

Country	Method of cleaning	Preparation techniques for otolith examination	No. otoliths per slide
Norway	In 2% CaOH	Otoliths placed on black perspex slides and covered with two layers of non plastic resin (Eukit). No coverslip on surface	10
Ireland	In hot water	Otoliths fixed to black perspex slides with one drop of fibreglass resin, allowed to dry and then covered with another layer of resin. If time permits the otoliths are covered with a coverslip while the resin is wet.	25
Scotland	In hot water	In the past the otolithsk been mounted on black perspex slides and covered with one layer of resin with no coverslip on the surface. More recently, to save time, the otoliths are left unmounted and viewed in a black dish in alcohol.	10
Germany	In hot water	Otoliths are fixed to a transparent perspex slide with a drop of non plastic resin. The otoliths are covered over with another layer of resin with no coverslip on the surface.	60

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Summary of the mackerel otolith preparation techniques used (contd)

Country	Method of cleaning	Preparation techniques for otolith examination	No. otoliths per slide
The Netherlands	In alcohol for 5 mins	The otoliths are stuck to a black hardboard slide with a drop of gum arabic. The otoliths are then covered with polyester resin a little at a time to allow for shrinkage of the resin. This resin dries to a smooth hard surface and no coverslip is needed.	25
England	In hot water	The otoliths are stuck to a black perspex slide with a drop of resin. \Yhen dry, another layer of resin is used to cover the otoliths and allowed to dry. When dry, a final layer of resin is used to enable a cover-slip to be placed over the slide.	25
Denmark	In alcohol	Otoliths are lightly fixed on back perspex slides with Ganada Balsam so they can be moved. The slide ís covered with clear adhesive tape to hold the otoliths in position.	10

At the Worshop otolith samples from all the countries represented were used for fomparative age determinations and it was possible to compare the ease viewing of otoliths prepared by different mounting methods. The Workshop concluded that when otoliths are mounted the best results are achieved as follows:

a.   Befare mounting otoliths should be cleaned in alcohol and left to dry befare covering with resin.

b.   Both otoliths from a fish should be mounted.

c.   The slides should be of opaque black material.

d.   The slides should have cavities in which the otoliths are placed.

e.   It is preferable to limit the number of otoliths mounted on a single slide to 25 pairs.

f.   The advantage of using a glass coverslip can depend on the type of resin used.

g.   If a coverslip is not used the resin covering should have a smooth uniform surface rather than covering individual otoliths with blobs of resin.

h. When viewing a cold light sou ce, such as is available f om fib e
    optic illuminatos is p efe able.

4.2 <u>Development of the edge of otoliths</u>

    Pa ticipants at the Workshop observed that the time of year at which
the opaque summer zone is first visible at the edge of the otolith varies
according to the a ea of capture. Opaque mate ial is visible on the edge
ea ly in the year to the southwest of B itain, lateWest of Scotland
later still in the North Sea. No mally this should not be a cause of
er oin age determination but, if a readeis switching between samples
from diffe ent areas, errors could esult in the inte p etation of the
edge if the eadeis unaware of the area differences in the development
of the edge of the otolith.

S. METHODS

    The first sample of otoliths selected for comparative age determina-
tion was a sub-sample of the otoliths used in the earlier otolith
exchange and consisted of 177 otoliths. This sample included fish cover-
ing the full range of ages and only a small proportion, about 15%, were
expected to be aged 11 years or older. The length of fish corresponding
to each otolith was available to the readers. From the results of age
determination it would be possible to make comparisons between readers
for the cur ent set of age determinations and also, for each reade , to
compare the cur ent age dete minations with those made p eviously during
the otolith exchange. For count ies where two readers wee rep esented
at the Workshop a single agreed age was recorded for each otolith. The
age determinations made du ing the Workshop with those made during the
otolith exchange have been compared foeach country but it should be
noted that for sorne countries the readers at the Workshop were different
f om those pa ticipating in the otolith exchange (Ireland and Germany).

    After the results of the age determinations of the first sample had
been examined the Group went on to discuss together the interpretation of
selected otoliths from the sample. Fodiscussion purposes photographs
of otoliths were projected and the actual otoliths were displayed on a
video monitor using a video camea fitted to a microscope. Where these
methods provided inadequate esolution direct microscopic examination was
used.

    Also available was a small numbeof otoliths taken from recaptu ed
tagged mackerel which had been at libe ty for varying periods up to
9 yea s. These otoliths were all examined by di ect microscopic examina-
tion and the various interp etations wee discussed.

    A second sample of otoliths was then prepared for comparative age
determination. For this sample predominantly old fish were selected and
the sample was made up of 10 otoliths contributed by each of the seven
countries. Again after the results of the second sample had been
examined there was a furthediscussion of interpretation of selected
otoliths from this sample.

6. RESULTS OF COMPARATIVE AGE DETERMINATIONS

6.1 Sample 1 age determinations made during the
    Workshop and during the otolith exchange

     Table 1 gives the results of age determinations made at the Workshop
for the first sample (Sample 1) of 177 otoliths. For comparison the age
determinations recorded during the otolith exchange are also included in
the table. Figure 1 illustrates the range of ages determined during the
Workshop for each otolith in the sample. In this figure the otoliths
have been arranged in increasing order of the average of the age
determinations.

     For Sample 1 for each country age determinations made during the
otolith exchange can be compared with the age determinations made during
the Workshop. (Note that for Ireland and Germany different readers were
involved.) There was a fairly good degree of consistency between the two
sets of age determinations. Over the combined set of age determinations
59% of readings were in agreement on both occasions and 89% were within +
or – one year. This comparison is summarised in Table 2 which shows for
each country the frequency distributions of the differences in the age
determiinations made on the two occasions. If the otoliths were divided
into older fish (average age 11 and older)and younger fish (average age
0-10) there was more consistency between readings made at the Workshop
with those made during the otolith exchange for the younger fish than for
the older ones (Table 3).

     For the age determinations made at the Workshop for Sample 1 the
range of ages determined for each otolith (Figure 1) indicates that there
are differences in interpretation over the whole range of ages. There
are sorne 'problem' otoliths where the range of ages is larger than
average and there is a tendency for the range to increase with increasing
age.

6.2 Discussion on interpretation of otoliths
    of recaptured tagged fish

     After making their age determinations for Sample 1 in the Workshop
participants then discussed age determinations from a sample of seven
recaptured tagged fish (Table 4). The period of liberty provided an
absolute mínimum age for these fish. When discussing otoliths where
there was a range of interpretations it was generally the case that the
higher ages were more consistent with the information on the history of
the fish. It was agreed that these otoliths had been particularly help-
ful in providing sorne help in age determination validation for older
fish.

6.3 Discussion of otolith interpretation

     The participants then went on to a group discussion of their inter-
pretations of a sub-sample of otoliths from Sample 1. This was found to
be beneficiaás readers are generally working in isolation and have very
little opportunity to meet readers from other countries working with the
same species. After a discussion of each otolith, and with the benefit
of the assistance to interpretation provided by the tagged fish otoliths,
it was possible to reach a concensus age determination of a single age or
an alternative of two adjacent ages (Table S). The participants

considered that the discussions of the selected Sample 1 otoliths plus
the information provided by the tagged fish otoliths could be expected to
improve the consistency of interpretation between readers.

6.4 Sample 2 age determinations

The work of the Workshop then continued with the comparative age
determinations for Sample 2 and the results are given in Table 6. This
sample was made up of what were expected to be predominantly older
otoliths.
Figure 2 illustrates the range of ages determined for each
otolith. There appears to be greater consistency between readers over
the greater part of the sample and wide ranges in the determined ages are
restricted mainly to the oldest fish. The age ranges for each otolith
(maximum age – mínimum age)for Sample 1 Workshop readings and for
Sample 2 are plotted as percentage frequency distributions in Figure 3.
Although Sample 2 contains a much higher proportion of older fish there
is little difference in the distributions.

6.5 Assessment of Results

For assessment purposes the main objective of age determination is
to be able to allocate each fish aged to its true year class. Age-based
analytical assessments are concerned with monitoring changes in the
abundance of each year class in the stock over successive years. However
unless there is a reliable method of validation the true age is not known
and cannot therefore serve as a reference point with which individual age
determinations may be compared. Age determinations may be subject to
error or bias and it is most unlikely that any set of age determinations
would be free of these sources of variation.

The comparison of the two sets of age determinations for Sample 1
gives an indication of within-reader variation. Tables 2 and 3 show for
each country the frequency of agreements in the two sets of age deter-
minations and the frequencies of the differences at each level. In
Table 3 these data have been divided into younger (average age for both
sets of age determinations 10 years)and older fish.   Table 7 gives for
each country the standard deviations of its age determinations from the
average age. Overall there was no difference in the standard deviations
for the two sets of data. For the individual countries there were dif-
ferences in the standard deviations for the two sets of data but none of
the differences was significant.

In examining the variation between readers three sets of data were
used: the two readings for Sample 1 and the readings for Sample 2. To
examine the extent of disagreement in age determinations a disagreement
score was calculated for each data set as follows:

(i) The number of age determinations which differ from the most
    frequently recorded value is determined for each otolith
    (maximum number of disagreements = 6 per otolith).

(ii) The number of disagreements is summed for the whole sample and
     divided by the total number of age determinations in the
     sample.

The resultant score will then be zero if there is complete agreement for
all otoliths in the sample or will approach 0.86 when there is no

agreement for any otolith. The results for the three data sets are given
in Table 8. It should be noted that befare calculating the disagreement
scores all ages greater than 15 were converted to 15 to be consistent
with the oldest age group being 15+. There is a slight improvement in
the degree of agreement in the Workshop readings of Sample 1 compared
with the otolith exchange and a larger improvement in the readings from
Sample 2 despite the higher proportion of older fish in that sample.

     For the three data sets the frequency distributions of the standard
deviations have been calculated and these are given in Table 9 and
plotted in Figure 4. For each data set otoliths have been divided into
two groups on the basis of average age 10 or 11 and older (for ages
> 15 the recorded ages were used rather than collapsing them into a 15+
age roup).

     For Sample 1 (Workshop age determinations) and for Sample 2 func-
tional linear regressions were calculated for each reader against each
other reader (Tables 10 and 11). For all the regressions the slopes are
close to unity and the intercepts close to zero with no evidence of
systematic error or bias.

     Figure 5 shows for each country the mean age differences with each
of the other countries. The age difference is the average for each
age-group as determined by the reference country.

     It is most unlikely that age determinations of an otolith sample by
a number of readers will ever be in complete agreement. However it is
difficult to determine for any fish stock what level of agreement has to
be achieved for the results to be acceptable, although it would be
possible to analyse by simulation the effect on assessments of different
levels of error or bias. The problem is further compounded by the fact
that the true age of otoliths cannot be determined with complete cer-
tainty. For the mackerel age determinations ne of the statistical ana-
lyses made was in any way conclusive andÃare o ^{t}limited validity when
samples contain different age compositions. The conclusions of the
Workshop are therefore somewhat subjective. Based on comparisons between
Sample 1 (Workshop) and Sample 2 for standard deviations, the disagree-
ment scores, and the ranges of age recorded it is considered that the age
determinations of Sample 2 of predominantly older fish are no worse than
for Sample 1 consisting predominantly of younger fish.

7.   SUMMARY AND CONCLUSIONS

   (i) Three sets of age determinations were analysed:

        Sample **1** – otolith exchange

        Sample **1** – Workshop

        Sample 2 – Workshop.

  (ii) There appears to be little difference between the first two data
        sets. The repeat readings at the Workshop were made using
        unfamiliar equipment and befare the participants had any discus-
        sions on interpretation.

(iii) Discussion sessions at the Workshop using ordinary otoliths and also otoliths from recaptured tagged fish proved to be very bene- ficial for all participants. Various interpretations could be understood when demonstrated and it was generally possible to reach a concensus age for the otoliths discussed. The otoliths from tagged fish were particularly helpful in providing a degree of validation for older fish.

(iv) The third set of age determinations contained a high proportion of older fish. There was evidence that the discussion sessions had helped to improve the degree of agreement. If the age range used in assessments was to be extended to cover age-groups 0-14 and 15+, the results from the third data set suggest that the relia- bility of ageing for fish older than ten years should be as good as that for the younger fish.

(v) If the Mackerel Working Group considers that there would be advan- tages in having an extended age range for assessment purposes it is recommended that ageing is extended to cover age-groups O to 14 with a 15+ group for fish of age 15 and older.

8.   REFERENCE

Dawson, W. A., 1986. Analysis of the Mackerel (Scomber scombrus L.) Otolith Exchange Programme. I.C.E.S. C.M. 1986/H:25, 20 PP• (mimeo).

Table 1. Sa1ple 1 : *Aqe* deter1inations 1ade dur1ng the Workshop and during the otolith exchange.

REF.NO.	LENSTH	ASE !IIORKSHOP1							ABE IEXCHANSE1						
		ENGLAND	SERHANY	IRELAND	SCOTLAND	N'LAND	NORIIAY	DENHARK	ENGI.ANO	GERHANY	IRELAND	SCOTLAND	N'LANO	NORWAY	OENHARK
1	36	b	b	b	6	b	b	6	b	b	b	b	b	b	4
2	43	14	17	14	lb	17	13	13	13	1S	13	14	17	13	12
3	41	9	10	9	9	9	9	B	9	9	9	10	10	9	11
4	41	8	9	10	9	8	8	6	8	8	8	10	11	8	6
5	37	b	b	b	6	b	b	11	5	5	b	b	6	5	5
b	36	4	5	4	5	4	4	5	4	4	4	4	5	4	4
	38	8	B	8	7	8	8	7	8	8	8	B	9	9	7
8	40	10	10	10	10	10	10	11	10	10	10	10	10	10	9
9	42	10	11	10	9	10	10	7	8	10	10	11	11	B	7
10	37	8	8	8	10	B	8	B	8	8	8	8	B	B	7
11	38	b	b	b	6	b	6	5	b	5	6	6	6	5	5
12	37	5	5	5	5	5	5	3	5	S	5	5	b	S	5
13	41	7	7	b	b	7	6	B	6	6	b	6	b	6	7
14	41	11	12	10	11	11	10	b	8	9	12	10	12	10	9
15	39	b	b	b	6	6	b	7	6	b	6	6	b	b	b
lb	39	8	9	8	9	9	B	6	9	8	9	9	9	8	7
17	39	7	7	7	7	7	7	7	7	7	7	7	7	6	6
18	39	8	8	8	8	9	8	7	8	8	8	9	9	9	7
19	39	9	9	10	9	9	9	9	9	9	10	9	9	9	8
20	39	5	5	5	5	5	5	5	5	5	b	S	S	4	6
21	37	5	5	5	5	5	5	5	5	S	5	S	S	5	4
22	39	7	7	7	b	7	b	7	6	b	7	7	7	7	6
23	39	7	7	8	8	8	7	6	8	8	7	7	8	7	b
24	40	7	7	7	7	B	7	7	7	7	10	8	8	7	7
25	41	11	11	11	11	11	10	10	10	10	7	11	11	9	8
2b	37	4		4	5	5	4	b	4	S	3	4	1	2	3
27	41	10	10	9	9	10	9	11	10	10	10	11	10	10	9
28	37	5	5	5	5	5	5	4	5	5	5	S	5	5	4
29	39	11	12	11	11	13	10	9	11	13	11	12	12	10	10
30	39	b	b	b	b	6	b	b	6	b	b	6	b	b	5
31	41	10	q	9	9	9	9	B	10	9	9	9	9	9	8
32	37	3	3	4	4	4	5	3	3	b	4	4	4	5	5
33	38	b		b	8	8	7	4	5	7	7	8	8	7	4
34	41	11	9	10	10	12	11	10	11	11	11	11	11	11	11
35	42	13	11	13	12	15	13	12	11	13	15	14	14	13	11
3b	41	9	15	8	9	9	9	7	9	9	9	9	9	10	8
37	38	11	11	10	11	11	11	9	11	10	11	11	11	11	9
38	H	12		8	7	11	10	4	8	10	10	11	11	10	B
39	37	b	b	b	5	b	6	5	b	b	6	6	6	b	b
40	37	4	4	4	4	4	4	4	4	4	6	4	4	4	4

REF. NO.	LENGTH	ASE !NDRKSHOPl							ABE !EXCHANSEI						
		ENGLAND	GERHANY	IRELAND	SCOTLAND	N'LAND	NORNAY	OENHARK	ENGLAND	GERHANY	IRELAND	SCOTLAND	H'LAND	NDRWAY	DENHARK
41	40	9	9	9	9	9	9	8	9	9	9	9	9	9	8
42	40	9	9	11	9	9	9	4	8	B	9	9	9	9	7
43	45	15	14	14	14	14	15	12	10	10	lb	15	14	15	15
44	42	∥	12	10	12	12	10	10	9	11	10	12	11	9	9
45	44	13		lO	12	11	11	7	8	11	12	13	13	9	7
46	38	8	9	8	8	8	8	7	8	8	8	9	8	8	8
47	37	6	6	6	6	b	b	ó	6	6	6	b	6	6	6
48	40	10	11	11	11	11	11	10	9	10	10	11	11	11	9
49	36	8	8	7	7	8	7	7	7	8	8	B	8	B	7
50	40	∥	11	11	11	11	11	10	10	10	11	11	11	10	10
51	36	5	6	5	5	5	5	5	5	5	ó	5	5	5	5
52	35	4	5	4	5	4	4	4	4	4	5	4	4	4	4
53	36	5	5	6	b	8	5	4	4	b	5	B	5	5	4
54	38	6	6	6	6	6	6	ó	ó	6	7	6	6	6	6
55	40	∥	11	10	11	11	10	10	10	11	11	11	11	9	11
56	40	11	11	10	11	12	9	8	9	11	12	10	12	10	10
57	37	5	5	5	5	5	5	4	5	5	4	5	S	5	4
58	36	9	10	10	10	11	10	8	10	10	9	11	11	10	9
59	40	∥	12	15	12	11	10	9	11	11	13	12	13	12	11
60	36	S	8	S	b	7	6	ó	5	&	8	6	7	6	5
61	36	7	8	7	8	8	8	6	7	8	B	B	8	8	8
62	35	3	4	4	4	3	4	4	3	4	4	4	4	3	3
63	41	7	8	8	7	8	7	8	7	7	7	B	8	8	b
64	36	S	5	6	S	5	5	5	5	5	5	5	5	5	5
65	37	5	5	6	5	5	5	5	5	5	5	6	5	5	4
b6	37	b	8	8	b	8	7	6	ó	7	7	8	B	7	3
67	33	3	3	3	3	3	3	3	3	3	3	3	3	3	3
68	39	7	7	7	7	7	b	7	b	5	b	B	7	7	5
69	37	4	4	4	4	4	4	4	4	4	4	4	4	4	3
70	40	8	9	8	9	9	8	7	ó	7	8	9	9	7	7
71	37	5	6	6	6	b	5	5	5	5	5	b	6	5	5
72	41	6	6	6	b	b	6	7	ó	6	b	6	ó	6	7
73	43	13	14	13	14	14	13	12	∥	10	12	13	14	13	9
74	37	5	6	5	b	6	b	7	b	6	ó	6	6	6	5
75	36	5	5	6	5	5	6	6	5	5	5	5	5	6	5
76	43	6	6	10	7	b	7	11	7	7	ó	7	7	7	6
77	43	11	12	14	12	12	12	12	11	11	11	12	12	11	11
78	43	10	10	11	10	11	10	10	∥	10	9	10	10	10	9
79	5	4	5	5	4	5	4	4	4	4	4	4	4	4	5
80	38	6	b	7	b	b	6	6	6	6	6	b	6	6	6

Table l lt:ontinuedl

REF.NO.	LENGTH	ASE !WORKSHOP1							ASE !EXCHAN6E1						
		EN6LAND	6ERHANY	IRELAND	SCOTLAND	N'LAND	NORWAY	DENMARK	ENGLAND	GERHANY	IRELAND	SCOTLAND	N'LAND	NDkWAY	DENHARK
81	3S	2		3	2	2	2	3	2	2	2	3	2	2	2
82	39	9	10	12	10	10	10	b	8	9	8	10	10	7	7
83	34	4	4	5	4	4	4	S	4	4	4	4	4	4	4
84	37	10	10	10	10	10	10	9	9	10	10	10	10	10	9
8S	40	9	9	9	9	9	9	B	9	8	9	9	9	9	9
86	36	5	5	5	5	5	5	S	5	5	5	5	S	5	5
87	34	b	5	5	5	5	6	5	b	5	b	5	5	b	b
88	38	8		8	8	10	8	7	8	8	7	8	8	8	7
89	34	8	8	B	B	8	8	4	6	7	8	8	8	8	7
90	0	6	b	b	b	b	b	7	b	b	b	b	b	6	b
91	35	5	S	5	5	5	5	5	5	5	S	5	S	5	4
92	37	9	9	B	9	9	9	9	8	8	8	9	9	10	8
93	40	10	11	9	11	11	11	10	10	11	10	11	11	11	14
94	43	10			15	16	11	1S	11	10	!S	lb	lb	12	S
9S	38	8	9	8	9	8	B	6	B	8	8	B	8	B	5
9b	39	8	9	8	9	B	9	7	8	8	B	9	8	9	b
97	36	4	4	4	4	4	4	3	4	4	3	4	4	4	3
98	40	11		10	13	13	11	11	11	10	11	13	12	12	10
99	31	3	3	3	3	3	3	3	3	3	3	3	3	3	3
100	33	4	4	4	4	4	4	2	4	4	4	4	4	4	3
101	30	1	1	2	1	1	1	1		1	1	1	1	▌	1
102	38	b	b	b	7	6	b	b	b	6	b	b	b	b	5
103	31	4	5	5	5	5	4	2	4	5	5	b	S	4	3
10	35	b	6	b	6	b	6	S	S	b	b	b	b	b	:,
JOS	39	10		9	JO	11	9	9	8	9	8	11	10	7	‖
JOb	41	9	10	10	11	10	10	9	9	8	9	10	10	8	7
107	38	4	4	b	5	5	4	4	4	5	5	6	4	4	3
108	31	4	4	3	4	4	4	2	4	4	3	4	4	3	3
109	30	2	3	3	3	2	3	2	3	2	2	3	3	3	2
110	36	5	5	5	5	5	5	5	S	5	5	5	5	5	4
111	41	10	10	15	10	10	10	10	10	10	10	10	10	B	10
112	38	S	S	5	6	S	5	S	S	5	5	5	5	S	S
113	41	8	8	7	8	9	9	7	B	B	8	8	8	8	b
114	39	5	b	b	b	b	6	S	b	5	6	6	6	b	S
11S	38	8	7	7	8	8	9	8	9	8	8	8	8	9	9
116	38	5	4	5	5	5	S	9	4	5	5	5	S	5	4
117	40	11	13	8	11	13	12	10	11	10	12	13	13	11	9
118	44	10	11	9	10	11	10	10	10	10	9	10	11	10	9
119	39	b	b	b	6	b	6	5	b	6	b	6	b	b	5
120	42	8	9	8	9	9	B	8	B	8	9	9	9	9	7

Table 1 (continuedl

REF. NO.	LENSTH	AGE lWORKSHOPl							ASE (EXCHAN6El						
		ENSLAND	SER"ANY	lRELAND	SCOTLAND	N'LAND	NORWAY	DENHARK	ENSLAND	GER"ANY	lRELAND	SCOTLAND	N'LAND	NORNAY	DENHARK
121	43	9		10	10	11	10	8	9	9	10	10	12	10	9
122	42	10	12	10	13	13	12	13	10	13	12	13	13	12	10
123	39	10	11	11	11	11	11	10	11	11	12	11	11	11	10
124	37	4	4	4	4	5	5	4	4	4	5	4	5	4	4
125	40	7	11	7	11	10	10	8	9	10	8	11	11	10	8
12b	40	11		9	11	13	10	9	9	10	12	11	13	9	B
127	39	8	9	8	9	9	9	10	9	8	9	9	9	9	B
128	41	8	8	8	8	B	B	8	B	8	8	8	8	B	9
129	37	S	5	5	5	5	5	5	5	5	5	S	5	S	5
130	44	13	15	15	14	15	15	15	15	14	15	15	15	IS	11
131	38	b	b	b	b	b	b	b	b	b	7	b	b	b	b
132	43	10	10	10	10	14	10	11	11	13	14	14	13	11	10
133	41	9		B	10	10	10	10	9	lO	10	10	12	9	10
134	39	9	11	9	10	11	11	12	10	10	11	11	11	10	10
135	41	11	13		14	13	11	9	12	11	12	14	14	9	11
13b	38	4	S	S	S	5	5	11	S	S	5	5	5	4	4
137	42	10	11	10	11	13	10	8	10	10	9	11	11	13	9
138	38	b		8	11	10	10	b	7	10	8	11	10	9	7
139	39	S	5	5	S	5	5	5	5	5	S	5	5	4	3
140	3b	7	8	8	8	8	8	8	8	7	7	B	8	7	7
141	35	10	11	10	11	11	11	10	11	11	12	11	11	11	10
142	34	4	4	4	4	4	4	4	4	S	4	4	4	4	4
143	3b	4	4	4	4	4	4	4	4	4	4	4	4	4	3
144	3b	4	4	4	4	4	4	4	4	4	4	4	4	4	4
145	41	7	8	8	9	8	9	9	B	9	8	9	9	B	B
14b	38	4	5	5	S	5	5	5	3	5	4	5	5	4	4
147	37	5	5	5	S	5	S	5	5	5	5	5	5	5	4
148	41	9	12	10	10	14	11	12	10	11	10	13	14	11	11
149	39	7	7	7	7	B	7	7	7	7	7	7	8	7	b
150	37	5	S	b	b	b	b	5	S	5	5	b	b	b	4
151	43	9	10	10	10	10	10	10	10	9	11	10	10	10	8
152	40	4	S	5	S	4	5	5	4	5	5	5	!i	4	4
153	40	11	11	11	11	11	10	11	11	11	12	11	11	11	10
154	41	8	10	9	10	10	9	9	9	10	9	10	10	9	7
155	37	4	5	b	S	5		4	4	S	4	S	5	4	4
1Sb	3S	10			14	13		11	11	10	11	12	13	14	11
157	37	9	9	9	9	9	9	B	9	9	7	9	9	9	7
1S8	38	4	5	5	4	5	5	4	4	4	5	4	5	4	4
159	40	7	8	8	8	8	8	7	8	B	8	8	8	8	7
160	39	b	7	7	B	B	8	7	7	8	8	8	8	B	b

Jable 1 lcontinuedl

REF. NO.	LENSTH	ASE IWDRKSHOPl							ASE !EXCHANSEl						
		ENSLAND	6ERHANY	IRELAND	SCOTLAND	N'LAND	NORWAY	DENHARK	ENSLAND	SERHANY	IRELAND	SCOTLAND	N'LANO	NORWAY	DENMRK
161	37	ó	ó	ó	ó	ó	S	b	ó	ó	ó	b	ó	ó	S
162	37	S	b	ó	S	b	b	4	5	S	4	ó	5	4	3
	37	ó	b	b	b	b	o								
164	41	8	9	9	8	8	9	8	9	B	8	8	9	8	7
lbS	36	4		5	5	S	6	ó	5	5	5	S	5	b	4
166	34	4	4	4	4	4	4	4	4	4	4	4	5	4	4
167	34	6	B	4	B	8	ó	6	ó	8	9	9	8	8	5
168	41	B	8	B	8	8	8	8	8	B	B	8	B	8	7
169	41	8	9	B	B	9	B	7	9	9	8	9	9	B	4
170	41	9	10	11	10	10	10	9	9	10	9	10	11	10	9
171	39	7	7	7	9	9	B	9	b	B	7	9	9	6	6
172	39	B	9	B	9	B	9	9	7	9	B	9	9	7	8
173	40	B	9	9	9	9	9	B	9	9	8	9	9	9	8
174	37	6	7	7	7	7	7	6	6	7	6	7	7	7	6
17S	39	10	11	11	11	12	10	12	10	10	10	12	12	10	9
176	36	4	4	4	4	4	4	3	4	4	4	11	4	4	3
177	38	11	12	8	12	13	B	4	11	10	11	4	13	13	9

Table 2   Frequency distributions of differences in age determinations between the otolith exchange and the Workshop

Age difference (Exchange-Workshop)	Scotland	Norway	Ireland*	Netherlands FREQUENCY	Denmark	Germany*	England	Total
-10					1			1
- 9								
- 8								
- 7					1			1
- 6					1	1		2
- 5			1		1		2	4
- 4			3	1	1	2	1	9
- 3		1	1	1	7	2	1	13
- 2	3	10	8	2	13	6	9	51
- 1	12	27	34	13	58	45	21	210
0	125	119	80	138	58	90	111	721
1	28	15	28	18	21	12	30	152
2	6	2	12	3	6	2	2	33
3	1	1	4	1	5	2		14
4	2		2		2			6
S		1	1		1			3
N	177	176	174	177	177	162	177	1220

* Different readers in otolith exchange and Workshop

Table 3 Per entage frequency distributions of differences in age determinations between the otolith exchange and the Workshop subdivided into fish of average ages less than eleven and eleven and older (Sample 1)

Age difference Exchange-Workahop	Average age 0-10 Percentage frequency							Average age 11 or older Percentage frequency						
	Scotland	Norway	Ireland*	Netherlands	Denmark	Germany"'	England	Scotland	Norway	Ireland"'	Netherlands	Denmark	Germany"'	England
−10												3.7		
− 9														
− 8														
− 7					0.7									
− 6					0.7	0.7								
5			0.7	.−	1.3	−						−		7.4
− 4			2.0	0.7	−	−	0.7					3.7	8.7	
− 3		0.7	−	0.7	2.7	0.7	0.7			4.2		11.1	4.4	
− 2	0.7	5.3	4.7	1.3	8.7	2.9	4.0	7.4	7.7	4.2		−	8.7	111
− 1	7.3	14.7	20.7	4.7	n.7	26.6	12.0	3.7	19.2	12.5	22.2	33.3	348	11.1
0	74.7	70.0	50.0	80.0	34.7	61.2	66.7	48.2	53.9	20.8	66.7	22.2	217	40.7
1	14.0	7.3	14.0	11.3	12.0	7.2	15.3	25.9	15.4	29.2	3.7	11.1	8.7	25.9
2	2.7	.0.7	4.7	0.7	2.7	−	0.7	7.4	3.9	20.8	7.4	7.4	8.7	3.7
3	−	0.7	2.7	0.7	2.7	0.7		3.7		−		3.7	4.4	
4	0.7	−	−		0.7			3.7		8.3		3.7		
5		0.7	0.7		0.7									

* Different readers in otolith exchange and Workshop

Table 4   Details of otoliths from recaptured tagged fish

Number	Release			Recapture			Period at liberty (years)	Concensus age
	Time	Division	Length (cm)	Time	Position	Length (cm)		
1	May 1977	Vllj	?	Jul 1982	Ila	40	S	8
2	May 197S	IVa	27	Sep 1982	IVa	42	7	9
3	Aug 1980	lila	31	Aug 1982	IVb	36	2	4?S
4	Jul 1978	IVa	3S	Dec 1982	Vla	39	4	6?7
S	Aug 1975	IVb	30	Jul 1984	Ila	41	9	12?11?10
6	May 1979	Vllj	38	Aug 1984	Ila	43	5	14?15
7	Jul 1978	IVa	41	Oct 1984	IVa	43	6	14?15

Table S   Sample 1: Age determinations made during the \ orkshop   (W)and the otolith exchange (E)of a selected subsample, and the concensus ages agreed after discussion

Ref. No.	Ages by individual readers														Average of all individual age determinations	Concensus age after discussion
	England		Germany*		Ireland*		Scotland		Netherlands		Norway		Denmark			
	W	E	W	E	l_i	E	W	E	l_i		W	E	W	E		
1	6	6	6	6	6	6	6	6	6	6	6	6	6	4	S.9	6
2	14	13	17	15	14	13	16	14	17	17	13	13	13	12	14.4	1S?
3	9	9	10	9	9	9	9	10	9	10	9	9	8	11	9.3	9?
5	8	8	9	8	10	8	9	10	8	11	8	8	6	6	8.4	9?8
7	6	S	6	S	6	6	6	6	6	6	6	5	11	S	6.1	6
8	4	4	5	4	4	4	5	4	4	5	4	4	5	4	14.3	4
9	8	8	8	8	8	8	7	8	8	9	8	9	7	7	7.9	8
10	10	10	10	10	10	10	10	10	10	10	10	10	11	9	10.0	10
11	10	8	11	> 9	10	10	9	11	10	11	10	8	7	7	9.4	11
12	8	8	8	8	8	8	10	8	8	8	8	8	8	7	8.1	8
13	6	6	6	5	6	6	6	6	6	6	6	5	5	5	5.7	6
14	5	S	5	S	S	5	5	5	5	6	5	S	3	5	4.9	5
16	7	6	7	6	6	6	6	6	7	6	6	6	8	7	6.4	6?7
17	11	8	12	9	10	12	11	10	11	12	10	10	6	9	10.1	11?10
18	6	6	6	6	6	6	6	6	6	6	6	6	7	6	6.1	6
27	7	7	7	7	7	10	7	8	8	8	7	7	7	7	7.4	7?8
29	4	4	-	5	4	3	S	4	5	-	4	2	6	3	4.1	4?5
32	11	11	12	13	11	11	11	12	13	12	10	10	9	10	11.1	11?12
35	3	3	3	6	4	4	4	4	4	4	S	S	3	S	4.1	4?5
36	6	5	-	7	6	7	8	8	8	8	7	7	4	4	6.5	7?8
39	13	11	11	13	13	15	12	14	15	14	13	13	12	11	12.8	15
48	1S	10	14	> 9	14	)15	14	15	14	14	1S	1S	12	IS	13.8	1S?

* Different readers in otolith exchange and Workshop

Table *b.* SAHPLE 2 : Aaes determined durlng the Workshop.

REF. NO.	LENGlH	AGE (WORKSHOP>							HAX.	HIN.	RANGE	AV. AGE
		ENGLAND	GERHANY	IRELAND	SCOTLANO	N'LANO	NORWAY	DENHARK				
	4(1	6	*b*	6	*b*	6	*b*	*b*	*b*	*b*	0	6.00
2	41	8	B	8	B	8	8	7	B	7		7.86
3	41	11	10	10	10	10	10	1(1	11	10		10.14
4	42	12	11	11	12	12	11	11	12	11		11.43
5	42	17	16	16	17	17	*lb*	*lb*	17	16		16.43
6	43	12	12	12	12	12	12	11	12	11		11.86
7	43	15	12	12	12	12	12	11	15	11	4	12.29
B	43	13	13	12	13	13	11	12	13	11	2	12.43
9	44	11	11	11	11	11	11	11	11	11	(I	11.00
10	46	11	11	1(1	11	12	11	9	12	9	3	1(1.71
11	44	15		13	14	14	14	12	15	12	3	13.67
12	44	14	13	12	13	13	13	12	14	12	2	12.86
13	44	14	14	13	14	14	14	13	14	13	1	13.71
14	43	13	13	11	12	12	12	12	13	11	2	12.14
15	42	9	9	8	9	9	9	9	9	8		8.86
lb	42	*lb*		14	16	16	15	15	16	14	2	15.33
17	43	13	14	12	12	12	12	14	14	12	2	12.71
lB	45	15	15	14	15	15	15	15	15	14	1	14.86
19	43	16	15	15	15	15	14	14	16	14	2	14 Bb
20	45	17	15	15	*l b*	16	15	15	17	15	2	15.57
21	39	7		7		7	7	7	7		(1	7.(1(1
22	4(1	12	10	9	9	10	9	10	12	9	3	9.86
23	40	11	11	10	11	11	9	9	11	9	2	10.29
24	40	12	8	10	10	10	9	J(1	12	8	4	9.86
25	40	14	14	13	13	13	13	13	14	13		13.29
26	39	6	6	5	6	7	6	7	7	5	2	6.14
27	39	8	7	7		7	8	8	B			7.43
28	39	11	10	10	11	11	11	10	11	10		10.57
29	47	19		16	16	16	17	15	19	15		16.50
30	40	16		15	13	16		10	16	10	6	14.00
31	41	13	13	14	13	13	13	14	14	13		13.29
32	40	1(1	10	9	10	10	10	12	12	9	3	10.14
33	43	12	10	9	10	11		12	12	9	3	10.67
34	43	12	12	12	13	12	13	13	13	12		12.43
35	35	6	5	4	5	5	4	5	6	4	2	4.8b

lable *b* (Continued).

REF. NO.	LENSTH	ASE (WORKSHOP)							tiAX.	KJN.	RANSE	AV. ASE
		ENSLAND	GERMANY	lRELAND	SCOTLAND	N'LANO	NORWAY	DENIIARK				
36	3B	B	LO	9	LO	10	10	10	JO	B	2	9.57
37	43	13	Ll	!L	11	11	11	12	13	11	2	11.43
3B	43	12		16	lb	lB	14	11	lB	11	7	14.50
39	45	17	lB	15	lB	16	15	11	lB	11	7	15.71
40	41	11	11	9	11	11	10	a	1í	a	J	Hi.H
41	35	10	10	10	10	1(1	10	10	1(1	10	0	10.00
42	43	12	11	9	11	12	12	12	12	9	3	11.29
43	34	4	5	5	5	5	S	5	5	4	1	4.Bb
44	40	17		16	19	17	12	17	19	12	7	16.33
4S	3B	8	7	7	7	7	7	10	10	7	.J'	7.57
46	43	19	16	!S	18	15	14	17	19	14	S	16.29
47	44	12	15	!S	15	16	12	17	17	12	S	14.57
48	43	1S	15	15	16	15	15	16	16	15	1	15.29
49	39	10	10	9	10	10	10	14	14	9	5	10.43
SO	38	11	10	9	10	10	10	10	11	9	2	10.00
51	44		12	14	13	12	12	14	14	12	2	12.83
52	44	15		15	12	16	14	lB	lB	12	6	15,10
53	40	13	13	12	14	14	10	13	14	10	4	1271
54	3B	14	13	14	14	14	14	13	14	13	1	13.71
55	39	10	11	1(1	11	11	11	11	11	10	1	10.71
56	37	7	7	7	7	7	7	7	7	7	0	7.00
57	37	6	6	6	6	6	6	6	6	b	(1	6.00
58	37	14	13	12	13	14	14	14	14	12	2	13.43
59	41	14	14	14	14	14	14	14	14	14	0	14.00
60	41	13	14	lB	13	13	13	14	lB	13	S	14.00
61	32	3	3	3	3	3	3	3	3	3	0	3.00
62	39	12	12	11	13	12	12	10	13	10	3	11.71
63	35	10	11	10	11	11	11	7	11	7	4	10.14
64	39	6	6	6	6	6	6	6	b	6	(1	6.00
65	42	10	11	10	11	11	11	10	11	10	1	10.S7
66	37	7	7	6	7	7	7	6	7	6	1	6.71
67	38	6	6	6	6	6	b	6	6	6	(i	6.00
68	36	B	7	7	7	B	7	B	B	7	1	7.43
69	32	3	3	3	3	3	3	3	3	3	(1	3.00
70	3B	11	11	10	11	11	11	9	11	9	2	10.57

Table 7 Standard deviations of age determina-
         tions for Sample 1

Country	Workshop	Otolith exchange
Scotland	2.90	3.01
Norway	2.65	2.78
lreland	2.67	2.87
Netherlands	3.13	3.16
Denmark	2.73	2.57
Germany	2.92	2.61
England	2.71	2.56
	2.83	2.83

Table 8   Results of scoring each otolith according to the number of
          disagreements from the modal age at each reading session

| | Sample 1 | | Sample 2 |
	Otolith exchange	'-lorkshop	'-lorkshop
Number of otoliths	177	177	70
Disagreement score	0.35	0.33	0.27

N.B. The disagreement score covers the range zero (= total
      agreement) to 0.86 (= total disagreement)

Table 9   Percentage frequency distribution of the standard deviations of the age determinations for each otolith sample

Standard deviation (midpoint)	Sample	Otolith exchange Sample 1		Workshop Sample 1		Workshop Sample 2	
		Age <;10	Age 10	Age <10	Age >10	Age <;10	Age >10
0.0		9.2	4.0	16.9	0.0	32.1	4.8
0.5		63.8	24.0	46.6	24.1	35.7	38.1
LO		17.1	24.0	23.0	27.6	25.0	31.0
1.5		8.6	40.0	6.1	20.7	7.1	7.1
2.0		0.0	0.0	4.7	24.4	0.0	9.5
2.5		1.3	4.0	1.4	3.4	0.0	9.5
3.0		0.0	0.0	14	0.0	0.0	0.0
3.5		0.0	4.0	0.0	0.0	0.0	0.0
n		152	25	148	29	28	42

Table 10   Functional linear regressions of age determinations. Sample 1 - Workshop readings

y		X	Scotland	Norway	Ireland	Netherlands	Denmark	Germany	England
Scotland	Slope	-	-	1.026	1.016	0.967	1.077	0.982	1.054
	Intercept	-	-	-0.022	-0.004	0.058	0.055	0.035	0.008
Norway					0.990	0.943	1.050	0.958	1.027
					0.017	0.078	0.074	0.055	0.029
Ireland						0.952	1.060	0.967	1.037
						0.061	0.058	0.038	0.012
Netherlands							1.114	1.016	1.090
							-0.004	-0.024	-0.052
Denmark								0.912	0.978
								-0.018	-0.043
Germany									1.072
									-0.027

Table 11 Functional linear regressions of age determinations. Sample 2 – Workshop readings

y		X	Scotland	Norway	Ireland	Netherlands	Denmark	Germany	England
Scotland	Slope	–		1.044	1.053	1.006	1.028	1.013	0.984
	Intercept	–		−0.066	0.016	−0.051	−0.018	−0.022	−0.004
Norway					1.008	0.963	0.985	0.970	0.942
					0.079	0.015	0.046	0.042	0.059
Ireland						0.955	0.976	0.962	0.934
						−0.064	−0.032	−0.036	−0.019
Netherlands							1.022	1.007	0.978
							0.033	0.029	0.046
Denmark								0.985	0.957
								−0.004	0.013
Germany									0.971
									0.018

Figure 1. Ranges of ages determined at the Workshop for otoliths in Sample 1. Each line represents a single otolith and connects the maximum and minimum values of the age determinations
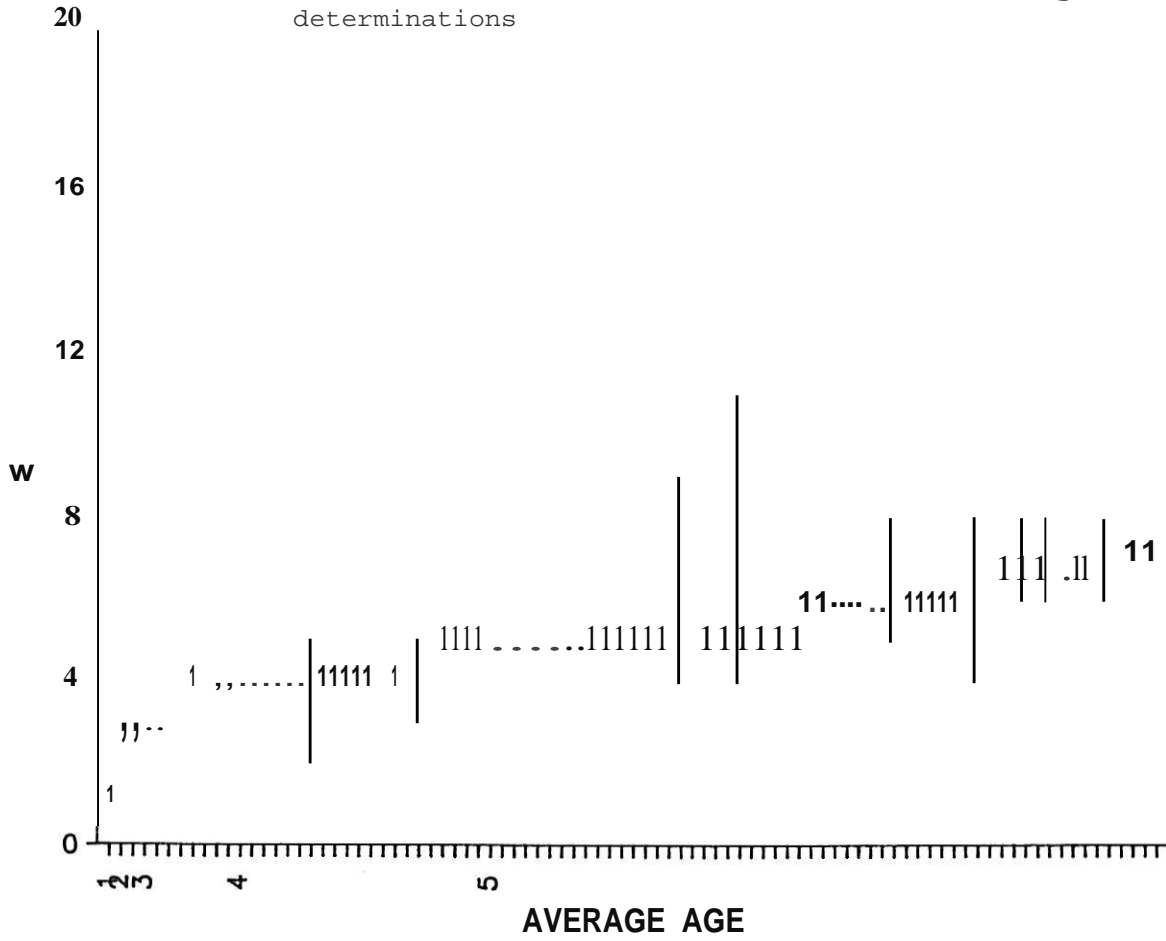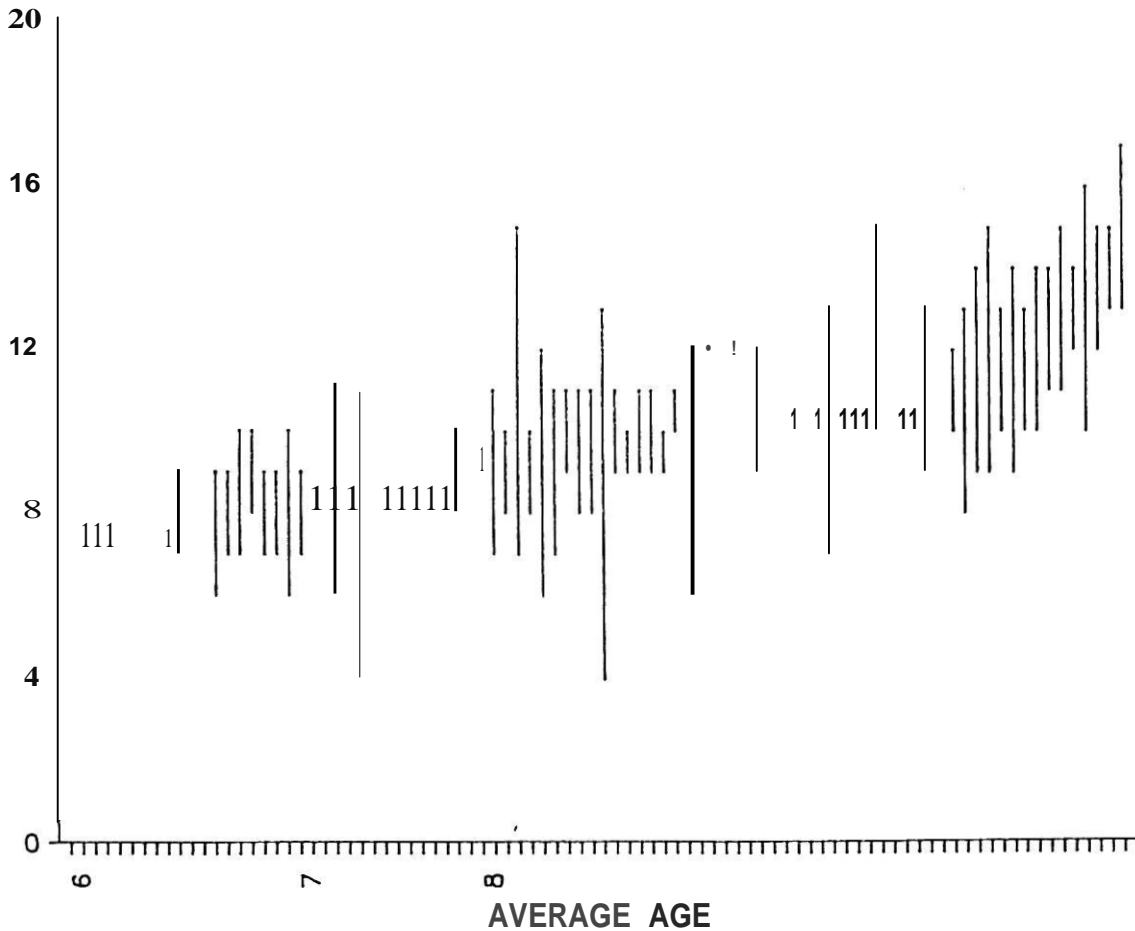
Figure 1 (continued)

Figure 2. Ranges of ages determined for otoliths in Sample 2. Each line represents a single otolith
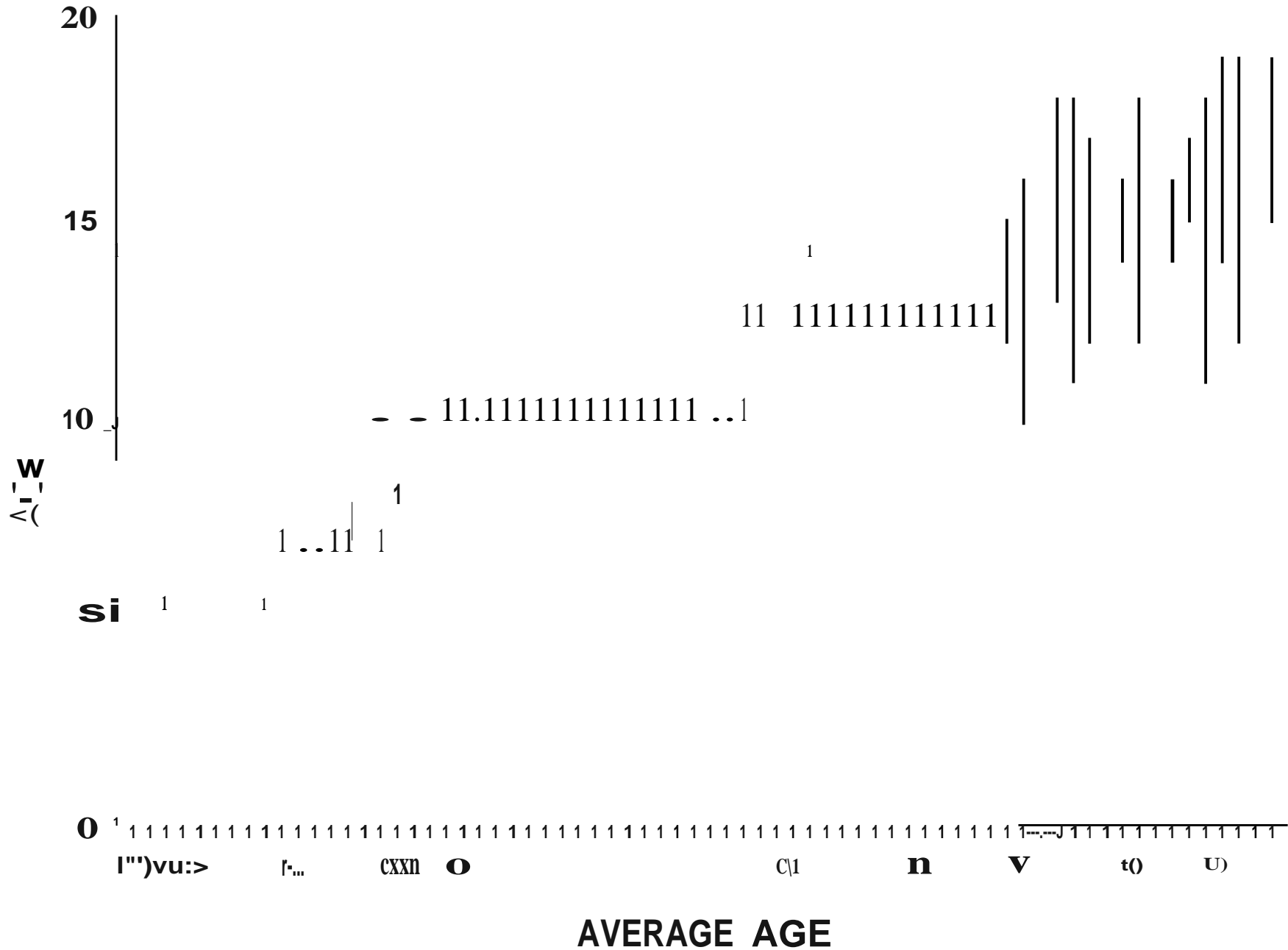and connects the maximum and minimum values of the age determinations

SAMPLE 2

AVERAGE AGE

Figure 3. Age ranges for each otolith plotted as percentage frequency distributions for Sample 1 (Workshop) and Sample 2
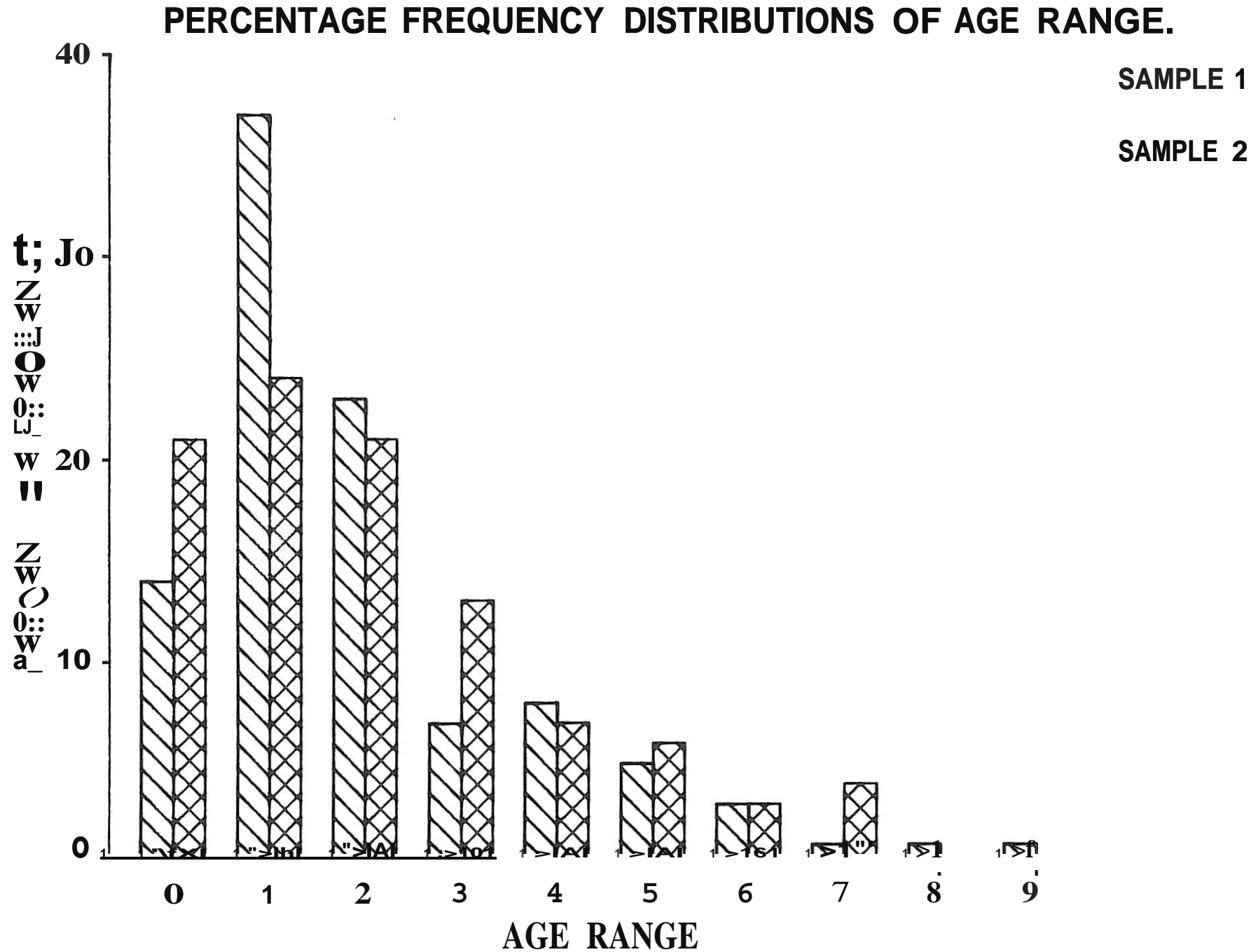
PERCENTAGE FREQUENCY DISTRIBUTIONS OF AGE RANGE.

SAMPLE 1

SAMPLE 2

AGE RANGE

Figure 4. Percentage frequency distributions of the standard deviations of the age determinations *for* each otolith sample. Data from Table 9.
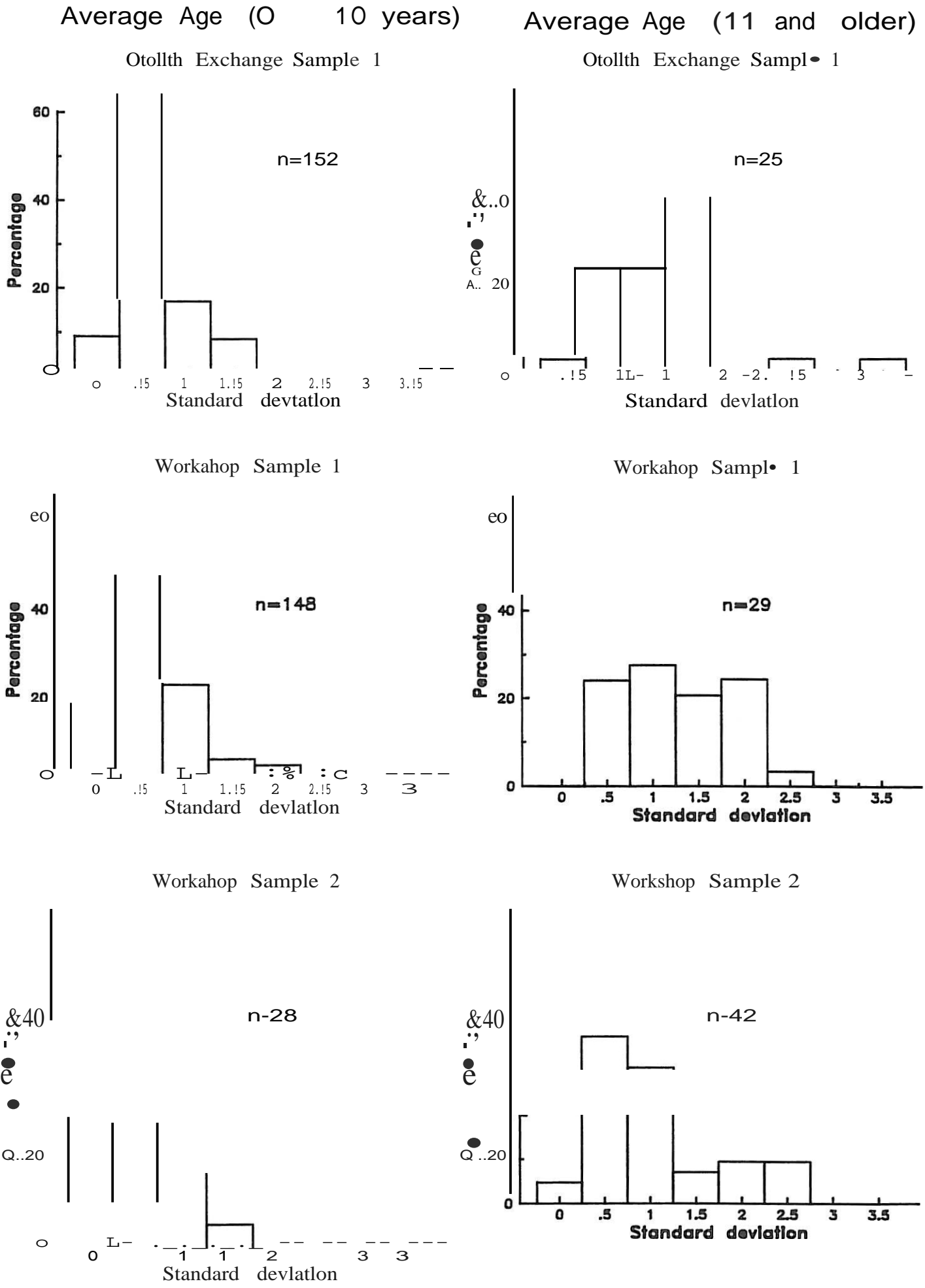
Figure 5.   Mean age drrecence ot WorKsnop Sarnple 2 oeween all   countries
participating in the otolith workshop.