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PRECISION OF AGE DETERMINATION OF NORTHERN OFFSHORE SPOTTED DOLPHINS

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U.S. DEPARTMENT OF COMMERCE
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Southwest Fisheries Center
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La Jolla, California 92038

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U.S. DEPARTMENT OF COMMERCE
Malcolm Baldrige, Secretary
National Oceanic and Atmospheric Administration
John V. Byrne, Administrator
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ABSTRACT

We investigated within- and between-reader precision in estimating age for northern offshore spotted dolphins and possible effects on precision from the sex and age-class of specimens. Age was estimated from patterns of growth layer groups in the dentine and cementum of the dolphins' teeth. Each specimen was aged at least three times by each of two persons. Two data samples were studied. The first comprised 800 of each sex from animals collected during 1973-78. The second included 45 females collected during 1981. There were significant, generally downward trends through time in the estimates from multiple readings of the 1973-78 data. These trends were slight, and age distributions from last readings and mean estimates per specimen appeared to be homogeneous. The largest factor affecting precision in the 1973-78 data set was between-reader variation. In light of the relatively high within-reader precision (trends considered), the consistent between-reader differences suggest a problem of accuracy rather than precision for this series. Within-reader coefficients of variation averaged approximately 7% and 11%. Pooling the data resulted in an average coefficient of variation near 16%. Within- and between-reader precision were higher for the 1981 sample, and the data homogeneous over both factors. CVs averaged near 5% and 6% for the two readers. These results point to further refinements in reading the 1981 series. Properties of the 1981 sample may be partly responsible for greater precision: by chance there were proportionately fewer older dolphins included, and preparation and selection criteria were probably more stringent.

INTRODUCTION

The precision of growth layer group ageing of cetaceans has not been previously addressed in the literature. In relation to ageing fish via scale pattern readings, Beamish and Fournier (1981) and Chang (1982) discussed statistics that are generally applicable to measurement of within-reader precision but did not develop quantification of between-reader precision.

In statistical jargon, accuracy is defined as the closeness of a measured or computed value to its true value; precision is the closeness of repeated measurements of the same value (Sokol and Rohlf, 1969). That is, accuracy refers to lack of bias, while high precision is generally synonymous with low variance. This terminology is followed here.

This paper addresses the precision of estimating age for northern offshore spotted dolphins (Stenella attenuata). Age is estimated from patterns of growth layer groups in the dentine and cementum of the dolphin's teeth (Perrin and Myrick 1980). Verification of the accuracy of this technique (for closely related Hawaiian spinner dolphins, Stenella longirostris) is addressed in Myrick et al. (MS) and is not directly considered here. Possible confounding of accuracy problems with apparent precision is discussed, in relation to the slightly different methods used by the two readers in this study to estimate age from growth layer group (GLG) patterns (Myrick et al. 1983).

We investigated both within- and between-reader precision and possible differences due to the sex and age class of specimens. Two data samples were selected and analyzed. Analyses for each sample are presented separately, then discussed jointly.

DATA SOURCES AND SAMPLING STRATEGY

The first data sample was selected from northern offshore spotted dolphins killed incidentally in tuna seines during 1973-78 (n=1600; 800 each sex, drawn randomly from over 8,000 total). The original experimental design called for each specimen to be read three times by two readers, allowing for computation of within- and between-reader variance. Each reading was made "blind," that is, without knowledge of previous readings for the specimen by either reader, and with no accessory information on the size or life history traits of the specimen. Time intervals between successive readings varied from days to months.

Data from each reading of a tooth preparation were recorded in a common format (Figure 1). Additional elements were added to the reading record post facto: sex, consecutive reading days and reading number for the specimen by the reader.

During the course of the study, it became apparent that the ageing techniques were still under development. Also, through trial and error, the tooth preparation techniques improved, and standards for accepting a preparation as "readable" became more rigid. Consequently, later readings were not necessarily aged using exactly the same techniques or under the same conditions as earlier readings and are therefore not true replicates for measuring within-reader precision.

A second sample was drawn from northern offshore spotted dolphin females captured during 1981, to investigate within-reader variance under constant conditions. There was some indication of differences in precision for ageing "young" and "older" animals in the 1973-78 series (discussed below). The 1981 sample was drawn in two age groups to address this: below and above 160 cm in total length (this was approximately the length at which both between- and within-reader estimates began to diverge: also discussed below).

Sample size for each stratum was determined with the following criteria: 95% confidence with a relative bound of 10% (1.5 yrs) on the average age estimate (about 15 yrs). Presample estimates of the variance were taken from the 1973-78 readings (s^2 = approx. 9.5 for <160 cm; 13.5 for >160 cm). For each stratum the sample size was estimated as $n_1 = t^2s^2/b^2$ (Cochran, 1977). The stratum estimates are $n_1 = 4(9.5)/2.25 = 17$, and $n_2 = 24$. The sum (41) was set as a minimum. A sample of 45 was actually drawn.

Within-Reader Precision

Methods

Acknowledging the possible change over time in methods used for the 1973-78 readings, we analyzed the multiple readings per specimen by each reader as repeated measures. This was done to compare the magnitude of within-reader variance between the 1973-78 and 1981 data, the later having been examined with constant methods. Following Chang (1982) the coefficients of variation (CV=SDx100/mean) and "indices of precision" ($D=CV/\sqrt{n}$) were calculated. Here the sample was divided into three age groups: 0-4 yrs; 4-12; 12+ yrs. Four is the approximate age at 160 cm total length (Hohn and Hammond, manuscript: and see above), and 12 is the approximate age at sexual maturity (Myrick, unpublished). To extend the analysis beyond that defined by Chang (1982), we tested for age-group differences in CV and D by analysis of variance (ANOVA). We also tested for differences between the readers' precision within each age class (and over all ages) by t-tests.

Results

Even considering the suggested change in methods over time, the overall CVs are not high: 11.2% average for reader 1, 7.7% average for reader 2 (Table 1). The CVs increase significantly with increasing age for both readers. The Ds show a very similar pattern (Table 2).

CV and D represent relative precision within the readers' estimates. The actual mean ages for each reader by age-group cell are in Table 3.

Between-Reader Precision

Methods

A graphic measure of between-reader differences by age was defined. For each specimen, the signed difference between reader 1's mean and reader 2's mean as a percentage of the pooled mean age (PM) was plotted against PM. In the resulting figures, values greater than zero for a specimen indicate that the mean estimate by reader 1 was higher than the mean estimate by reader 2.

Values less than zero indicate the opposite. Values on the figures are also informative in representing the between-reader differences relative to the pooled mean value, rather than in absolute time units.

Between-reader precision was also measured in the CV and D analyses, and (as discussed below) in an analysis of covariance. On a per specimen basis, significant differences between the readers' means were tested for with t-tests. The frequency of significant t values is an indicator of overall between-reader precision.

Results

The reader means appear to diverge with increasing age (Table 3). This can be seen in Figures 2 and 3, which show the signed % differences between reader means as a function of pooled mean age. Reader 1 estimated higher than reader 2 for older animals. For younger animals (<4.0 years pooled mean) reader 2's estimates are slightly higher. These differences are apparent in the means (Figure 2) and last readings Figure 3). In all, the mean estimates are significantly different for 46.8% of the males, 47.0% of the females (from t-tests).

The by-reader, within age-class comparisons of mean CV and D show significant differences in the magnitude of precision as well, reader 1 generally having higher CVs and Ds (Tables 1 and 2).

Tests for Trend in Age Estimates

Methods

Multiple regressions of last readings per specimen were made on earlier readings (X1) and elapsed time in days (X2) between the readings. This was done for the entire data set, and for six reader (2) by age-group (3) categories. In each multiple regression, we tested for departure from unity of the coefficient relating last to earlier readings (B1). Such a departure would indicate a trend in ageing method with time. Actual values of the coefficients are not easily interpretable, though, due to possible covariance with B2, the coefficient for the elapsed time variable. An ANOVA of regression coefficients over groups was also conducted.

Secondly, we ran a multiple analysis of covariance (MANCOVA) of last readings on the same two predictors, with age group (3) sex and reader (2) as factors. This method examined the importance of these three factors and their interactions, after adjusting for covariance between the last readings and the predictor variables.

Results

The multiple regressions show a significant departure from unity in the regression coefficients of last on earlier age estimates, in five of six reader by age-group cells, and in the combined data (Table 4). The data subset with no time trend in age estimates (B1=1) is reader 2, age <4.0. Otherwise, the last reading was slightly lower than earlier readings, on average (i.e., B1 significantly less than 1.0). The ANOVA indicated that regression coefficients were different between the cells. That is, there were different rates of change over time, the greatest decrease being in reader 1's ageing of "large" animals.

The MANCOVA showed that reader and (as expected) age-class were significant factors in estimating age from GLGs, as was their interaction (Table 7). Sex was not significant in this test nor were any interaction terms involving sex. These results can be interpreted as tests of the significance of sex, age class and reader on estimated age, after adjustment for the covariates, which both relate to a trend with time.

Age Distribution Comparisons

Methods

In tests above, reader, age-class and (in some tests) sex have shown significant effects on precision and magnitude of estimated ages. Given this, it was of interest to see if such differences were translated into the resulting age distributions. Possible differences between readers, sexes and estimate types (means vs last readings) in the resulting age distributions were examined via chi-squared contingency tests. Animals of 15 years or older were pooled in these tests. This was done because nearly all 15 year olds are sexually mature (Myrick, unpublished data) and because differences in age structure are primarily relevant to studies of reproductive rates.

Results

The age distributions tested (Table 6) are heterogeneous across all reader comparisons, within both estimate types (Table 7). The distribution of chi-squared statistics by age-class for the between-reader comparison of females using pooled mean ages (Figure 4) shows that the greatest contribution to the difference comes from a few older age groups. Differences in the 15+ group contributed heavily in all between- eader comparisons. The distributions for the two estimates (pooled mean and last reading) are not different, however.

For comparison of males using pooled means, the ages contributing to between-reader differences were more widely distributed among the 4+ year olds (Figure 5). Similar patterns were seen in the between-reader comparisons of last reading age distributions: significant differences in female- being primarily in the 12+ year olds, and in the males being distributed more widely in younger age groups. It is not clear why this sex related difference has occurred. It is perhaps related to the differing age distributions recorded for females and males, the latter having relatively more individuals in the 4 to 12 year classes.

1981 SAMPLE

The overall mean age in this sample of 45 females is 10.912 years (SD=8.09), as compared to 13.93 years (SD=8.36) in the larger 1973-78 sample.

Within-Reader Precision

Methods

For the 1981 sample, within-reader precision was determined by three methods. The coefficients of variation and indices of precision were computed and compared, as with the 1973-78 sample. As a third approach, we conducted an ANOVA of agebest, with age-groups (3) and readers (2) as factors, and cycle as a repeated measure within reader. While not assigning an explicit statistic for precision such as CV or D, this method measures the significance of variance from each effect in determining overall "agebest" and its variance.

Results

For reader 1 the CVs and Ds are lower on average in the 1981 than the 1973-78 sample: CV=4.85 vs 11.28, D=2.79 vs 6.59 for females (Tables 8 and 9). Reader 2 maintained about the same CV level (6.90 vs 6.12) but declined in D (3.53 vs 4.55). For both readers, average coefficients of variation of less than 5% indicate high within-reader precision. The change in within-reader precision between the two data sets is discussed further below.

As in the 1973-78 sample, precision declined with increasing estimated specimen age for both readers. For the oldest age-group (over 12 yrs) CVs are 7.08% and 8.47% for readers 1 and 2, respectively. In the earlier sample, these were 13.26% and 8.03%. Cell means and variances for the actual age estimates are presented in Table 10.

Between-Reader Precision

Methods

As with the 1973-78 sample, between-reader precision was studied using t-tests of mean age estimates by specimen, and of mean CV and D within age-groups. The ANOVA described in Within-Reader Precision also tested between-reader precision.

Results

The analysis of variance (Table 11) indicates that there is no significant difference in cycle within reader, agreeing with the low within-reader CVs. By definition, there is a significant age-group effect, but for this data series, there is no reader effect. Nor are the reader by group, or group by cycle (within-reader) interactions significant. These results for actual age estimates are supported by the lack of significant differences between reader mean precision statistics (CVs and Ds) within age classes (Tables 8 and 9). A plot of the signed differences between-reader mean ages, as percentages of the pooled means, shows a narrow, relatively uniform band around zero (Figure 6). In combination, these results indicate that for the 1981 sample, there was generally high precision both within- and between-readers in repeated age estimates.

The actual percent of cases in which the within-reader mean ages differed significantly, by one year or more, was around 20% (9/45). This is down from nearly 50% in the 1973-78 sample. In keeping with the generally lower precision in ageing older animals, the mean age of the animals for which the readers' means were different was 16.7 years, compared to 10.9 for the entire sample.

Age Distributions

Methods

To compare the age distributions resulting from the 1981 sample estimates, we used the same techniques as with the 1973-78 sample: pooling animals aged 15 and older and computing chi-squared statistics to test the null hypothesis of homogeneity.

Results

The age distributions resulting from the 1981 sample readings from the two readers are not different, when pooled as described above ($X^2 = 0.87$) (Appendix 3). The limited sample of 45 is not, however, really adequate to define an age distribution with a maximum age of over 30 years. (The entire 1981 sample was not prepared for analysis in time for this writing. When it is complete, more meaningful age distribution comparisons involving these data can be made.) These preliminary age distribution comparisons are consistent with the other between-reader comparisons discussed above in indicating no significant between-reader differences.

DISCUSSION

There are significant, generally downward trends through time in the estimates from multiple readings of the 1973-78 data. These trends are slight and do not result in different age distributions from last readings and pooled mean estimates (at least on the scale examined here). The largest single factor affecting precision in this data series is between-reader variation. In light of the relatively high within-reader precision (trends considered), the consistent between-reader differences suggest a problem of accuracy rather than precision for the 1973-78 series. That is, the two readers, using slightly different methods to determine age from a series of GLGs produced significantly different results for this data set.

Within- and between-reader precision in estimating age is higher for the 1981 series, and the data are homogeneous over both factors. It may be that the readers have refined their respective techniques to the point that they produce essentially the same results. No conscious consensus or melding of the techniques has taken place. Properties of the 1981 sample and its selection may be partly responsible for the greater precision in ageing that data set. There were relatively fewer older animals in the 1981 sample (Appendix 3): the mean age was significantly younger. In both samples, within- and between-reader precision declined with increasing specimen age. Also, the quality of tooth preparations was better on average for the 1981 set, and no "unreadable" specimens were included. However, even for the younger animals, precision is higher in the 1981 set.

Whatever the reasons for change between data sets, the important questions remaining relate to interpretation of the 1973-78 data. What is the best estimate of age for each specimen? What variance shall be assigned to each estimate?

Given the lack of significant differences between age distributions from last readings and pooled means, of those two statistics, it would be preferable to use the latter as age estimates, because they allow direct estimation of variance (if multiple readings are regarded as replicates). However, because of the large contribution from between-reader differences, the overall CVs for the pooled means average near 16%. For the over 12 years component, the CVs are nearly 20% (as opposed to 8% and 13% from individual reader estimates). This may be too high for some potential uses of age data. Consequently, it may be advisable to conduct some subsequent analyses with each reader's mean ages separately and examine the sensitivity of results to the differences in input.

The two statistics proposed by Chang (1982) to estimate precision gave very similar results here. The coefficient of variation is easier to interpret, being in units of percent of actual estimates, and therefore seems preferable.

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Table 1. Coefficients of variation (CV) for two readers, by age groups (3), with analysis of variance testing within-reader differences over age groups, and t-tests of between reader differences within age groups. Data are from spotted dolphins, both sexes, killed during 1973-78.

Age Group (yrs)	n	(Reader 1) mean CV	SD	n	(Reader 2) mean CV	SD	$t(CV_1=CV_3)$	P(t)
*A≤4.0	215	8.26	15.56	59	4.39	9.35	2.571	0.009
4.0<A≤12.0	309	8.73	8.21	72	6.39	6.69	3.065	0.005
12.0<A	724	13.26	10.27	163	8.03	7.32	8.855	<0.001
all	1248	11.28	11.18	294	6.90	7.74	9.091	<0.001
Within Sum of Squares		149072.390			16936.677			
D.F.		1245			291			
Mean Square		119.737			58.202			
Between Sum of Squares		6802.346			599.506			
D.F.		2			2			
Mean Square		3401.173			299.753			
Equality of Means:								
F		28.405			5.150			
D.F.		2, 1245			2, 291			
P(F)		<0.001			0.006			

*A is the pooled mean age.

Table 2. Indices of precision ($D=CV/\sqrt{\bar{n}}$) for two readers, by age groups (3), with analysis of variance testing within-reader differences over age groups, and t-tests of between-reader differences within age groups. Data are from spotted dolphins, both sexes, killed in 1973-78.

Age Group (yrs)	n	(Reader 1) mean D	SD	n	(Reader 2) mean D	SD	$t(D_1=D_2)$	P(t)
*A≤4.0	215	5.23	10.40	59	2.85	6.53	2.327	0.020
4.0<A≤12.0	309	5.06	4.79	72	4.32	4.64	1.532	0.145
12.0<A	724	7.64	6.07	163	5.27	4.82	6.482	<0.001
all	1248	6.59	6.86	294	4.55	5.24	6.620	<0.001

		Reader 1	Reader 2
Within Sum of Squares		56834.582	7697.605
	D.F.	1245	288
Mean Square		45.650	26.728
Between Sum of Squares		1925.677	257.050
	D.F.	2	2
Mean Square		962.838	128.525
Equality of Means:			
	F	21.092	4.809
	D.F.	2, 1245	2, 288
	P(F)	<0.001	0.009

*A is the pooled mean age.

Table 3. Summary statistics for "agebest," by reader (2) age-class (3) and sex. The "agebest" is itself a mean of a series of readings per specimen by each reader. The within reader precision is reported in Tables 3 and 4. Data are from offshore spotted dolphins from 1973-78.

		Age Class (From Pooled Mean)							
		A≤4.0		4.0<A≤12.0		12.0<A		All	
Reader		Male	Female	Male	Female	Male	Female	Male	Female
1	Mean	2.037	1.965	8.157	8.665	22.823	21.543	14.076	15.112
	SD	1.257	1.176	2.782	2.854	6.165	5.761	10.082	9.397
	n	173	147	217	163	385	464	775	774
2	Mean	2.189	2.145	7.829	8.186	18.001	17.275	11.278	12.267
	SD	1.210	1.143	2.244	2.358	4.584	4.359	7.467	7.149
	n	175	146	223	163	351	428	749	737

Table 4. Coefficients and tests of significance from multiple regressions of last reading age estimates on 1) earlier age estimates and, 2) elapsed time between the estimates. For B_1, t-tests of the hypothesis last estimate = previous estimate (B_1=1) are shown. Data are from 1973-78 offshore spotted dolphin tooth glg readings.

Data Set	F from ANOVA	P(F)	B_1	$SE(B_1)$	$t(B_1=1)$	$P(t_1)$	B_2	$SE(B_2)$
All n=5867	24943	<0.001	1.032	0.00464	6.80	<0.001	0.0090	0.0007
Reader 1, Small n=682	7090	<0.001	0.974	0.00819	3.13	<0.001	0.0002	0.0002
Reader 2, Small n=409	29306	<0.001	1.002	0.00414	0.49	0.688	0.0006	0.0002
Reader 1, Mid n=961	1722	<0.001	0.906	0.01547	6.05	<0.001	0.0007	0.0007
Reader 2, Mid n=470	8815	<0.001	0.974	0.00735	3.52	<0.001	0.0046	0.0006
Reader 1, Large n=2350	1837	<0.001	0.876	0.01451	8.58	<0.001	0.0089	0.0015
Reader 2, Large n=995	4774	<0.001	0.967	0.00992	3.35	<0.001	0.0065	0.0014

ANOVA of Regression Coefficients Over Groups: F=38.573, P<0.001

Table 5. Multiple analysis of covariance of last reading age estimate by reader (2), sex (2), and age group (3), with earlier age estimates and the elapsed time between estimates as covariates.

Source of variation	SS	DF	MS	F	P(F)	Regression coefficients
Age Class	3054.369	2	1527.185	149.30	<0.001	
Reader	376.935	1	376.935	36.85	<0.001	
Sex	17.714	1	17.714	1.73	0.188	
A X R	1349.808	2	674.904	65.98	<0.001	
A X S	0.579	2	0.289	0.03	0.972	
R X S	14.131	1	14.131	1.38	0.239	
A X R X S	0.005	2	0.003	0.00	0.999	
Previous Estimate (1st covariate)	116,889.053	1	116,889.053	11,427.41	<0.001	0.888
Elapsed Time (2nd covariate)	609.268	1	609.268	59.56	<0.001	0.006
Both Covariates	117,125.201	2	58,562.601	5725.25	<0.001	
Error	59,869.346	5853	10.229			

Table 6. Frequencies of individuals estimated to be within 15 age classes by sex, reader and estimate type. Chi-squared tests of homogeneity are in Table 9. The full distributions from which these were summed are reported in Appendices 1-4.

Variable:	Mean Reading				Last Reading			
Reader:	1	2	1	2	1	2	1	2
Sex:	M	M	F	F	M	M	F	F
Age Group								
1	45	40	37	30	45	40	42	29
2	46	44	42	39	46	44	41	40
3	42	41	34	41	44	40	35	40
4	41	59	35	42	43	60	34	43
5	41	23	27	20	39	22	29	20
6	25	42	14	20	25	43	13	19
7	30	19	14	13	26	23	18	14
8	20	33	17	17	20	30	10	17
9	19	28	7	26	18	29	14	31
10	20	34	22	29	23	33	17	25
11	21	28	23	28	18	27	21	30
12	25	29	22	38	25	30	28	33
13	23	35	24	33	16	33	15	35
14	16	25	23	51	21	26	20	49
≥15	361	269	432	310	363	258	428	298
SUM	775	749	773	737	772	738	765	723

Table 7. Summary of χ^2 statistics from contingency table tests of homogeneity of age distributions, across methods (2), readers (2) and sexes. Animals of 15 year or older were pooled. Each test had 14 degrees of freedom, fetal frequencies are in Table 8.

Data Set	Test Factor	χ^2	$P(\chi^2)$
Females, Mean Readings (M_1)	Rdr_1 vs Rdr_2	52.17	<0.001
Males, M_1	" "	42.74	<0.001
Females, Last Reading (M_2)	" "	61.15	<0.001
Males, M_2	" "	45.08	<0.001
Females, Rdr_1	M_1 vs M_2	8.83	0.842
Males, Rdr_1	" "	2.83	0.999
Females, Rdr_2	" "	1.47	>0.999
Males, Rdr_2	" "	0.87	>0.999

Table 8. Coefficients of variation (CV) for two readers, broken down by age groups (3), with analysis of variance testing within-reader differences over age groups, and t-tests of between reader differences within age groups. Data are from female spotted dolphins killed in 1981.

Age Group (yrs)	n	(Reader 1) mean CV	SD	n	(Reader 2) mean CV	SD	$t(CV_1=CV_2)$	P(t)
*A≤4.0	12	1.35	3.20	12	3.08	4.26	1.136	0.134
4.0<A≤12.0	15	5.11	3.94	15	5.87	6.04	0.417	0.340
12.0<A	17	7.03	4.46	17	8.47	5.29	0.831	0.206
all	44	4.85	4.53	44	6.12	5.63	1.173	0.122

	Reader 1	Reader 2
Within Sum of Squares	648.536	1157.760
D.F.	41	41
Mean Square	15.818	28.238
Between Sum of Squares	232.247	205.183
D.F.	2	2
Mean Square	116.124	102.592
Equality of Means:		
F	7.341	3.633
D.F.	2, 41	2, 41
P(F)	0.0019	0.0353

*A is the pooled mean age.

Table 9. Indices of precision (D=CV/√n) for two readers, by age groups (3), with analysis of variance testing within-reader differences over age groups, and t-tests of between-reader differences within age groups. Data are from female spotted dolphins killed in 1981.

Age Group (yrs)	n	(Reader 1) mean D	SD	n	(Reader 2) mean D	SD	$t(D_1=D_2)$	P(t)
*A≤4.0	12	0.781	1.847	12	1.781	2.459	1.138	0.133
4.0<A≤12.0	15	2.948	2.277	15	3.388	3.484	0.418	0.339
12.0 A	17	4.088	2.576	17	4.889	3.057	0.829	0.206
all	44	2.798	2.613	44	3.529	3.250	1.169	0.123

	Reader 1	Reader 2
Within Sum of Squares	216.179	385.920
D.F.	41	41
Mean Square	5.273	9.413
Between Sum of Squares	77.416	68.394
D.F.	2	2
Mean Square	38.708	34.197
Equality of Means:		
F	7.341	3.633
D.F.	2, 41	2, 41
P(F)	0.002	0.035

*A is the pooled mean age.

Table 10. Means and standard deviations of age estimates for the 1981 female offshore spotted dolphin subsample. Age estimates are broken down by age group (G1=<4.0; 4.0<G2<12.0; 12.0<G3), reader (2) and cycle as a repeated measure within reader.

A N A L Y S I S   O F   V A R I A N C E

Cell Means and Standard Deviations
Variable . . AGEBEST

Factor	Code	Mean	Std. Dev.	N	95 Percent Conf. Interval	
AGE GROUP	1					
READER	1					
CYCLE	1	2.30833	1.24350	12	1.51825	3.09841
CYCLE	2	2.30833	1.25369	12	1.51178	3.10489
CYCLE	3	2.35000	1.26023	12	1.54929	3.15071
READER	2					
CYCLE	1	2.35833	1.29647	12	1.53460	3.18207
CYCLE	2	2.44167	1.26954	12	1.63504	3.24830
CYCLE	3	2.44167	1.29857	12	1.61659	3.26674
GROUP	2					
READER	1					
CYCLE	1	7.83333	2.96808	15	6.18966	9.47700
CYCLE	2	7.63333	2.78046	15	6.09357	9.17310
CYCLE	3	7.83333	3.05700	15	6.14042	9.52624
READER	2					
CYCLE	1	7.90000	2.68568	15	6.41272	9.38728
CYCLE	2	7.44000	2.27056	15	6.18261	8.69739
CYCLE	3	7.54667	2.76583	15	6.01500	9.07833
GROUP	3					
READER	1					
CYCLE	1	19.70588	4.36985	17	17.45911	21.95265
CYCLE	2	19.82353	4.85071	17	17.32952	22.31754
CYCLE	3	20.73529	5.26818	17	18.02665	23.44394
READER	2					
CYCLE	1	20.11765	5.67761	17	17.19849	23.03681
CYCLE	2	19.23529	4.29432	17	17.02736	21.44323
CYCLE	3	19.05882	4.42254	17	16.78497	21.33268
FOR ENTIRE SAMPLE		10.91212	8.09623	264	9.93098	11.89326

Table 11. Analysis of variance for 1981 female spotted dolphin subsample. Dependent variable is agebest. Factors tested were reader (2), size group (3) and cycle as a repeated measure within reader.

ANALYSIS OF VARIANCE

Tests of significance for agebest using sequential sums of squares

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig. of F
Within cells	2999.01269	246	12.19111		
Constant	31435.63880	1	31435.63880	2578.57099	0.0
Cycle W Reader (ERROR 1)	12.28833	4	3.07208	.25199	.908
G by Cycle W Reader (ERROR 2)	11.65552	8	1.45694	.11951	.998
ERROR 1	12.28833	4	3.07208		
READER	4.48242	1	4.48242	1.45908	.294
ERROR 2	11.65552	8	1.45694		
G	14206.09837	2	7103.04918	4875.32180	0.0
G by Reader	5.82388	2	2.91194	1.99867	.198

TOOTH READING RECORD

SPECIMEN, GENERAL

Reading of Day	* Specimen No.	Tooth of Specimen	Slide of Tooth	Preparation Date (yr. mo. day)	Preparator	Tooth Treatment	Mounting Medium
1	4	11	12	13	19	21	22

CONDITION OF SLIDE (1:Yes, blank:No/Unrecorded)

Note: if all 7 elements are blank, the slide is good.

Faded	Shrinkage	Off Center	Dark	Light	Shredded	Unknown
23	24	25	26	27	28	29

READING, GENERAL

* Reader Code	Request Remount/Recut	Reading Date (yr. mo. day)	Microscope I.D.	Pulp Cavity Condition
30	32	33	39	41

AGE RECORDED

(99.9: unknown, not recorded)

Best	High	Low
42	45	48

DENTINAL

Dentinal GLG Condition (1:Yes, blank:No/Unrecorded)

indistinct	irregular	pearls
51	52	53

* Number of Dentinal GLG's (99.9: unknown , not recorded)

Best	High	Low	Confidence of Reading
54	57	60	63

CEMENTAL

Cemental GLG Condition (1:Yes, blank:No/Unrecorded)

indistinct	multiples	halves
64	65	66

* Number of Cemental GLG's (99.9: unknown, not recorded)

Best	High	Low	Confidence of Reading
67	70	73	76

Note: ____

Stock Code

77

CODE TABLES:

* Can not be blank

"SPECIMEN, GENERAL"

Preparator (1.19-20)
- 01 SLOAN
- 02 KIMURA
- 03 STANLEY
- 04 HOHN
- 05 BIOANALYSIS INC.
- 06 PERRIN, ET AL

Tooth Treatment (1.21)
- 1 STAINED
- 2 UNSTAINED

Mounting Medium (1.22)
- 1 PERMOUNT
- 2 GLYCERIN JELLY
- 3 GLYCERIN

"READING, GENERAL"

Reader Code (1.30-31)

01 PERRIN	13 MEAD
02 HOLTS	14 ODELL
03 CLAPP	15 STUART
04 SUANICO	16 KASUYA
05 COE	17 BROWNELL
06 MYRICK	18 HOHN
07 HENDERSON	19
08 KIMURA	20
09 SLOAN	21
10 HUI	22
11 SEAGARS	
12 GUREVICH	

Confidence of Reading (1.32)
- 1 EXCELLENT
- 2 VERY GOOD
- 3 GOOD
- 4 OK
- 5 MARGINAL
- 6 UNACCEPTABLE

Request Remount/Recut (1.33)
- 'blank' NO ACTION
- 1 YES, REMOUNT
- 2 YES, RECUT
- 3 UNKNOWN

Microscope I.D. (1.40-41)
- 01 PETROGRAPHIC PHOTOMICROSCOPE
- 02 ZEISS COMPOUND

Pulp Cavity Condition (1.42)
- 1 OPEN
- 2 NARROW
- 3 CLOSED?/CLOSED

Figure 1. Coding format used for dolphin tooth ageing record.

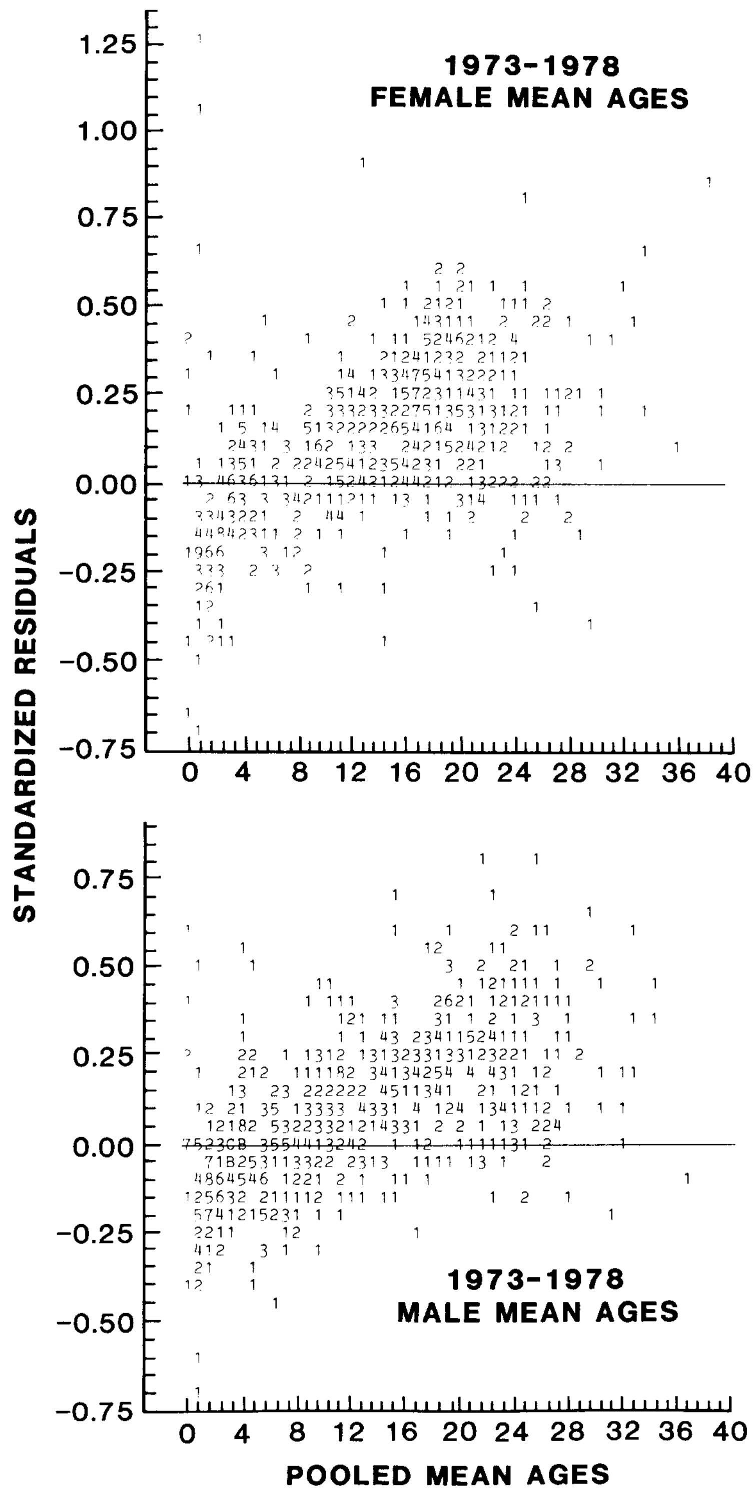

Figure 2. Plots of signed difference between individual readers' mean estimates as a percent of the mean pooled age. The data are from female offshore spotted dolphins, 1973-78 sample: Females in the upper panel, males in the lower panel.

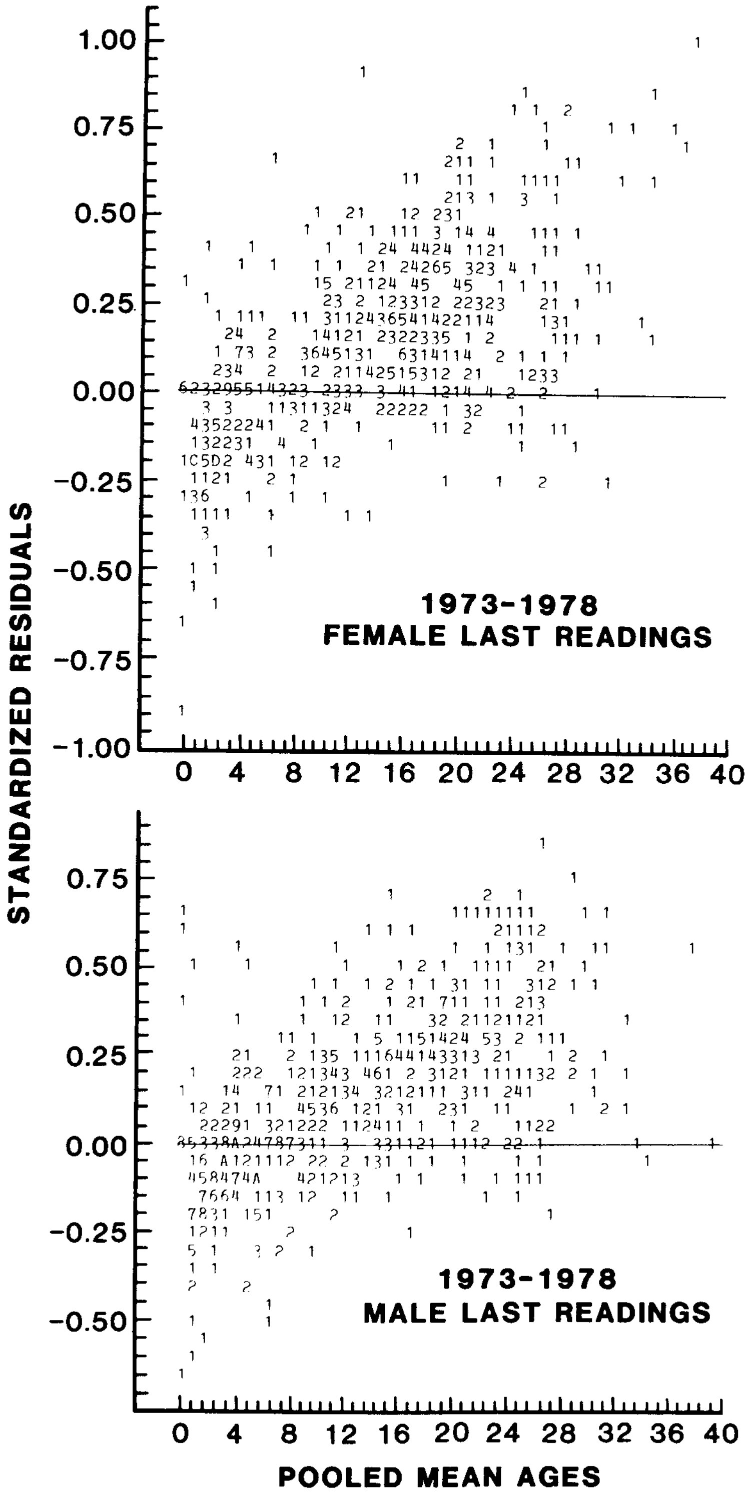

Figure 3. Plots of signed difference between individual readers' estimates from last readings as a percent of the pooled mean age. The data are from offshore spotted dolphins, 1973-78 sample: Females in the upper panel, males in the lower panel.

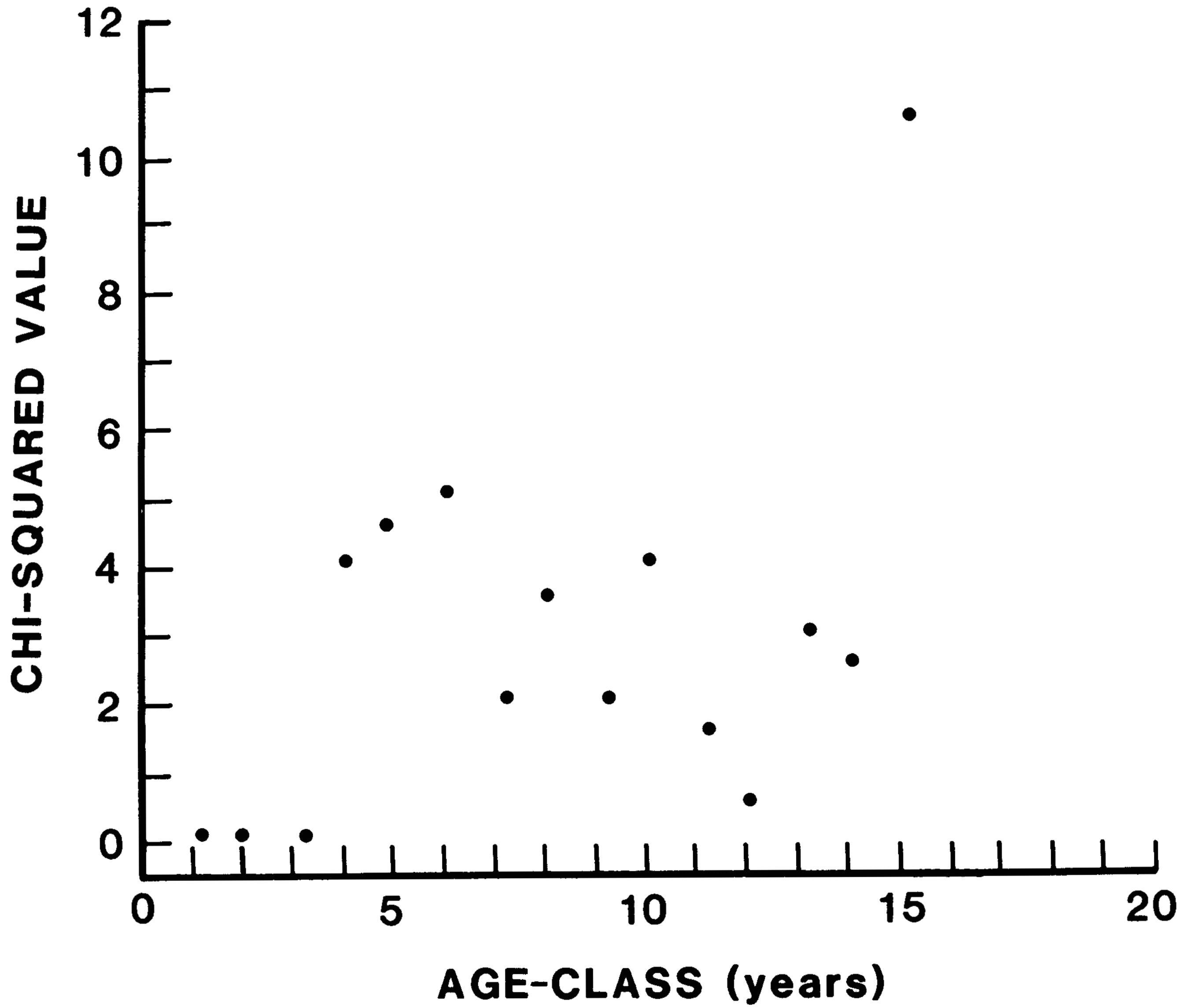

Figure 4. Chi-squared values by age-group, from comparison of frequencies of female spotted dolphins, as estimated by two different readers. The age statistics compared were means of multiple readings per specimen by each reader.

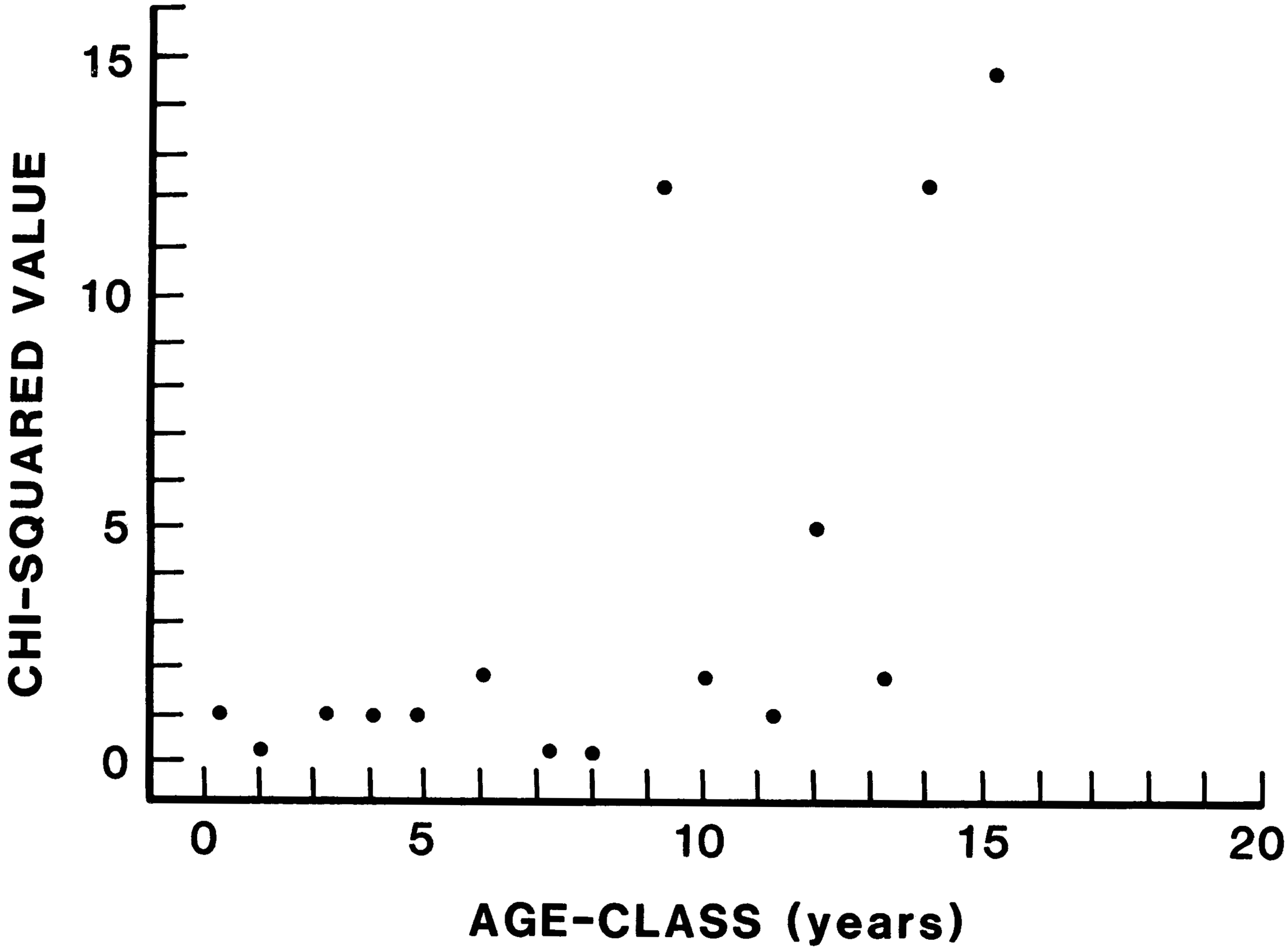

Figure 5. Chi-squared values by age-group, from comparison of frequencies of male spotted dolphins, as estimated by two different readers. The age statistics compared were means of multiple readings per specimen by each reader.

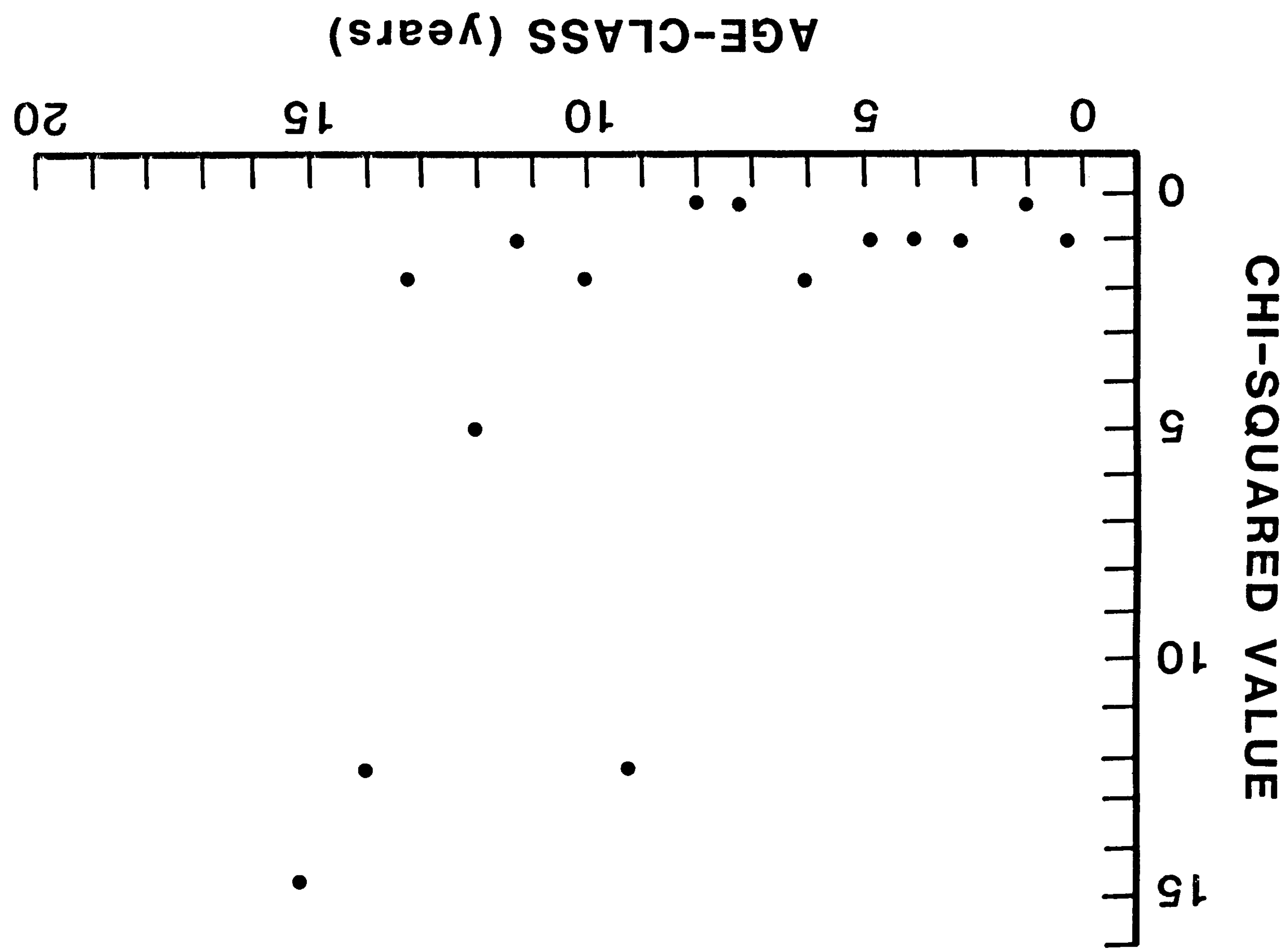

Figure 5. Chi-squared values by age-group, from comparison of frequencies of male spotted dolphins, as estimated by two different readers. The age statistics compared were means of multiple readings per specimen by each reader.

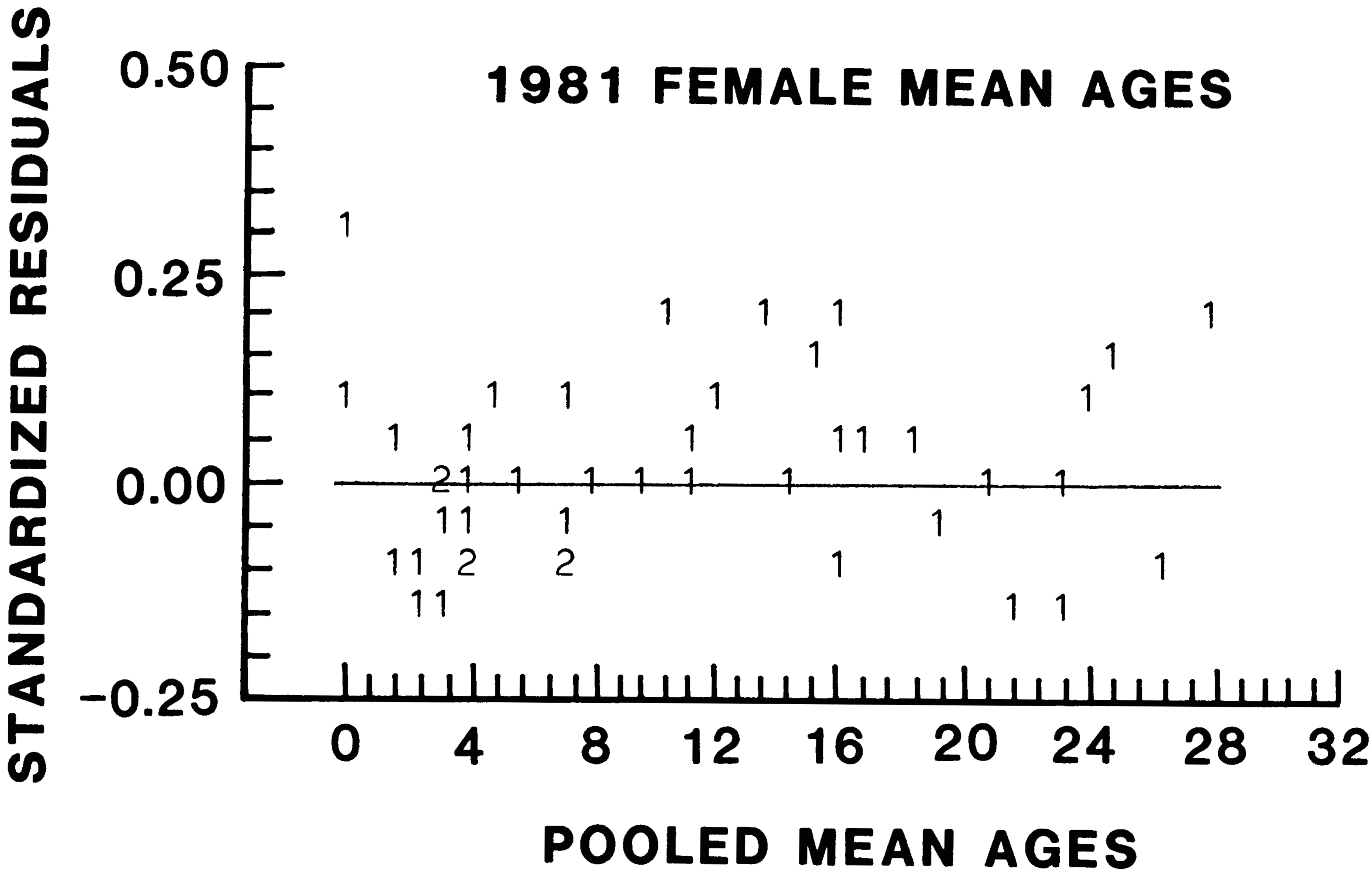

Figure 6. Plots of signed differences between reader estimates as a percent of the pooled mean age. The data are from female offshore spotted dolphins, 1981 sample.

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