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RESULTS OF A BLINDFOLD TEST ON BALTIC SALMON (Salmo salar L.) SCALE READING

by

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Abstract

This paper describes the results of a blindfold test in which the accuracy of Baltic salmon scale reading was tested. Scale readers from Estonia, Finland, Latvia, Poland, Russia and Sweden participated in the test. Using scales of known origin, it was found that 62 - 84 % of the fish were classified correctly by origin (hatchery-reared or wild). The proportion of correct determinations of the age of fish was 41 - 77 %. Classification of a catch sample from the Baltic Main Basin also showed considerable heterogeneity between scale readers, in both determination of fish age and origin. Means of improving the scale reading skills of Baltic salmon scale readers are briefly discussed.

1. Introduction

In accordance with a recommendation made at the Baltic Salmon and Trout Assessment Working Group meeting in 1992, a blindfold test in scale reading was started in autumn 1992. The aim of the test, which is being coordinated by the Finnish Game and Fisheries Research Institute (FGFRI), is to check the accuracy of ageing and of determination of origin (hatchery-reared or wild) of Baltic salmon in laboratories involved in Baltic salmon scale reading.

2. Material and methods

To obtain sufficiently diverse test material, scale samples were requested from the major laboratories carrying out Baltic salmon scale reading in addition to those collected by the FGFRI.

The scale material for the test thus consisted of 418 scale samples from the following countries and salmon stocks:

Finland (all fish Carlin-tagged)
- River Simojoki (Sub-division 31), wild, from smolt traps, n = 48
- River Oulujoki/Montta (Sub-division 31), hatchery-reared, n = 27
- Kvistforsen (hatchery-reared stock from Sweden, stocked in Finland, Sub-division 31), n = 25

Latvia (Sub-division 28)
- Rivers Daugava and Salaca, hatchery-reared, n = 36
- River Salaca, wild, n = 24
- the determination of origin of wild salmon from Latvia was not completely reliable, as it was determined by the presence or absence of the adipose fin, and in some cases substantially less than 100% of the hatchery-reared salmon had had their adipose fin clipped; therefore the scales of River Salaca wild salmon were omitted from the test

Sweden
- River Mörrum (Sub-division 25), wild , Carlin-tagged, from smolt traps, n = 49
- River Mörrum, hatchery-reared, Carlin-tagged, n = 54
- River Ume (Sub-division 31), wild, n = 22
- River Ume, hatchery-reared, n = 33
- River Ume samples were caught in a trap for ascending spawners; all reared fish had had their adipose fin clipped, not tagged
- one catch sample from the Baltic Main Basin (Sub-division 28) origin not known, n = 100

Only scales of the Carlin-tagged fish were used to check the accuracy of ageing.

Plastic impressions were made of the scales if this had not already been done. The scales and impressions were stored in standard FGFRI paper scale bags giving the following information, when available: total length of fish, weight of fish (round or gutted) and date of capture. Information on fishing locality and gear was intentionally left out to avoid giving the readers clues about the origin of the fish. The scale bags were assigned random numbers. The staff of the FGFRI who selected the scales, made the impressions and wrote the data on the bags did not participate in the test.

The test scales were sent to participants together with a covering letter asking them to include the following information: the number of the scale bag, the origin of the fish and the age of the

fish (including the number and position of any spawning marks). They were also asked to determine the freshwater age of the fish they considered wild. The environmental conditions in fish hatcheries are such that determining the juvenile age of hatchery-reared fish is frequently problematic. The juvenile ages are not treated here, however, as the freshwater ages of wild fish in the test material were not known for certain, and in salmon fishery management it is sea age that is important.
The scale reading was done by the visual method, which distinguishes wild and hatchery-reared salmon by the structure of the freshwater zone of the scales (see Antere & Ikonen 1983).

The scales were read in Estonia, Finland, Latvia, Poland, Russia and Sweden .One country gave separate results for two readers; they are naturally treated separately. Another country gave the combined results of two readers; these are treated as one.

Note that most scale readers omitted one or more scales for various reasons (e.g. human error, lack of time). In addition, the results of two scale readers led us to suspect that, in some cases, the scales in a single scale bag were either from two or more different salmon individuals or from a sea or rainbow trout; these scales were omitted from the test. Thus, every scale reader has a personal N (N=number of scale readings) ,and the frequencies differ slightly from those given in a preliminary report of the results of this test (Ikonen et al. 1994).

3. Results and discussion

3.1. Classification of the origin of the fish

The initial results are listed in Table 1 for each reader and Sub-division as rightly (=OK) or wrongly classified fishes and as rightly or wrongly determined sea ages. Reader number 2 read only 100 scales, 40 of which were omitted because either their origin (e.g. Main Basin catch sample) or the number or species of fish from which the scales had been sampled were not known. Hence, the total N of reader 2 is 60 for the origin of fish but only 36 for the determination of sea age.

Tables 2 and 3 and Figures. 1-5 give the correct classification of fish in percentages by scale reader, fish category (r or w) and sub-division. The overall classification efficiencies are not very high, ranging from a total efficiency of c. 62% to c. 84%. The percentages for hatchery-reared fish are usually higher than for wild fish, indicating that scale readers found it difficult to recognise wild fish. Wild fish in Sub-division 31 seem to be identified correctly more readily than wild fish in Sub-division 25. This may be because the higher juvenile growth rate in the River Mörrum causes the freshwater zone of the scales to look more "hatchery-like". Moreover, the freshwater age of the River Mörrum fish is lower: a small proportion of the fish smoltify at the age of one year (Alm, 1928). It is conceivable that fish with only one river year could be wrongly classified as hatchery-reared more easily than those with two or more river years and with winter bands of closely spaced circuli between areas of faster summer growth.

X^2 tests were run to determine any differences between readers and the "readability" of scales of wild and hatchery-reared fish. The tests were run by SYSTAT for Windows™5.03. The results are given in Tables 4 and 5. As seen in Table 4, differences between readers were highly significant for wild fish, but not significant for reared fish in Sub-division 31. The differences in the readings for reared fish in Sub-division 25 seem significant, but the result is suspect due to the low expected frequencies. The data confirm that identification of hatchery-reared fish is more reliable.

Table 5 was obtained by comparing the differences in classification performances of fish of either wild or hatchery origin by different readers. The classification performances of most readers were significantly different for wild and hatchery-reared fish. According to Table 5, reader 2 classified wild and hatchery-reared fish similarly. This result is, however, questionable, owing to the small value of N (see Table 1). Reader 5 classified wild and hatchery-reared fish in Sub-division 31 similarly, and had rather small differences in the classification of fish in Sub-division 25.

The classification performances of individual readers stress the importance of looking at the overall "correctness" of the whole material examined, because, theoretically speaking, classification errors might balance each other out. The "evenness" of the classification, i.e. more or less equal misclassification percentages for both categories of fish, is also important. Two readers, numbers 2 (whose N value is small) and 5, classified hatchery-reared and wild fish more or less similarly, but the classification efficiency of reader 2 is about 44-76%, which is somewhat low.

3.2. Determination of the sea age of the fish of known origin

When the age determination results were calculated, age groups A.1 and A.1+,A.2 and A.2+, and A.3 and A.3+ were treated as single groups, and no comparisons were made concerning the consistency in reading the plus element (the +-growth).

The results of the determination of sea ages are given in Figures 6 and 7 and in Table 6 (initial data in Table 1). The overall results show that the sea age was determined correctly for 41-77% of the fish, depending on the reader. Fish in Sub-division 25 seem to be aged somewhat more accurately than fish in Sub-division 31, but the result is not quite statistically significant (Ttest by SYSTAT: T = 2.363, df = 6, prob. =0.056).

There is considerable disagreement between readers in determining the sea age of fish, in both Sub-divisions 25 and 31; the proportions of correct determination range from 37 % to 82 %. The heterogeneity X^2 values are 58.8*** and 35.4*** for Sub-divisions 25 and 31, respectively.

Figures 8 and 9 give the means of sea age determinations by reader for Sub-divisions 25 and 31, respectively. The numerical means and ranges of the sea age determinations are listed in Table 8, from which it is clear that all readers tend to give higher sea ages to fish in Sub-division 25. This may be related to the higher growth rate in that sub-division: perhaps readers subconsciously "create" annuli in scales of big fish with broad summer growth areas. It was also found that the sample fish in Sub-division 25 had a greater mean length than those in Sub-division 31 (Table 7); significant differences were found for 1- and 3-year-old fish (values of separate variances T were 2.933** and 3.612**, respectively). No significant differences were found for 2-year-old fish.

Figure 10 and Table 9 give the determined and true sea age distributions of the test material for each reader. The figures show the results of the reading exercise in a "practical" way, i.e. the results contain mistakes that compensate for each other. Thus, if a reader determined a 3 sea-year fish as a 2 sea-year fish or vice versa, the mistakes are not visible in the figures.

3.3. The Main Basin catch sample

The catch sample from the Baltic Main Basin originally comprised 100 scales, but for reasons given above, some of the specimens were omitted from the test. Since the age and origin of the fish are unknown, the Main Basin catch sample is used for between-reader comparisons only and is treated separately from the known material.

Figure 11 and Table 10 present the classification of the sample as reared and wild fish by different readers. The proportion of wild fish found by different readers varied considerably, from 0% to almost 60%, indicating considerable heterogeneity between readers. The heterogeneity X^2 value was 86.8***.

Figure 12 and Table 11 show the sea age distributions found by different readers for the catch sample. Comparison of Figures 10 and 12 reveals that readers were consistent, at least to some extent, in ageing the fish. For instance, readers 2 and 6 tended to overestimate the proportion of A.0 fish in the known origin sample (Fig. 10). The same tendency is seen also in Figure. 12.

4. Conclusions and recommendations

From the results of this test it is clear that all Baltic salmon scale readers need to improve their skills in scale reading, particularly when determining the origin and age of fish. The quality of the test scales may have partially contributed to the rather unsatisfactory results. Some of the scales, at least, arrived with tag recoveries from fishermen and because they had no information of the importance of the right sampling location on the fish body, the scales have been sampled from the wrong part of the fish body. In this regard, Scarnecchia (1979), has shown that the sampling site affects the values of total radius and freshwater zone radius of coho salmon scales.

The determination of origin could be improved by computer-aided scale reading techniques based on discriminant analysis. According to preliminary results of Ikonen et al. (1993), only one fish in 42 was misclassified by this technique. Hiilivirta et al. (1991) had a 94% correct classification using the same technique (also preliminary results). As to the continent of origin of Atlantic salmon, Lear and Sandeman (1980) reported a misclassification rate of 15.3%, and Reddin and Burfitt (1983) misclassification rates of 2% and 13% .

When it comes to age determination, however, it seems that computer-based systems can offer little or no help. The annuli have to be detected by humans, either when programming the computer or when marking the annuli in the course of reading the scales. Practising with scale material collected from fish of known age (e.g. Carlin- or coded-wire-tagged) may be one solution. It is recommended that the "reference material" should include scales from as many Baltic salmon stocks as possible in order to broaden the "scale eyes" of the readers. In the future, this would mean a considerable increase in fish marking efforts and increased cooperation between laboratories involved in Baltic salmon scale reading.

5. Summary

The correct classification of sample fish into reared and wild by the seven scale readers participating in the test was rather low and heterogeneous: 62-84% for the whole material.

Recognising wild fish seemed to be particularly difficult, the classification efficiency ranging from 19% to 79%.

The correct determination percentages of sea age ranged from 41% to 77% for the material of the fish of known origin. Inconsistencies between readers were considerable for the samples in both Sub-divisions 25 and 31. All readers thought the fish in Sub-division 25 were older than those in Sub-division 31.

The classification of the Baltic Main Basin catch sample into reared and wild fish gave a rate of 0-59 % for wild fish, depending on the reader. The result is rather consistent with the classification of the known-origin scales: readers with better correct classification percentages determined more fish as being wild.

The ageing of the Main Basin catch sample fish is also fairly consistent with the ageing of the known-age fish: readers with a tendency to give excessively high ages to fish of known origin found more old fish in the catch sample and vice versa.

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TABLE.1. RESULTS OF CLASSIFICATION OF FISH ORIGIN AND DETERMINATION OF SEA AGES BY SCALE READER AND SUB-DIVISION, INDIVIDUALS.

		REARED			WILD		SEA AGE	
READER	SUB-DIVISION	25	28	31	25	31	25	31
1	OK	46	35	65	6	25	35	37
	wrong	3	0	10	37	38	57	47
2	OK	4	5	16	4	8	8	7
	wrong	4	5	5	5	4	9	12
3	OK	48	34	65	13	29	75	51
	wrong	1	1	9	30	34	17	32
4	OK	40	34	67	5	24	70	52
	wrong	9	1	8	38	40	22	33
5	OK	43	29	66	29	56	71	64
	wrong	6	6	9	14	8	21	21
6	OK	49	34	72	4	16	69	41
	wrong	0	0	3	39	48	23	44
7	OK	48	34	70	4	40	73	64
	wrong	0	1	4	39	23	20	21

TABLE 2. CORRECT CLASSIFICATION OF ALL FISH, WILD AND REARED COMBINED (%).

READER	25	28(only r)	31	TOTAL
	SUB-DIVISION			
1	56.52	100.0	65.2	66.8
2	47.06	50.0	72.7	61.7
3	66.3	97.1	68.6	71.6
4	48.91	97.1	65.5	63.9
5	78.26	82.9	87.8	83.8
6	57.61	100.0	63.3	66.0
7	57.14	97.1	80.3	74.5

r=reared

TABLE 3. CORRECT CLASSIFICATION OF ALL FISH, WILD AND REARED SEPARATELY (%).

	SUB-DIVISION						
	25		28	31		TOTAL	
READER	r	w	r	r	w	r	w
1	93.9	14.0	100.0	86.7	39.7	91.8	29.2
2	50.0	44.4	50.0	76.2	66.7	64.1	57.1
3	98.0	30.2	97.1	87.8	46.0	93.0	39.6
4	81.6	11.6	97.1	89.3	37.5	88.7	27.1
5	87.8	67.4	82.9	88.0	87.5	86.8	79.4
6	100.0	9.3	100.0	96.0	25.0	98.1	18.7
7	100.0	9.3	97.1	94.6	63.5	96.8	41.5

r=reared
w=wild

TABLE 4. RESULTS OF CHI-SQUARE TESTS FOR DIFFERENCES BETWEEN READERS. X = LIKELIHOOD RATIO CHI-SQUARE, P = PROBABILITY THAT THERE ARE NO DIFFERENCES BETWEEN READERS.

	REA RED		WI LD	
	X	P	X	P
SUB-DIVISION				
25	35.9	0.000 *	58.1	0.000
31	10.7	0.097	70.4	0.000

* N.B. MORE THAN A FIFTH OF FITTED CELLS ARE SPARSE (FREQUENCY < 5), SIGNIFICANCE TESTS ARE SUSPECT

TABLE 5. RESULTS OF CHI-SQUARE TESTS FOR DIFFERENCES BETWEEN CLASSIFICATION OF REARED AND WILD FISH. X = YATES CORRECTED CHI-SQUARE, P = PROBABILITY THAT THERE ARE NO DIFFERENCES IN CLASSIFICATIONS, PF = PROBABILITY GIVEN BY FISHER EXACT TEST (TWO TAILED).

	SUB-DIVISION 25				SUB-DIVISION 31			
READER	X	P	PF	N	X	P	PF	N
1	56.3	0.000	0.000	92	31.3	0.000	0.000	138
2	0.000	1.000	1.000	17	0.034	0.853	0.690	33
3	44.0	0.000	0.000	92	25.7	0.000	0.000	137
4	42.2	0.000	0.000	92	38.8	0.000	0.000	139
5	4.4	0.035	0.023	92	0.000	1.000	1.000	139
6	73.5	0.000	0.000	92	71.9	0.000	0.000	139
7	72.5	0.000	0.000	91	18.9	0.000	0.000	137

TABLE 6. CORRECT DETERMINATION OF SEA AGE (%).

READER	S-D. 25	S-D. 31	TOTAL
1	38.0	44.1	40.9
2	47.1	36.8	41.7
3	81.5	61.5	72.0
4	76.1	61.2	68.9
5	77.2	75.3	76.3
6	75.0	48.2	62.2
7	78.5	75.3	77.0

S-D.=SUB-DIVISION

TABLE 7. MEAN LENGTHS (IN CM) OF SCALE SAMPLE FISH IN SUB-DIVISIONS 25 AND 31 WITH VALUES OF SEPARATE VARIANCES T-STATISTICS AND ASSOCIATED PROBABILITIES.

SEA AGE	S-D. 25		S-D. 31			
	MEAN	N	MEAN	N	T	P
1	69.3	47	62.1	31	2,933**	0.005
2	79.9	31	76.7	26	1.221	0.227
3	99.8	5	73.0	5	3,612**	0.008

S-D.=SUB-DIVISION

TABLE 8. MEANS AND RANGES OF DETERMINED SEA AGES BY READER AND SUB-DIVISION.
(FREQUENCIES GIVEN IN FIGURES 8. AND 9.)

	S-D. 25						S-D. 31							
TRUE SEA AGE	1		2		3		0		1		2		3	
READER	mean	range	mean	range	mean	range	mean	range	mean	range	mean	range	mean	range
1	1.92	1-3	2.34	2-3	3.00	3	2.00	2	1.56	0-2	2.14	1-3	2.67	2-4
2	0.50	0-1	1.33	1-2	-	-	-	-	0.60	0-1	0.89	0-2	-	-
3	1.08	0-3	1.89	1-3	3.00	3	1.00	1	0.95	0-2	1.67	1-3	1.83	1-2
4	1.12	0-2	1.71	1-2	2.60	2-3	1.00	1	0.95	0-2	1.56	1-3	1.67	1-2
5	1.25	1-2	2.03	1-3	3.20	3-4	1.00	1	1.05	0-2	1.95	1-3	2.17	1-3
6	1.13	0-3	1.91	1-3	3.00	2-4	1.00	1	0.68	0-2	1.54	0-3	2.00	2
7	1.25	1-3	2.03	1-3	2.60	2-3	1.00	1	0.95	0-2	1.80	1-3	2.17	1-3

S-D.=SUB-DIVISION

TABLE 9. SEA AGE DISTRIBUTION OF FISH OF KNOWN ORIGIN AND THAT DETERMINED BY READERS 1 - 7 (IN NUMBERS).

S-D. 25

SEA AGE	TOSI	READER 1
0	-	-
1	52	7
2	35	63
3	5	22
4	-	-

SEA AGE	TOSI	READER 2
0	-	7
1	14	9
2	3	1

SEA AGE	TOSI	READER 3
0	-	2
1	52	52
2	35	29
3	5	9

SEA AGE	TOSI	READER 4
0	-	1
1	52	55
2	35	32
3	5	4

SEA AGE	TOSI	READER 5
0	-	-
1	52	42
2	35	41
3	5	8
4	-	1

SEA AGE	TOSI	READER 6
0	-	3
1	52	46
2	35	35
3	5	7
4	-	1

SEA AGE	TOSI	READER 7
0	-	1
1	53	42
2	35	44
3	5	6

S-D. 31

SEA AGE	TOSI	READER 1
0	1	1
1	36	21
2	41	46
3	6	15
4	-	1

SEA AGE	TOSI	READER 2
0	-	6
1	10	12
2	9	1

SEA AGE	TOSI	READER 3
0	1	3
1	37	52
2	39	24
3	6	4

SEA AGE	TOSI	READER 4
0	1	3
1	37	56
2	41	24
3	6	2

SEA AGE	TOSI	READER 5
0	1	3
1	37	36
2	41	41
3	6	5

SEA AGE	TOSI	READER 6
0	1	15
1	37	42
2	41	25
3	6	3

SEA AGE	TOSI	READER 7
0	1	3
1	37	45
2	41	33
3	6	4

S-D.=SUB-DIVISION

TABLE 10. CLASSIFICATION OF MAIN BASIN SCALE SAMPLE INTO REARED AND WILD FISH BY READER (BY INDIVIDUALS AND %).

INDIVIDUALS	READER						
	1	2	3	4	5	6	7
REARED	55	9	63	68	47	83	49
WILD	27	13	18	14	36	0	34
%:							
REARED	67.1	40.9	77.8	82.9	56.6	100.0	59.0
WILD	32.9	59.1	22.2	17.1	43.4	0.0	41.0

TABLE 11. SEA AGE DISTRIBUTION OF MAIN BASIN SCALE SAMPLE BY READER (INDIVIDUALS AND %).

INDIVIDUALS	READER						
SEA AGE	1	2	3	4	5	6	7
0	-	14	-	-	-	13	-
1	5	8	76	80	70	69	74
2	74	-	5	2	12	1	8
3	2	-	-	-	1	-	1
%:							
0	0.0	63.6	0.0	0.0	0.0	15.7	0.0
1	6.2	36.4	93.8	97.6	84.3	83.1	89.2
2	91.4	0.0	6.2	2.4	14.5	1.2	9.6
3	2.5	0.0	0.0	0.0	1.2	0.0	1.2

FIG.1. CORRECT CLASSIFICATION OF ALL FISH (R OR W).

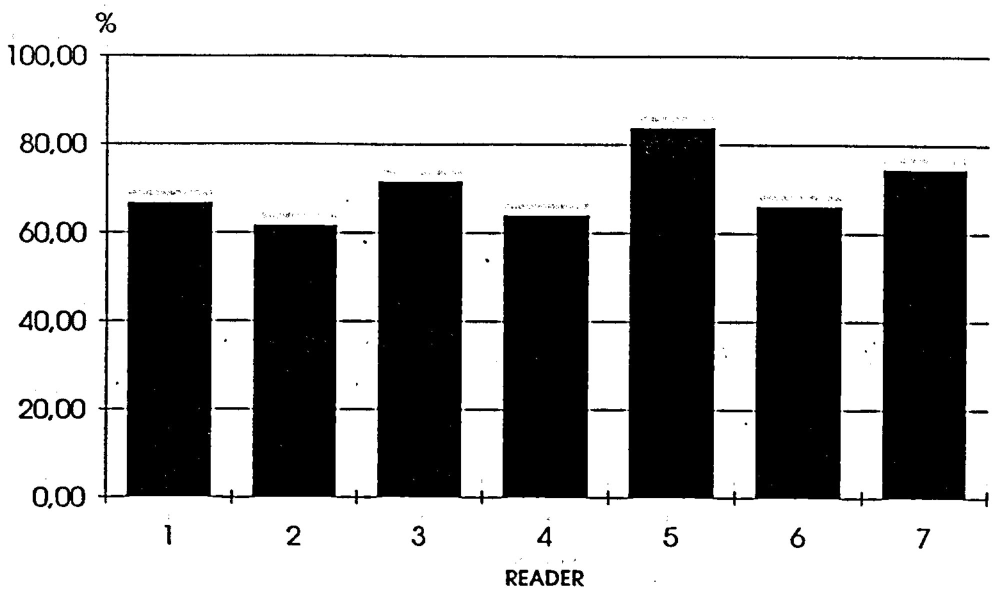


FIG.2. CORRECT CLASSIFICATION OF ALL FISH, R (WHITE) AND W (BLACK) SEPARATELY.

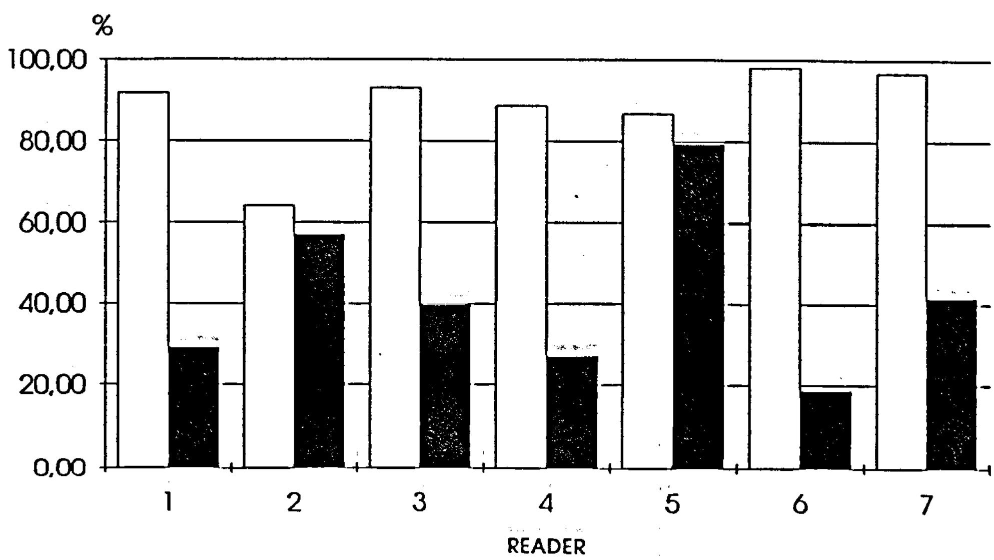


FIG.3. CORRECT CLASSIFICATION, S-D. 25, R (WHITE) AND W (BLACK) SEPARATELY.

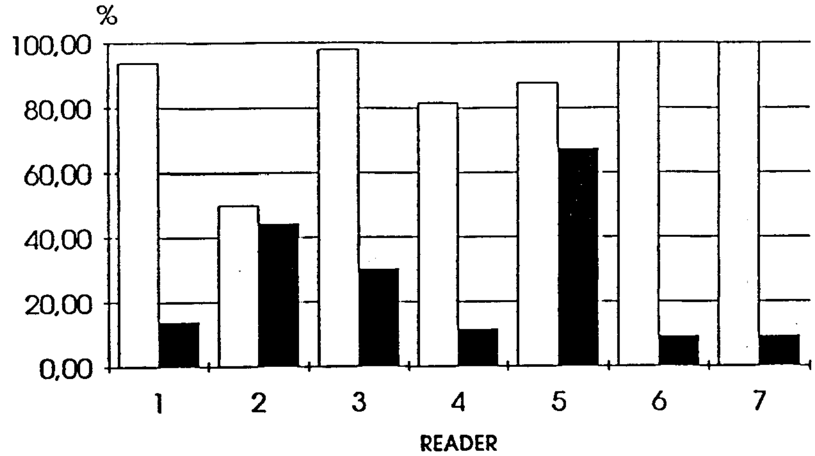


FIG.4. CORRECT CLASSIFICATION, S-D. 28, ONLY R.

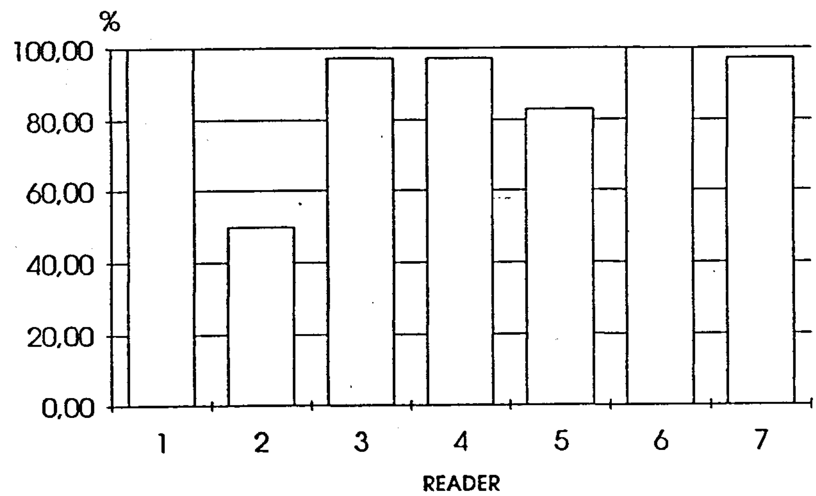


FIG.5. CORRECT CLASSIFICATION, S-D. 31, R (WHITE) AND W (BLACK) SEPARATELY.

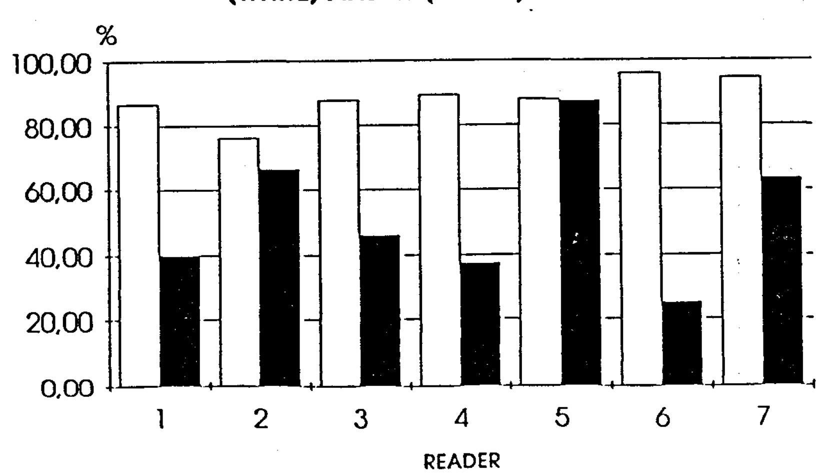


FIG.6. CORRECT DETERMINATION OF SEA AGE, ALL FISH (SUB-DIVISIONS 25 AND 31 COMBINED).

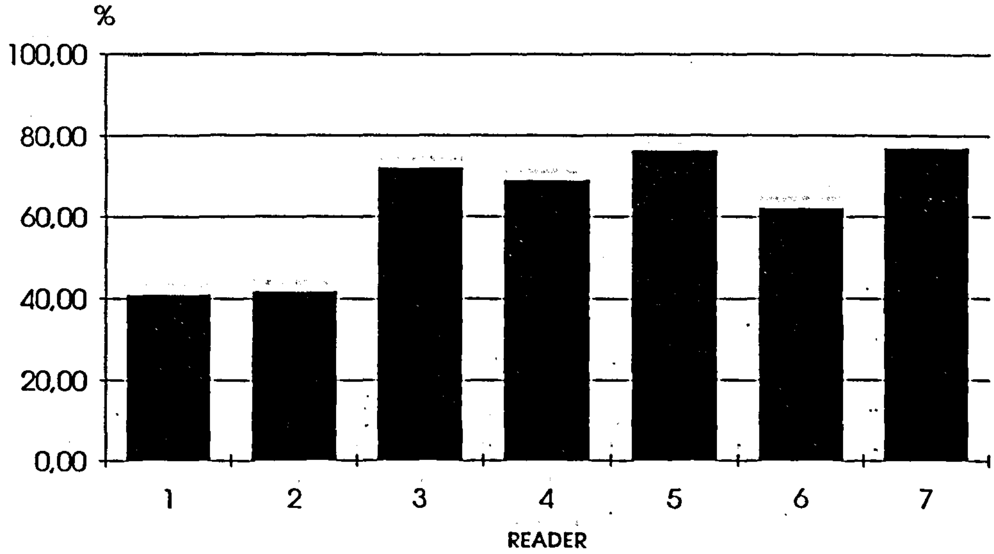


FIG.7. CORRECT DETERMINATION OF SEA AGE, SUB-DIVISIONS 25 (WHITE) AND 31 (BLACK).

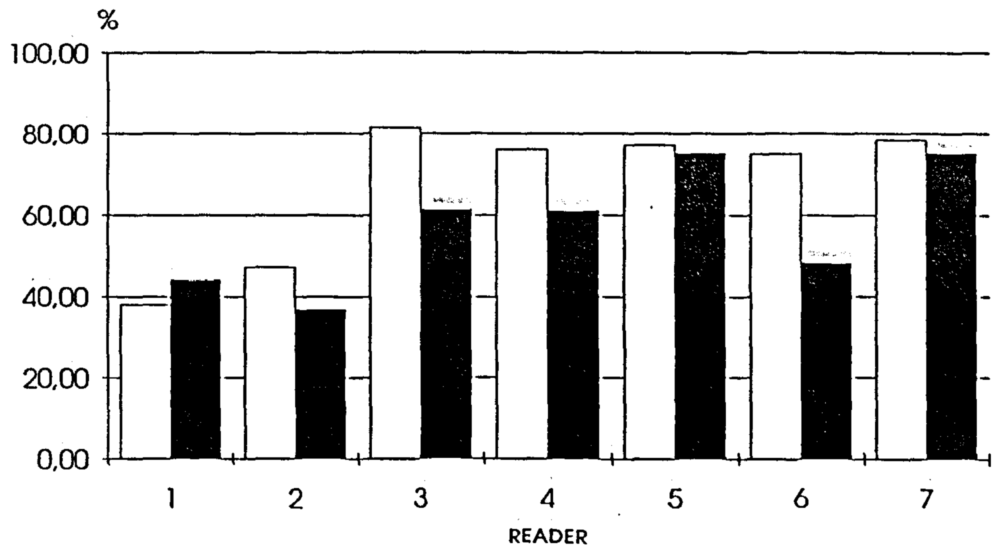


FIG.8. THE MEANS OF DETERMINATIONS OF SEA AGES BY READER, S-D. 25. FREQUENCIES ON THE TOPS OF THE COLUMNS.

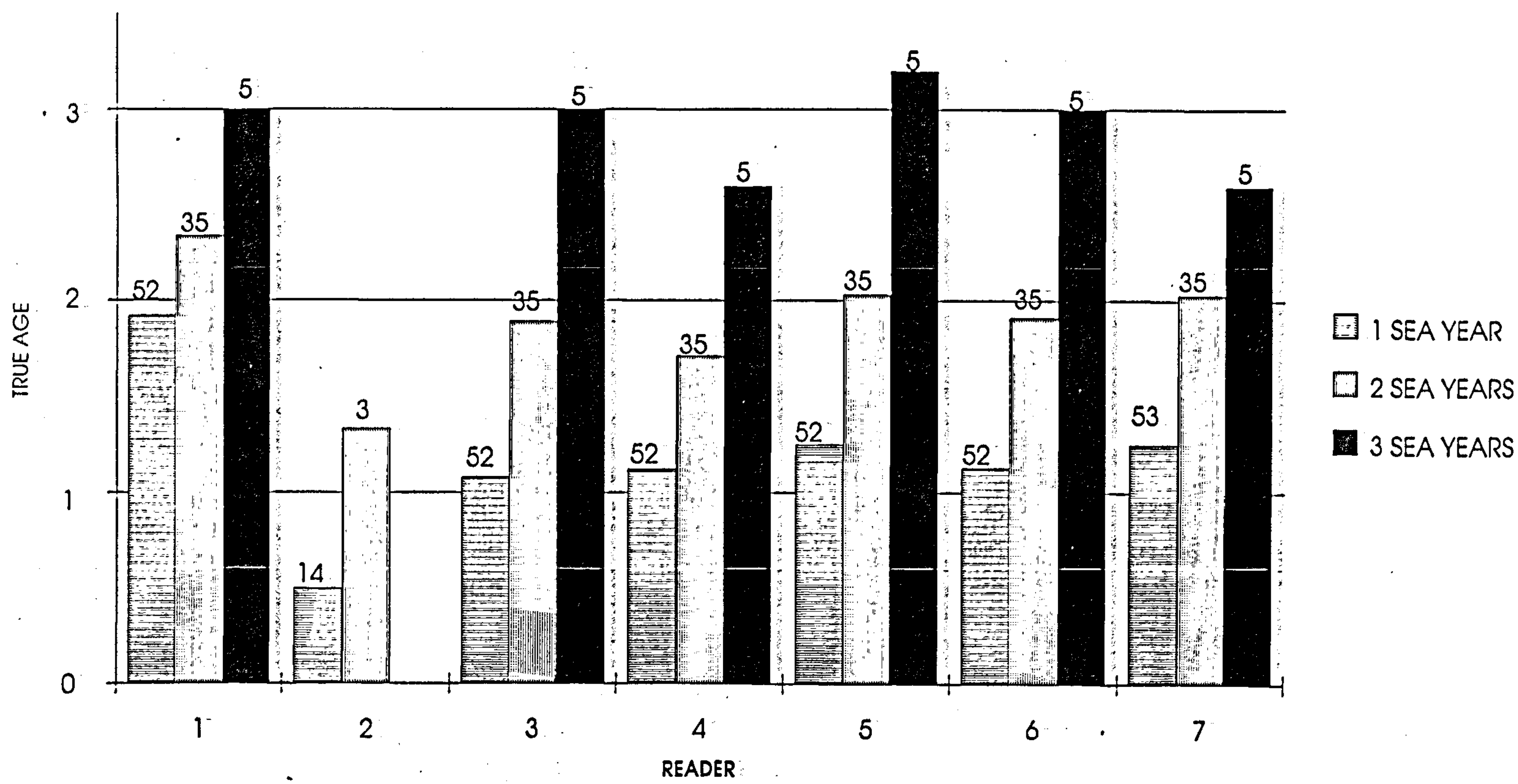


FIG.9. THE MEANS OF DETERMINATIONS OF SEA AGES BY READER, S-D. 31. FREQUENCIES ON THE TOPS OF THE COLUMNS.

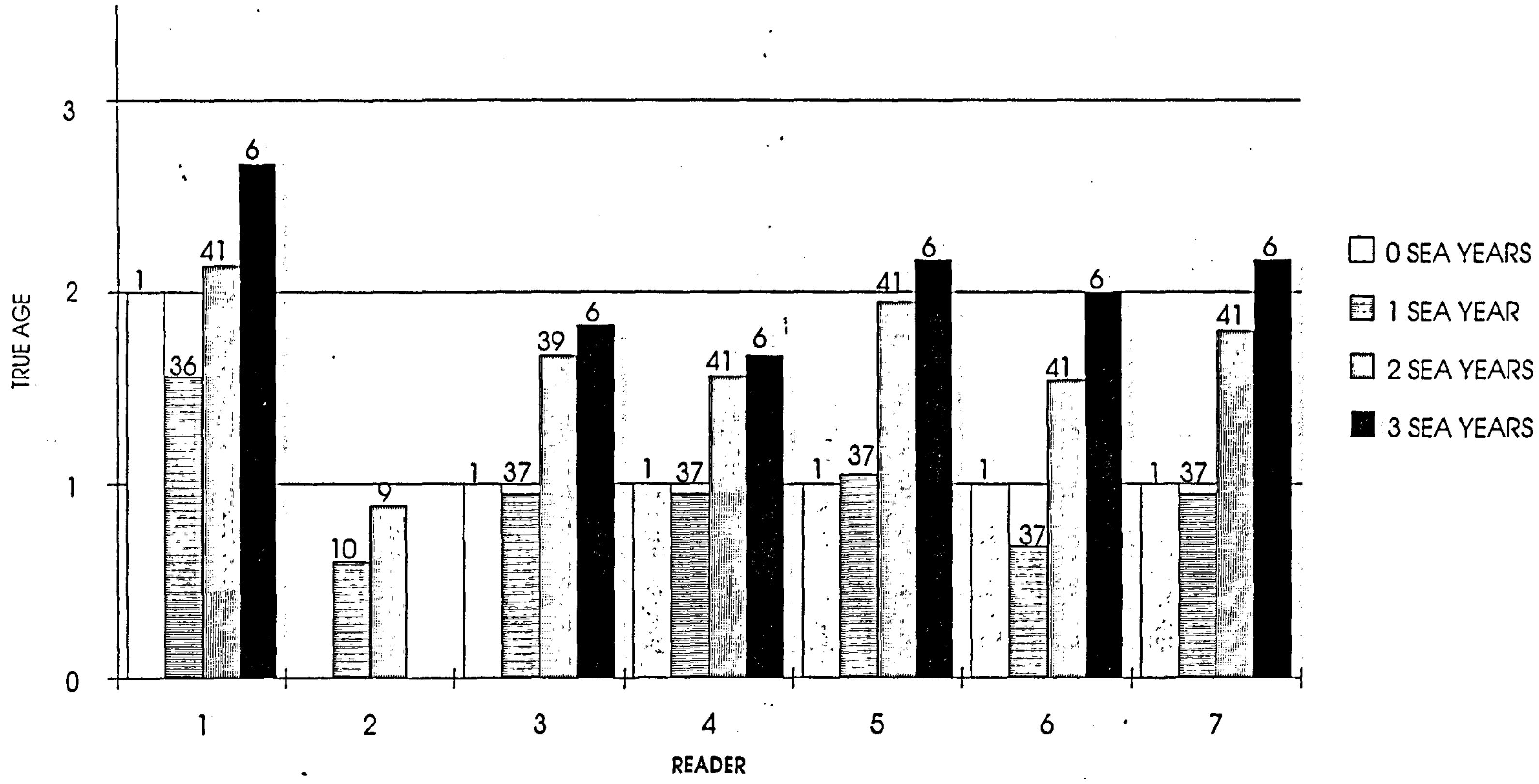


FIG.10. THE SEA AGE DISTRIBUTION OF THE SCALE MATERIAL AS DETERMINED BY READERS COMPARED WITH THE TRUE SEA AGE DISTRIBUTION OF THE SAMPLE SCALES.

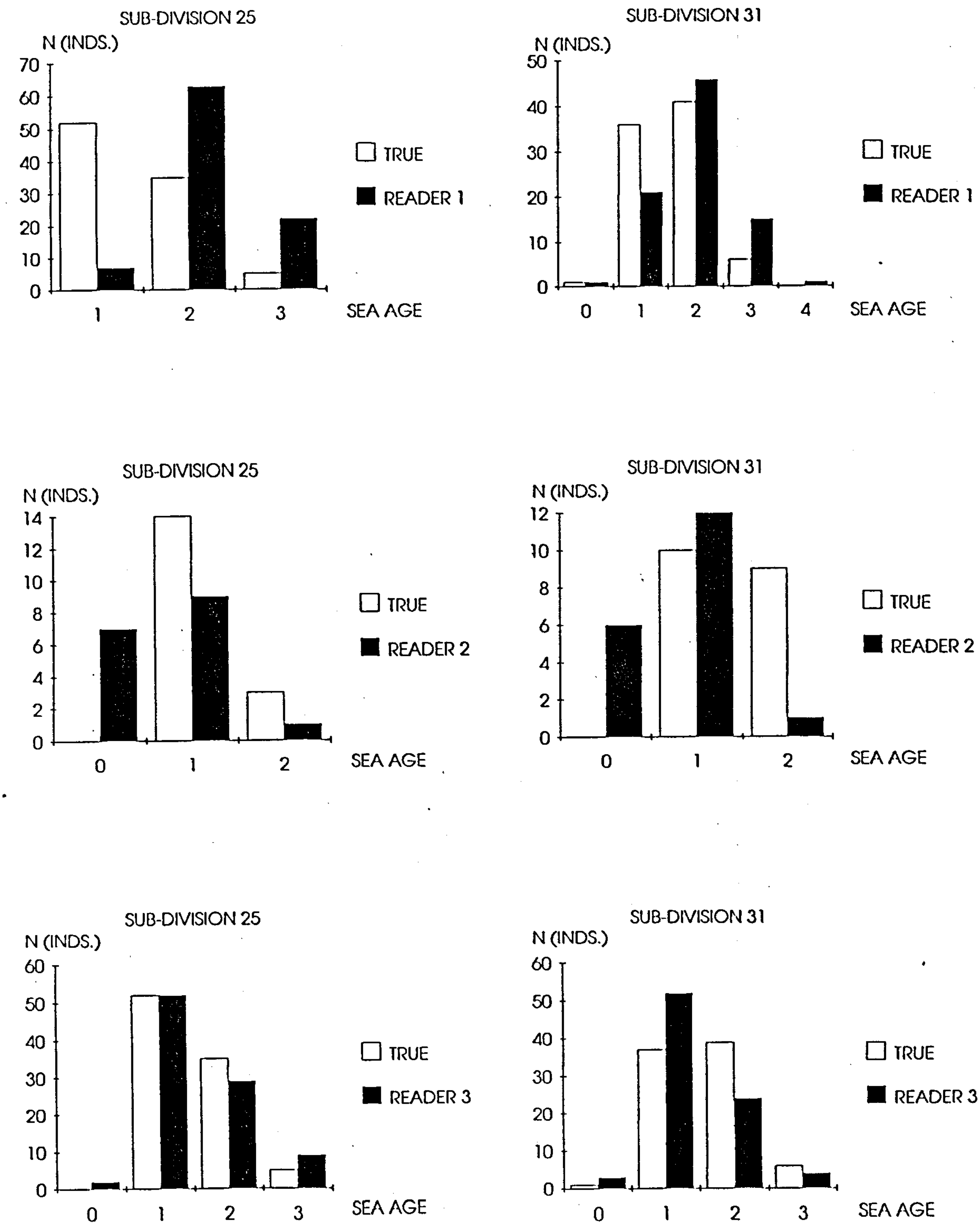
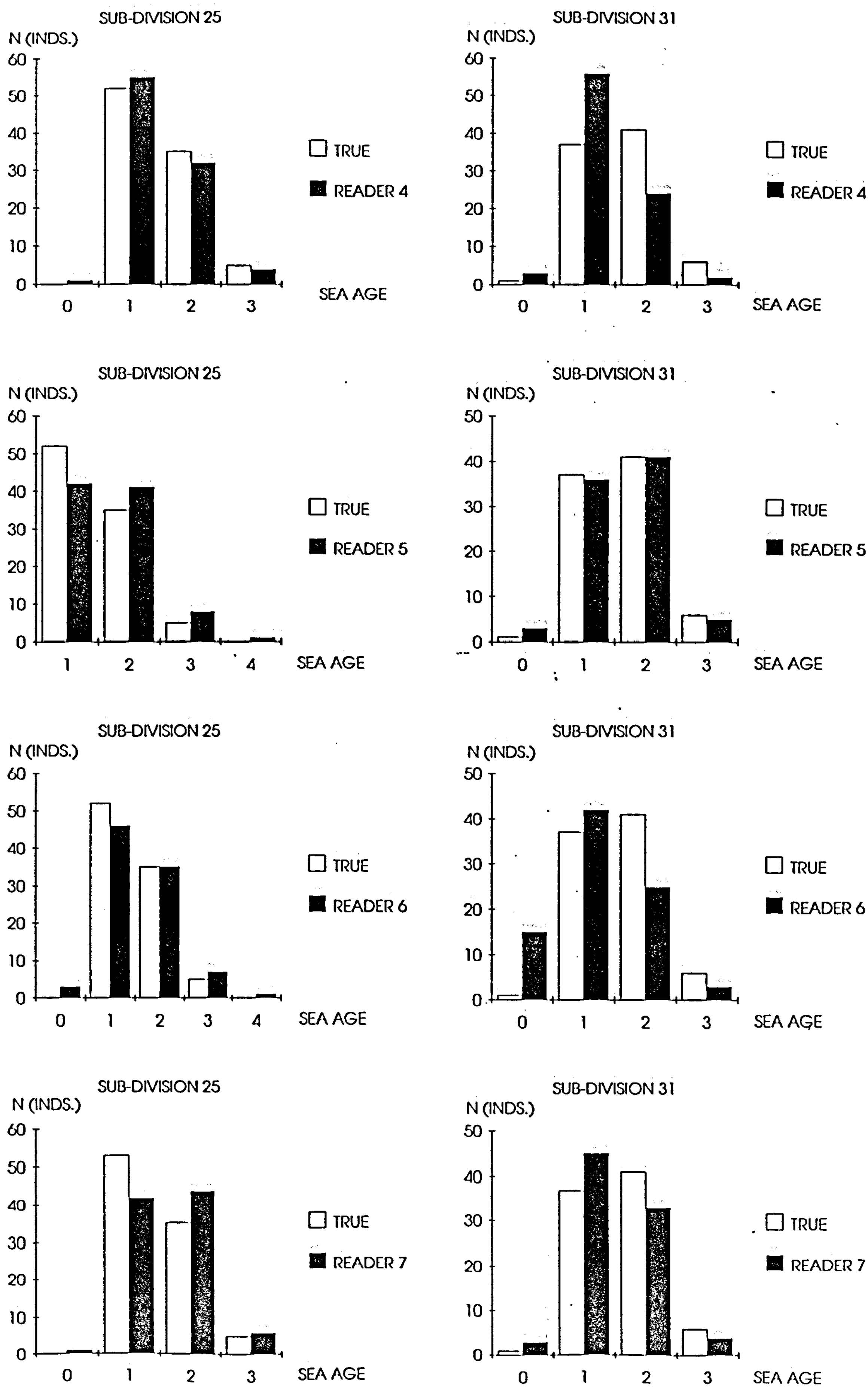


FIG.10. (cont'd)



SUB-DIVISION 25
N (INDS.)
TRUE
READER 4
SEA AGE
SUB-DIVISION 31
N (INDS.)
TRUE
READER 4
SEA AGE
SUB-DIVISION 25
N (INDS.)
TRUE
READER 5
SEA AGE
SUB-DIVISION 31
N (INDS.)
TRUE
READER 5
SEA AGE
SUB-DIVISION 25
N (INDS.)
TRUE
READER 6
SEA AGE
SUB-DIVISION 31
N (INDS.)
TRUE
READER 6
SEA AGE
SUB-DIVISION 25
N (INDS.)
TRUE
READER 7
SEA AGE
SUB-DIVISION 31
N (INDS.)
TRUE
READER 7
SEA AGE

FIG.11. CLASSIFICATION OF THE MAIN BASIN SAMPLE INTO REARED (WHITE) AND WILD (BLACK) FISH BY DIFFERENT READERS.

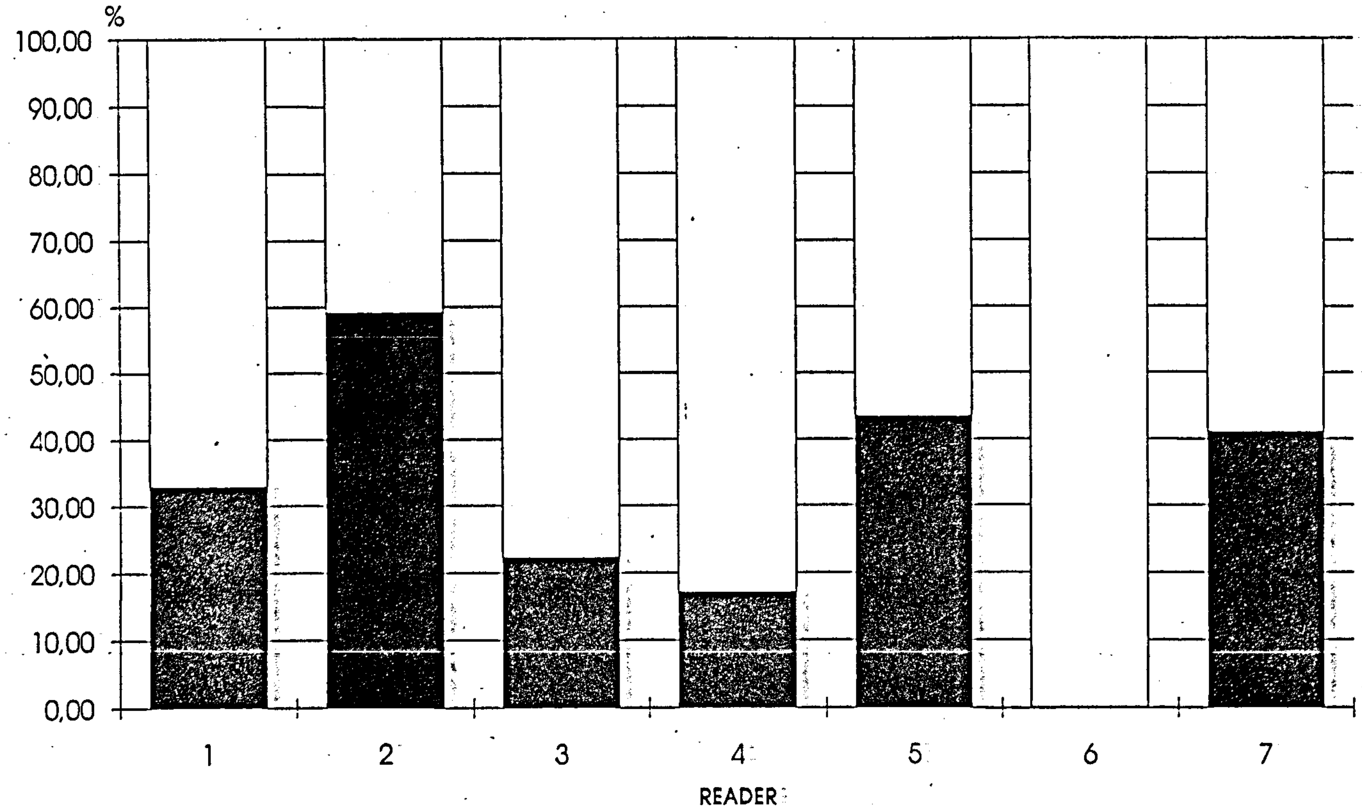


FIG.12. THE SEA AGE DISTRIBUTION OF THE MAIN BASIN SAMPLE AS DETERMINED BY READERS 1 - 7.