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# $L_1$ Calculations from Herring Otoliths

by

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## Introduction

Often few, if any, good scales can be obtained from samples of trawl-caught herring. For this reason the possibility was investigated of using herring otoliths, instead of scales for growth calculations. The validity of the use of $L_1$ values proportioned from herring scales is based upon the fact that the relationship between the growth of certain scales and the growth of the fish itself is linear over nearly all its range. This was demonstrated by Lea (Hjort, 1910), who also showed that the error involved in calculating $L_1$s from herring scales was very small.

The relationship between otolith and fish growth in the herring was not known. It was decided therefore to examine this relationship in 0-group herring up to the formation of the first winter ring in the otoliths, and to compare $L_1$ values calculated from both otoliths and scales.

## Material and Methods

A large number of 0-group herring otoliths were available for examination from samples collected between 1953-56. The samples from which these otoliths came had been examined in detail and it was known with a fair degree of certainty from which spawning stock (spring, longshore, autumn or winter) each originated (Wood, 1959). A number of otoliths from large 0-1 group herring ( $>$ 12 cm) collected more recently on research ship cruises were also examined. These were all assumed to be autumn spawned.

The otoliths to be measured were selected in order to cover adequately, as far as possible, the length range occurring in 0-1 group herring in each of the four spawning groups (spring, longshore, autumn and winter). Each otolith was measured along two axes (Figure 1) in micrometer eyepiece units, using a binocular microscope with a X25 magnification, which gave a ratio of 25 eyepiece units to 1 millimetre. The axes were chosen to give the measurements of the width and length of each otolith. Both otoliths from each fish were measured, if possible, but often only one otolith was available.

A number of otoliths from adult herring were also measured. These herring came from samples obtained in the North Shields, Aberdeen, Whitby and East Anglian fisheries. Besides total width and total length, the width and length of the $L_1$ to the outside edge of the first winter ring were also measured. The otoliths were selected from fish which had a scale $L_1$ range from 5.8 to 21.1 cm.

## Results

All otolith measurements made on the 0-1 group herring have been plotted in Figure 1. Clearly the growth rates on the two axes of the otolith are quite different, for while there is little increase in otolith width after a fish length of about 13 cm has been reached, there is a fairly sharp increase in otolith length with fish length even up to the maximum fish length here of 21.6 cm. It is important to note that neither regression is linear.

As could be expected from variability in otolith shape, there is a fair degree of scatter on the values plotted in Figure 1. However, especially at the lower end of each regression, some of this is due to the fact that for the same length of fish there is a marked difference in both otolith width and length, dependent upon the time of spawning. In Table 1 the means of otolith width, otolith length and fish length are given for each of the four spawning groups (spring, longshore, autumn and winter) calculated from all the observations within each cm interval of fish length. Without doubt the largest otoliths are from the herring of the longshore group, which spawn in late spring. Incidentally, although there does not seem to be any direct connection, because the otolith commences growing long before the fish metamorphic length is reached, it is interesting to note that the herring of the longshore group metamorphose at a much smaller length than those of the other groups. Intermediate in size are the true spring-spawned and winter-spawned herring, which have otoliths of fairly similar size and which both metamorphose at approximately the same length, while the autumn-spawned herring, which metamorphose at the largest length of all the group, have the smallest otoliths. The asymptotic nature of the composite regression shown in Figure 1 is also present in each individual spawning group. This can be seen in Table 1.

Although the origin of some of these herring could be disputed, it is a fact that similar conclusions were reached by Mužinić on the otoliths of spring-spawned and early autumn-spawned sardines of the mid-Dalmatian stock (Mužinić, 1952).

From the measurements made on the adult herring otoliths, $L_1$ values were calculated by simple proportion. These are listed in Table 2, together with other $L_1$ values from the otolith measurements, read off from the curves which have been fitted by eye to the regressions in Figure 1. Also given in Table 2 is the "error", or difference between the scale $L_1$ and each otolith $L_1$ value, obtained by both methods.

As would be expected from the nature of the relationships involved, the errors on $L_1$s proportioned from both the otolith width (mean 4.3 cm) and otolith length (mean 2.5 cm) are too high for this method of $L_1$ calculation to be of any use.

The errors are much reduced when $L_1$s are read off directly from the curves in Figure 1, the means being 1.4 cm on the otolith width and 0.9 cm on the otolith length. Although the mean errors are substantially lower, in some cases the individual errors are still too high if accurate $L_1$ values are required. This method of $L_1$ measurement might, however, prove of value where some idea of $L_1$ size was essential and no scales were available. Nevertheless, it is quite clear that for accurate $L_1$ calculations it is vital to use herring scales.

## Summary

1. In 0-1 group herring the relationship between the growth of the otolith along two axes (i.e. width and length) and the growth in length of the fish was investigated.

2. It was found that this relationship on both axes was curvilinear and that the rate of growth of the otolith on both axes progressively decreased as fish length increased. This was much more marked on the otolith width than on the otolith length.

3. It was shown that, in 0-group herring, the otolith size varies with time of spawning.

4. It was shown that the errors in proportioning $L_1$s from measurements of herring otolith width and length were too high for this method to be of any real value. The mean error, however, was found to be less than 1 cm when $L_1$s were read off directly from the otolith length/fish length curve for 0-1 group herring. It was suggested that this method of obtaining $L_1$ values from herring otoliths might be of value in cases where some idea of $L_1$ size was essential, but no scales were available.

## References

Hjort, J. 1910 "Report on herring investigations until January 1910" ICES, Publ. de Circ., 53.

Wood, R. J. 1959 "Investigations on 0-group herring". J.Cons.Int. Explor. Mer, 24(3).

Mužinić, R. 1952 "Remarques sur le développement et la croissance des otolithes de la sardine (Clupea pilchardus Walb.)" Acta Adriatica, 4(13).

NB. The otoliths from fish larger than 12 cm were all considered to be of the autumn spawned origin, owing to the lack of evidence to suggest that any were in fact of other origin.

Table 1. Comparison of otolith size in 0-group herring spawned at different times.

Mean Otolith Width in EPU'S

| Mean length of fish (cm) | Spring | L/shore | Autumn | Winter |
|---|---|---|---|---|
| Numbers of fish in brackets | | | | |
| 2.8 (1) | | 9.0 | | |
| 2.9 (2) | | | | 4.75 |
| 3.5 (8) | | 12.5 | | |
| 3.6 (32) | | | | 9.5 |
| 3.7 (6) | 10.4 | | | |
| 4.3 (27) | | | | 11.9 |
| 4.4 (5) | | 15.7 | | |
| 4.5 (12) | 13.5 | | | |
| 4.6 (18) | | | 10.9 | |
| 5.3 (12) | | | | 15.9 |
| 5.4 (16) | | | 13.8 | |
| 5.6 (16) | 16.6 | | | |
| 5.6 (10) | | 18.6 | | |
| 6.1 (6) | 17.6 | | | |
| 6.4 (9) | | | | 21.6 |
| 6.5 (13) | | 22.3 | | |
| 6.5 (22) | | | 19.2 | |
| 7.4 (6) | | 24.8 | | |
| 7.5 (6) | | | | 23.9 |
| 7.5 (28) | | | 20.8 | |
| 8.4 (18) | | | | 26.4 |
| 8.5 (18) | | | 23.5 | |
| 9.4 (20) | | | | 27.6 |
| 9.5 (22) | | | 25.9 | |
| 10.3 (1) | | | 27.0 | |
| 10.5 (13) | | | | 29.6 |
| 11.4 (15) | | | | 30.9 |
| 11.8 (4) | | | 32.0 | |
| 12.4 (8) | | | | 32.3 |
| 12.5 (15) | | | 32.7 | |

Mean Otolith Length in EPU'S

| Mean length of fish (cm) | Spring | L/shore | Autumn | Winter |
|---|---|---|---|---|
| Numbers of fish in brackets | | | | |
| 3.6 (6) | | 19.2 | | |
| 3.7 (6) | 13.8 | | | |
| 3.7 (7) | | | | 12.6 |
| 4.3 (2) | | 23.8 | | |
| 4.4 (13) | | | | 18.6 |
| 4.5 (12) | 18.1 | | | |
| 4.6 (18) | | | 14.2 | |
| 5.3 (10) | | | | 24.4 |
| 5.4 (17) | | | 19.0 | |
| 5.5 (14) | 25.1 | | | |
| 5.6 (4) | | 31.9 | | |
| 6.1 (6) | 27.4 | | | |
| 6.3 (6) | | | | 35.2 |
| 6.4 (19) | | | 31.2 | |
| 6.6 (9) | | 38.1 | | |
| 7.3 (14) | | | 34.3 | |
| 7.4 (6) | | 41.2 | | |
| 7.5 (6) | | | | 42.3 |
| 8.4 (15) | | | | 45.7 |
| 8.6 (11) | | | 39.3 | |
| 9.4 (20) | | | | 49.8 |
| 9.5 (19) | | | 44.8 | |
| 10.5 (7) | | | | 52.7 |
| 10.5 (2) | | | 49.5 | |
| 11.5 (9) | | | | 58.8 |
| 11.6 (12) | | | 57.6 | |
| 12.4 (7) | | | | 61.2 |
| 12.4 (10) | | | 60.4 | |

Table 2. Comparison of $L_1$ s from herring otoliths and from scales.

| Reference Number of Fish | Otolith Width in Micrometer Eye Piece Units | | Otolith Length in Micrometer Eye Piece Units | | Fish Length (cm) | Fish Age in Growth Zones | Scale $L_1$ | Otolith $L_1$ by Proportion (cm) | | Otolith $L_1$ by extrapolation from graph (cm) | | Difference between Scale $L_1$ and Otolith $L_1$ (cm) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | By Proportion | | From Graph | |
| | $L_1$ | Total | $L_1$ | Total | | | (cm) | Width | Length | Width | Length | Width | Length | Width | Length |
| 2M62/92 | 23 | 5o | 35 | 1o5 | 23.8 | 4 | 5.8 | 1o.9 | 7.9 | 7.7 | 6.9 | +5.1 | +2.1 | +1.9 | +1.1 |
| | 23 | 5o | 4o | 1o9 | | | | 1o.9 | 8.7 | 7.7 | 8.6 | +5.1 | +2.9 | +1.9 | +2.8 |
| 2M62/34 | 24 | 51 | 38 | 1o3 | 23.o | 4 | 5.9 | 1o.8 | 8.5 | 8.1 | 7.4 | +4.9 | +2.6 | +2.2 | +1.5 |
| | 24 | 51 | 38 | 1o3 | | | | 1o.8 | 8.5 | 8.1 | 7.4 | +4.9 | +2.6 | +2.2 | +1.5 |
| 12NS61/9 | 22 | 5o | 35 | 1o6 | 26.6 | 7 | 6.5 | 11.7 | 8.8 | 7.3 | 6.9 | +3.2 | +2.3 | +o.8 | +o.4 |
| | 23 | 5o | 35 | 1o7 | | | | 12.2 | 8.7 | 7.7 | 6.9 | +5.7 | +2.2 | +1.2 | +o.4 |
| 39EA61/4 | 25 | 5o | 42 | 1o2 | 24.3 | 4 | 6.8 | 12.2 | 1o.o | 8.5 | 8.2 | +5.4 | +3.2 | +1.7 | +1.4 |
| | 25 | 5o | 44 | 1o3 | | | | 12.2 | 1o.4 | 8.5 | 8.6 | +5.4 | +3.6 | +1.7 | +1.8 |
| 39EA61/22 | 24 | 41 | 44 | 92 | 23.8 | 3 | 7.5 | 13.9 | 11.4 | 8.1 | 8.6 | +6.4 | +3.9 | +o.6 | +1.1 |
| | 25 | 4o | 44 | 93 | | | | 14.9 | 11.3 | 8.5 | 8.6 | +7.4 | +3.8 | +1.o | +1.1 |
| 8NS61/21 | 27 | 48 | 47 | 1o4 | 24.3 | 4 | 7.5 | 13.7 | 11.o | 9.3 | 9.3 | +6.2 | +3.5 | +1.8 | +1.8 |
| | 27 | 47 | 48 | 1o7 | | | | 14.o | 1o.9 | 9.3 | 9.4 | +6.5 | +3.4 | +1.8 | +1.9 |
| 27NS61/5o | 29 | 44 | 52 | 97 | 25.2 | 3 | 8.4 | 16.6 | 13.5 | 1o.4 | 1o.3 | +8.2 | +5.1 | +2.o | +1.9 |
| | 29 | 45 | 53 | 97 | | | | 16.2 | 13.8 | 1o.4 | 1o.6 | +7.8 | +5.4 | +2.o | +2.2 |
| 39EA61/67 | 27 | 42 | 45 | 88 | 22.7 | 3 | 8.6 | 14.6 | 11.6 | 9.3 | 8.8 | +6.o | +3.o | +o.7 | +o.2 |
| | 27 | 42 | 46 | 89 | | | | 14.6 | 11.7 | 9.3 | 9.o | +6.o | +3.1 | +o.7 | +o.4 |
| 31NS61/2o | 29 | 46 | 52 | 1o1 | 23.7 | 3 | 9.1 | 14.9 | 12.2 | 1o.4 | 1o.3 | +5.8 | +3.1 | +1.3 | +1.2 |
| | 28 | 45 | 53 | 1o3 | | | | 14.7 | 12.2 | 9.8 | 1o.6 | +5.6 | +3.1 | +o.7 | +1.5 |
| 39EA61/7 | 27 | 47 | 49 | 1oo | 26.6 | 4 | 9.4 | 15.3 | 13.o | 9.3 | 9.7 | +5.9 | +3.6 | -o.1 | +o.3 |
| | 27 | 47 | 5o | 1o2 | | | | 15.3 | 13.o | 9.3 | 9.9 | +5.9 | +3.6 | -o.1 | +o.5 |
| 32NS61/35 | 29 | 42 | 53 | 93 | 23.4 | 3 | 1o.2 | 16.2 | 13.3 | 1o.4 | 1o.6 | +6.o | +3.1 | +o.2 | +o.4 |
| | 28 | 41 | 53 | 92 | | | | 16.o | 13.5 | 9.8 | 1o.6 | +5.8 | +3.3 | -o.4 | +o.4 |
| 33NS61/5 | 29 | 41 | 59 | 96 | 25.o | 3 | 1o.9 | 17.7 | 15.4 | 1o.4 | 12.1 | +6.8 | +4.5 | -o.5 | +1.2 |
| | 29 | 43 | 59 | 97 | | | | 16.9 | 15.2 | 1o.4 | 12.1 | +6.o | +4.3 | -o.5 | +1.2 |
| 39EA61/72 | 31 | 53 | 55 | 1o8 | 28.3 | 5 | 11.1 | 16.6 | 14.4 | 11.4 | 11.1 | +5.5 | +3.3 | +o.3 | 0 |
| | 3o | 53 | 56 | 1o7 | | | | 16.o | 14.8 | 1o.8 | 11.4 | +4.9 | +3.7 | -o.3 | +o.3 |
| 8NS61/39 | 32 | 45 | 59 | 97 | 24.o | 3 | 11.5 | 17.1 | 14.6 | 12.o | 12.2 | +5.6 | +3.1 | +o.5 | +o.7 |
| | 33 | 44 | 6o | 99 | | | | 18.o | 14.5 | 12.6 | 12.4 | +6.5 | +3.o | +1.1 | +o.9 |

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| Reference Number of Fish | Otolith Width in Micrometer Eye Piece Units | | Otolith Length in Micrometer Eye Piece Units | | Fish Length (cm) | Fish Age in Growth zones | Scale $L_1$ | Otolith $L_1$ by Proportion (cm) | | Otolith $L_1$ by extrapolation from graph (cm) | | Difference between Scale $L_1$ and Otolith $L_1$ (cm) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | By Proportion | | From Graph | |
| | $L_1$ | Total | $L_1$ | Total | | | (cm) | Width | Length | Width | Length | Width | Length | Width | Length |
| 34NS61/81 | 32 | 45 | 63 | 1oo | 24.1 | 3 | 12.1 | 17.1 | 15.2 | 12.o | 13.2 | +5.o | +3.1 | -o.1 | +1.1 |
| | 32 | 44 | 61 | 99 | | | | 17.6 | 14.8 | 12.o | 12.7 | +5.4 | +2.7 | -o.1 | +o.6 |
| 34NS61/72 | 29 | 44 | 6o | 97 | 25.7 | 3 | 12.7 | 16.9 | 15.9 | 1o.4 | 12.4 | +4.2 | +3.2 | -2.3 | -o.3 |
| | 28 | 42 | 58 | 95 | | | | 17.1 | 15.7 | 9.8 | 11.8 | +4.4 | +3.o | -2.9 | -o.9 |
| 35EA61/31 | 33 | 51 | 66 | 116 | 27.9 | 5 | 13.4 | 18.1 | 15.9 | 12.6 | 14.2 | +4.7 | +2.5 | -o.8 | +o.8 |
| | 34 | 53 | 68 | 116 | | | | 17.9 | 16.4 | 13.3 | 14.7 | +4.5 | +3.o | -o.1 | +1.3 |
| 34NS61/95 | 33 | 43 | 63 | 95 | 25.6 | 3 | 13.6 | 18.4 | 17.o | 12.6 | 13.2 | +4.8 | +3.4 | -1.o | -o.4 |
| | 34 | 46 | 62 | 95 | | | | 18.9 | 16.7 | 13.3 | 12.9 | +5.3 | +3.1 | -o.3 | -o.7 |
| 35EA61/15 | 34 | 47 | 68 | 95 | 21.2 | 2 | 14.1 | 15.3 | 15.2 | 13.3 | 14.7 | +1.2 | +1.1 | -o.8 | +8.6 |
| | 34 | 46 | 66 | 95 | | | | 15.7 | 14.7 | 13.3 | 14.2 | +1.6 | +o.6 | -o.8 | +o.1 |
| 34NS61/76 | 36 | 48 | 7o | 1o4 | 26.1 | 3 | 14.7 | 19.6 | 17.6 | 15.o | 15.4 | +4.9 | +2.9 | +o.3 | +o.7 |
| 39EA61/46 | 31 | 45 | 67 | 98 | 27.5 | 3 | 15.5 | 18.9 | 18.8 | 11.4 | 14.6 | +3.4 | +3.3 | -4.1 | -o.9 |
| | 32 | 45 | 64 | 97 | | | | 19.6 | 18.1 | 12.o | 13.6 | +4.1 | +2.6 | -3.5 | -1.9 |
| 33NS61/46 | 34 | 46 | 73 | 1o4 | 26.4 | 3 | 15.6 | 19.5 | 18.5 | 13.3 | 16.5 | +3.9 | +2.9 | -2.3 | +o.9 |
| | 33 | 46 | 72 | 1o4 | | | | 18.9 | 18.3 | 12.6 | 16.1 | +3.3 | +2.7 | -3.o | +o.5 |
| 34NS61/91 | 35 | 47 | 69 | 97 | 26.3 | 3 | 16.3 | 19.6 | 18.7 | 14.2 | 15.1 | +3.3 | +2.4 | -2.1 | -1.2 |
| | 35 | 47 | 67 | 95 | | | | 19.6 | 18.5 | 14.2 | 14.6 | +3.3 | +2.2 | -2.1 | -1.7 |
| 39EA61/5 | 36 | 43 | 75 | 97 | 23.1 | 2 | 16.4 | 19.3 | 17.9 | 15.o | 17.1 | +2.9 | +1.5 | -1.4 | +o.7 |
| | 35 | 42 | 75 | 98 | | | | 19.3 | 17.7 | 14.2 | 17.1 | +2.9 | +1.3 | -2.2 | +o.7 |
| 35EA61/4 | 37 | 49 | 76 | 1o8 | 26.8 | 3 | 17.3 | 2o.2 | 18.9 | 16.5 | 17.5 | +2.9 | +1.6 | -o.8 | +o.2 |
| | 37 | 48 | 76 | 1o8 | | | | 2o.7 | 18.9 | 16.5 | 17.5 | +3.4 | +1.6 | -o.8 | +o.2 |
| 34NS61/6o | 37 | 47 | 77 | 1o5 | 26.2 | 3 | 17.5 | 2o.6 | 19.2 | 16.5 | 17.9 | +3.1 | +1.7 | -1.o | +o.4 |
| | 36 | 47 | 77 | 1o4 | | | | 2o.1 | 19.4 | 15.o | 17.9 | +2.6 | +1.9 | -2.5 | +o.4 |

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| Reference Number of Fish | Otolith Width in Micrometer Eye Piece Units | | Otolith Length in Micrometer Eye Piece Units | | Fish Length (cm) | Fish Age in Growth Zones | Scale $L_1$ (cm) | Otolith $L_1$ by Proportion (cm) | | Otolith $L_1$ by extrapolation from graph (cm) | | Difference between Scale $L_1$ and Otolith $L_1$ (cm) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | By Proportion | | From Graph | |
| | $L_1$ | Total | $L_1$ | Total | | | | Width | Length | Width | Length | Width | Length | Width | Length |
| 2NS62/8 | 37 | 46 | 77 | 1o1 | 25.7 | 3 | 18.1 | 2o.7 | 19.6 | 16.5 | 17.9 | +2.6 | +1.5 | -1.6 | -o.2 |
| | 38 | 46 | 78 | 1o2 | | | | 21.2 | 19.7 | 17.4 | 18.2 | +3.1 | +1.6 | -o.7 | +o.1 |
| 34NS61/73 | 38 | 47 | 83 | 111 | 26.6 | 3 | 18.9 | 21.5 | 19.9 | 17.4 | 2o.o | +2.6 | +1.o | -1.5 | +1.1 |
| | 37 | 46 | 82 | 11o | | | | 21.4 | 19.8 | 16.5 | 19.6 | +2.5 | +o.9 | -2.4 | +o.7 |
| 2NS62/39 | 39 | 49 | 84 | 112 | 27.2 | 4 | 19.o | 21.6 | 2o.4 | 19.o | 2o.4 | +2.6 | +1.4 | 0 | +1.4 |
| | 4o | 5o | 82 | 111 | | | | 21.8 | 2o.1 | 21.o | 19.6 | +2.8 | +1.1 | +2.o | +o.6 |
| 31NS61/7 | 39 | 5o | 81 | 1o7 | 26.5 | 3 | 19.2 | 2o.7 | 2o.1 | 19.o | 19.3 | +1.5 | +o.9 | -o.2 | +o.1 |
| GNS4/3 | 37 | 44 | 78 | 96 | 25.2 | 3 | 2o.1 | 21.2 | 2o.5 | 16.5 | 18.2 | +1.1 | +o.4 | -3.6 | -1.9 |
| | 37 | 44 | 82 | 99 | | | | 21.2 | 2o.9 | 16.5 | 19.6 | +1.1 | +o.8 | -3.6 | -o.5 |
| IM5/61 | 35 | 47 | 77 | 1o7 | 28.5 | 3 | 2o.4 | 21.2 | 2o.5 | 14.2 | 17.9 | +o.8 | +o.1 | -6.2 | -2.5 |
| | 38 | 49 | 78 | 1o9 | | | | 22.1 | 2o.4 | 17.4 | 18.2 | +1.7 | 0 | -3.o | -2.2 |
| IM5/61 | 4o | 49 | 85 | 111 | 27.8 | 3 | 21.1 | 22.7 | 21.3 | 21.o | 2o.9 | +1.6 | +o.2 | -o.1 | -o.2 |
| | 39 | 49 | | | | | | 22.1 | | 19.o | | +1.o | | -2.1 | |
| | | | | | | | | Total Difference | | | | 276.6 | 158.6 | 92.5 | 58.8 |
| | | | | | | | | No. of Observations | | | | 64 | 63 | 64 | 63 |
| | | | | | | | | Mean Difference between Otolith and Scale $L_1$s (cm) | | | | 4.3 | 2.5 | 1.4 | o.9 |

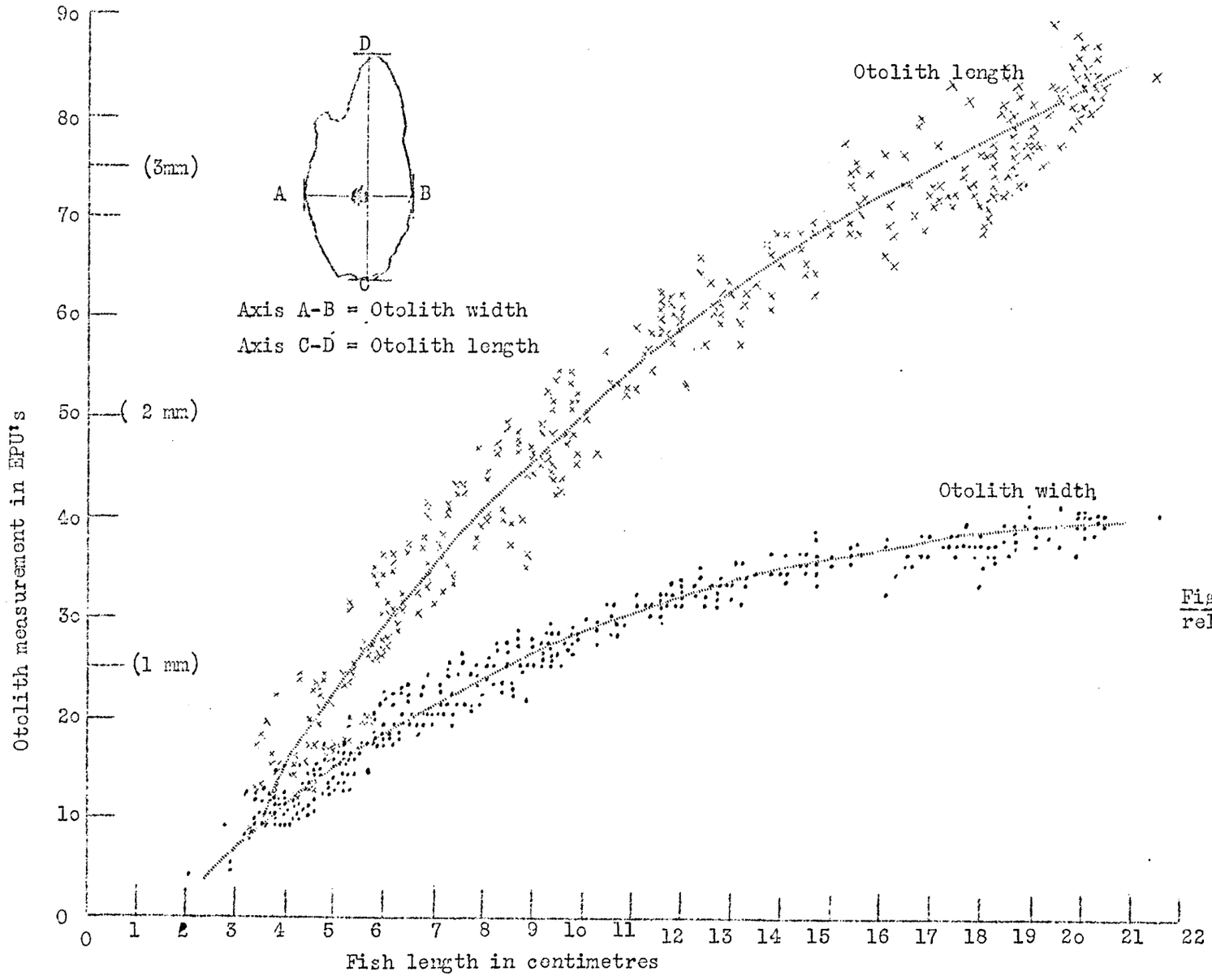


Figure 1. Otolith/fish length relationship in 0-1 group herring