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L_1 DETERMINATION FROM SCALES AND OTOLITHS

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Introduction

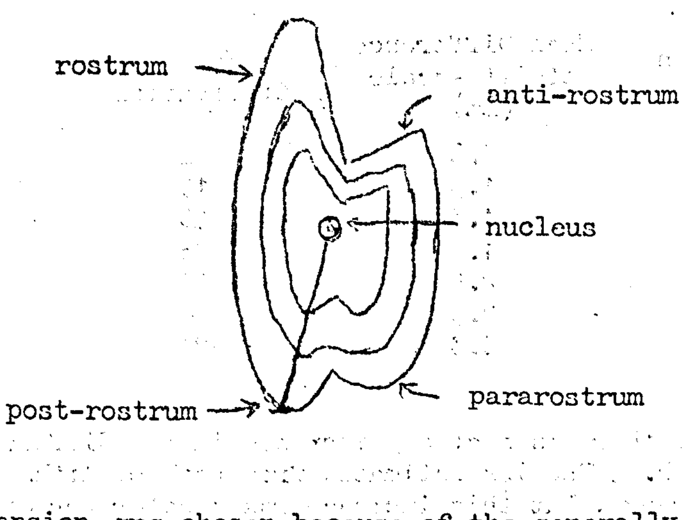
In recent years there has been a marked increase in the use of otoliths in herring biological investigations. In Scottish investigations they have replaced scales for routine age determination, the use of scales being confined to growth studies, in particular for routine estimations of L_1. However, owing to the extra labour involved in collecting and mounting scale material, in addition to otoliths, and to the difficulty in obtaining good quality scales from herring caught by trawl, a number of workers have investigated the possible use of otoliths in routine growth studies; the results of such an investigation for Baltic herring were presented by Dzin-Gi-Jun and J. Popiel at the meeting of the Herring Committee in 1961. This report deals with a similar study on autumn spawners from the north-western North Sea.

Material and Methods

The otoliths and scales used in this study were taken from the same fish collected during routine sampling at Scottish east coast ports during the summer drift net fishery in the north-western North Sea. Additional material from smaller, adolescent herring was also taken from the landings of the young herring fishery in the Moray Firth.

L_1 estimates from scales were made in the normal, routine manner from measurements made on their projected images, and using simple proportion estimations (see "Report on Methods used in North Sea Herring Investigations").

The corresponding otolith measurements were made from the centre of the nucleus to the post-rostrum, as shown in the following diagram:-



This dimension was chosen because of the generally better definition of the first (and usually the 2nd and 3rd) winter zone in the post-rostrum region of the otolith than in other regions, especially along the rostrum. However, a series of estimates of L_1 from measurements taken from the nucleus to the antirostrum, pararostrum and postrostrum gave approximately the same average values, and there was no evidence of systematic differences between them.

Most of the otolith measurements were made on photographs taken in the course of routine otolith investigations (Parrish and Sharman, 1959), but initially, a series of comparable microscope measurements were also made, using an eyepiece micrometer. These, again gave approximately the same average values.

As for scales, the estimations of l_1 were made directly from the otolith and fish length measurements, by simple proportion.

Results

The estimations of l_1, for otoliths and scales from the same fish, for pre-spawners (maturity stages II and III) in the north-western North Sea in 1958, for 3-13 year old spawners (maturity stages VI and VII) in 1955, and for one year old adolescent herring (maturity stage I) in 1955 are given in Figs. 1, 2 and 3 respectively. In Fig. 1 estimates for "narrow" and "wide" otolith types are shown separately, while in Figs. 2 and 3, the estimates are all for "narrow" type otoliths.

These results show that, in almost all cases, the estimates of l_1 from otoliths were larger than those from scales. The mean differences for the three sets of observations, based on the "narrow" otolith type, in Figs. 1-3 are given below.

	Adolescent herring 1955	Pre-spawners 1958	Spawners 1955
Mean difference (otolith-scale)	1.2	2.5	3.0
No. of observations	68	230	67

Thus, it seems that there is a large, highly significant systematic difference between the estimates of l_1 made from the two structures, which cannot be attributed to errors in the interpretation of the position of the winter zones in either the scales or otoliths (although a small number of the extreme differences shown in Figs. 1 and 2 might be due to this). Moreover, the smaller difference for the adolescent herring than for the adults, suggests that the bias increases with the size and age of the fish. The extent of this increase is shown in the following table, which gives the mean differences between l_1s estimated from otoliths and scales, for successive 2 cm size groups of fish (material for adolescents and pre-spawners only).

Length of Fish (cm)	Mean Difference otolith-scale (mm)	No. of Observations
16.5-18.4	0.8	2
18.5-20.4	1.3	19
20.5-22.4	1.3	46
22.5-24.4	1.9	23
24.5-26.4	2.4	113
26.5-28.4	2.5	70
28.5-30.4	3.3	21

These data show that there is a steady increase in the differences over the size range of the fish. The l_1s estimated from both otoliths and scales increased over the size range, but this increase was greater for otoliths than for scales, thus causing the greater differences between them for the larger fish.

A similar analysis for fish of the same size, but of different ages, showed no significant change in the bias with age alone.

Discussion

The large systematic bias, and its increase with the size of fish, suggests that it is at least partly associated with differences between the relative growths of the two structures and the growth in length of the fish. With both structures, the estimates of l_1 were made, using a simple proportion equation, as follows:-

$$l_1 = \frac{v_1}{V} \cdot L. \qquad (1)$$

where l_1 = length of fish at formation of 1st winter zone

L = total length of fish

v_1 = otolith and scale measurement to 1st winter zone

V = total otolith and scale measurement

This equation is strictly only valid if the relationship between the growth of the otolith and scale is linear, of the form $L = BV$, with the regression of fish length and otolith or scale length, passing through the origin. Biassed estimates will be obtained if it is curvilinear, or linear, of the form $L = A + BV$, with the regression of fish length on otolith or scale length having a significant intercept. In the latter case, unbiassed estimates of l_1 are given by the expression,

$$l_1 = \frac{v_1}{V} \cdot L. + A\left(1 - \frac{v_1}{V}\right), \qquad (2)$$

where A[1] is the intercept of the linear regression of fish length on otolith or scale length (Lea, 1938; Parrish, 1956).

Lea (1938) found that for Norwegian and Swedish scale material, the growth equation was of this linear form, with values of "A" ranging between 10 and 19 mm. Recent data for northern North Sea autumn spawners between 18 and 31 cm in length also give a similar linear relationship with a best estimate for "A" of 21 ± 6.5 mm.

An analysis of the growth relationship for otoliths has also been made on material collected from northern North Sea autumn spawners, between 5 and 31 cm long. The data for the nucleus-postrostrum lengths, plotted against fish length, are presented in Fig.4, together with the best fitting linear regression line[2].

As for scales, a linear relation provides the best fit to the data over the range of measurements considered. Furthermore, the intercept "A" of the regression is not significantly different from zero. It would seem therefore, that the simple proportionality equation is a valid one for estimating the l_1s from otoliths, using the nucleus-postrostrum distance.

Therefore, it seems likely from the available data that at least part of the difference between the l_1 estimates from otoliths and scales can be attributed to the method of estimation. Consequently, the estimates made from scales from adult pre-spawners were corrected, using expression (2), and a value of "A" of 21 mm, derived from the northern North Sea data.

The application of this correction reduced the mean difference between the otolith and scale estimates, from 2.5 cm for the adult pre-spawners, to 1.4 cm, and smoothed out, to some extent, the difference over the size range fish. That this difference is still highly significant, showing that the corrections used, accounts for only about half the total discrepancy between the estimates from the two structures.

1/ The value of A does not necessarily correspond with the length of the fish when scales are first formed.

2/ The points given in Fig.4 are the means of numbers of otolith measurements for cm length groups of fish. However, the regression equation was calculated from the individual measurements of otolith and fish in mm.

With the data available at present it is not possible to investigate the causes of the total discrepancy. It is possible that the true value of the intercept of the scale-fish length regression is higher than that used in the above corrections; it was derived from a relatively small number of observations (112) over a relatively narrow size range (20-30 cm), above the range of estimated l_1s. A value of "A" of between 40 and 50 mm would be sufficient to eliminate the average discrepancy between the estimates. A further, more extensive study of the growth of both scales and otoliths relative to growth in length of the fish is needed in order to determine more accurately the form of the relations over the whole range of sizes from the end of the first year's growth to the largest sizes normally encountered amongst North Sea autumn spawners.

References

Dzin-Gi-Jung and Popiel, J. 1961. Back calculation of the herring growth rate from scales and otoliths. Paper presented to I.C.E.S., C.M. 1961 Herring Committee No.114.

Lea, E. 1938. A modification of the formula for calculation of the growth of herring. Rapp. Int. Explor. Mer, 108(1), 13-22.

Parrish, B. B. 1956. The cod, haddock and hake. Graham, M. ed. Sea fisheries: their investigation in the United Kingdom. Chap. 7, pp.251-331. London, Arnold.

Figure 1.

Estimates of L_1 from scales and otoliths of adult prespawners (stages VII-II to V). Buchan Area 1958.

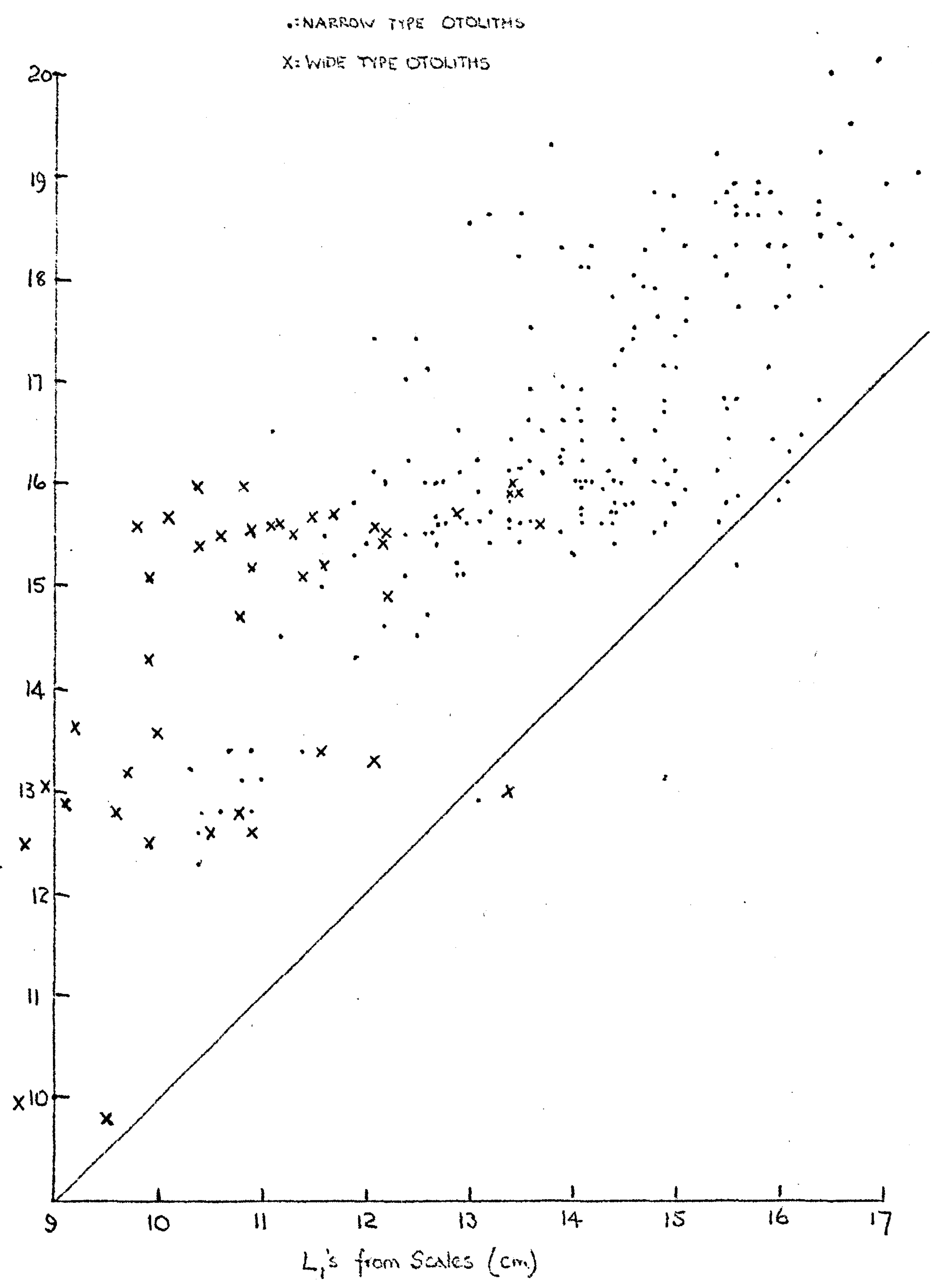


Figure 2.

Estimates of L_1 from scales and otoliths (narrow type) of adult spawners (stages VI and VII). Buchan Area 1955.

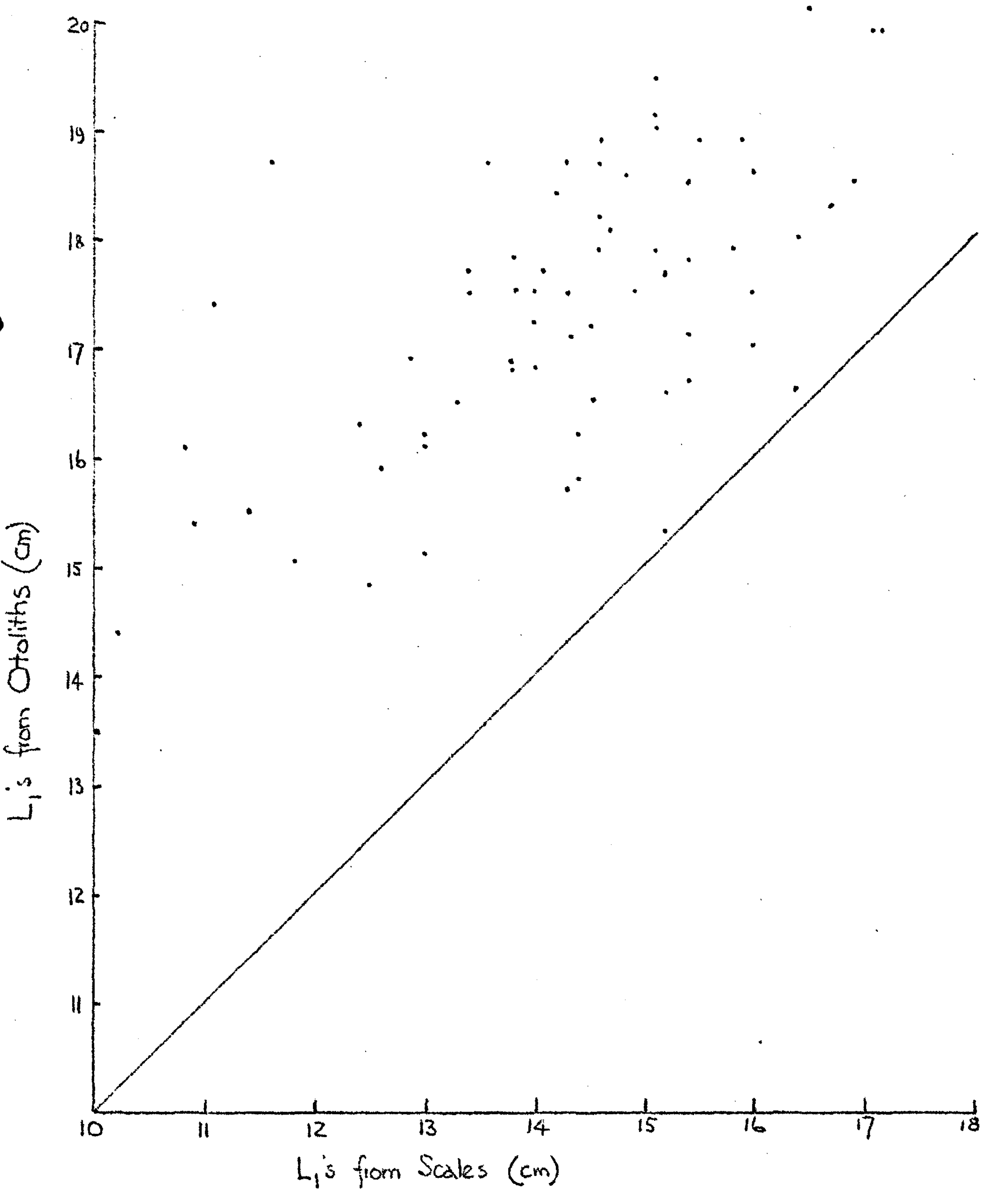


Figure 3.

Estimates of L_1 from scales and otoliths of adolescent herring (1 group). Moray Firth 1955.

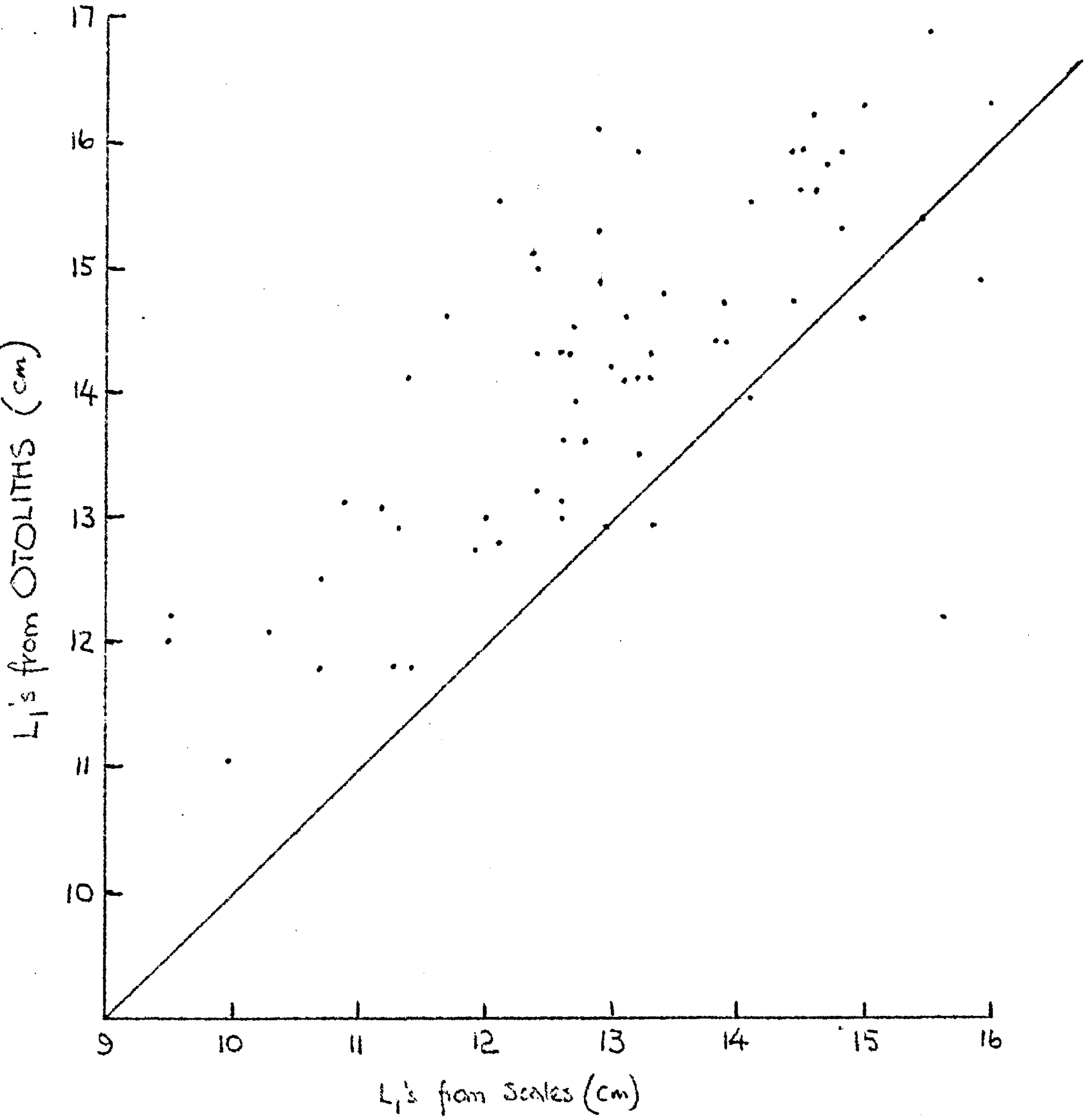


Figure 4.

Regression of fish length on otolith length.