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# THE GROWTH OF OTOLITHS OF NORTH SEA HERRING

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The scientists of several countries tend to resign the scale analysis in the herring investigations mainly for four reasons: 1) The scale analysis is often made on unsufficient material, since the herring loses nearly all scales in the trawl. 2) The age determinations are more reliable in otoliths than in scales. 3) After EINARSSON (1951) it is fairly easy to differentiate the spring and autumn spawning herring in the nucleus of otoliths. 4) After PARRISH and SHARMAN (1959) we are able to distinguish in the otoliths of North Sea herring a "Wide" or "Narrow" first winterring, which points to a different origin, and might help to follow the migrations of different populations.

Till now the scale analysis was still necessary for the important backcalculation of age, and it is the aim of this paper to investigate, whether we can do this work also on otoliths. On principle it must be required that the growth of otoliths is proportional to the growth of the fish. Furthermore, it is important that the otoliths of the different populations of North Sea herring grow in the same manner. The material, on which this paper is based, was unfortunely caught on the Doggerbank (in autumn of the years 1959/60/61), where the populationes are always mixed. At least it was tried to separate the herrings, which spawn in the Southern North Sea and the Channel, in dividing the material into following two groups: ripening herring (stages III + IV + V) and spent herring (stages VII + VII/II + II). This maturity groups were distinguished once more into herrings of the "Narrow" and the "Wide" otolith type.

The number of investigated herring is given in Table 1. The otoliths were measured with a microscope (enlargement 16 x), coupled with a micrometric screw. The enlargement is suitable for measuring the total length of the otolith and also the distances between the first three winterrings and the nucleus, yet it is insufficient for measuring elder winterrings. The measurements of the total length and of the first winterring were made in the two directions nucleus → rostrum and nucleus → post-rostrum, for it is quite uncertain, whether the otolith grows equally in both directions.

The phenomenon was observed that the first winterring is nearly imperceptible in the rostrum and very distinct in the post-rostrum, quite opposite to all the other winterrings.

Results

Relation between otolith length and body length: In Figure 1 the 0-group shows a very close relation between otolith length and body length. The means do nearly not deflect from the calculated line. The results in the 1-group are satisfying too. The one differing value is based on one animal only. The growth of the otoliths is faster in the 0-group than in the 1-group.

The Figures 2 and 3 demonstrate the otolith growth of adult herring,The otolith lengths are scattering considerably, especially in the 4-group. Consequently, there is little to say about the relation between otolith length and body length in this age groups.

A phenomenon, which is already described by POPIEL (1961) can be observed especially in Figure 3. It means that otoliths of elder fish are often much larger than those of younger fish, belonging to the same length group. (NAVRATIL, 1962, observed the same in scales). A similar phenomenon appears in the different otolith types, when otoliths of the "Narrow" typed fish are larger than those of the "Wide" typed from the same length group.

The different otolith growth of juvenile and adult herring is to be seen from Table 2. The quotient fish length /otolith length increases from the 0-group to the 2-group. That means, the otoliths of the 0-group and 1-group are relatively larger than those of following higher age groups. Refering to HEMPEL (1959), who found an allometric growth of otoliths in herring larvae and fry, we also can assume in the 0- and 1-group an allometric otolith growth. The quotients for adult herring in the different age groups are identical, but there are considerable differences between ripening and spent herring. The otoliths of spent herring are relatively larger than those of ripening fish.

The same fact is shown in Figures 4 and 5. Comparing the maturity groups, it can be seen especially in the "Narrow" typed fish that in ripening herring the otolith growth remains behind the body growth.

We have seen that there are differences in body length and otolith length between the maturity groups as well as between the different otolith types. As shown in the Tables 3 and 4, only the differences in body length are significant. Except the 1-group the standard errors

of the means of the otolith lengths are high, caused by the considerable scattering, mentioned above. Consequently the differences are not at all significant.

Conclusions: The differences in body growth and otolith growth between the two maturity groups, the wide scattering of otolith lengths within the single age group, and last not least the different otolith growth of juvenile and adult herring, require further exact investigations, before backcalculations of age by means of otoliths can be tried.

The different otolith measurements: All otoliths were measured in the two directions nucleus → rostrum and nucleus → post-rostrum, in order to find out, whether the otolith grows equally in both directions during the whole life. The quotient total length / part length, given in Table 5, demonstrates clearly a constant growth in the rostrum as well as in the post-rostrum, for all the investigated year classes. Therefore, it makes no difference, in which part of the otolith the measurement will be taken.

$l_1$- measurements in scales and otoliths: The rather inconvenient results obtained for the relation between the otolith length and the body length, does not include a linear correlation between the $l_1$ calculated from scales and the width of the first growth zone measured in otoliths (Figure 6). PARRISH (1959) has found the same correlation.

References

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Table 1 Number of investigated herrings, caught on the Doggerbank in autumn 1959/60/61

| rings | juvenile "N" | juvenile "W" | ripening "N" | ripening "W" | spent "N" | spent "W" | n |
|---|---|---|---|---|---|---|---|
| 0 | 394 | | | | | | 394 |
| 1 | 199 | 120 | | | | | 319 |
| 2 | | | 150 | 110 | 119 | 101 | 480 |
| 3 | | | 54 | 114 | 143 | 164 | 475 |
| 4 | | | 39 | 43 | 55 | 57 | 194 |
| 5 | | | 35 | 10 | 20 | 13 | 78 |
| 6 | | | 5 | 14 | 25 | 9 | 53 |
| 7 + over | | | 11 | 13 | 20 | 7 | 51 |
| | 199 | 120 | 294 | 304 | 382 | 351 | |
| | 713 | | 598 | | 733 | | 2044 |

Table 2 The quotient fish length / otolith length

| | "Narrow" juvenile | "Narrow" ripening | "Narrow" spent | "Wide" juvenile | "Wide" ripening | "Wide" spent |
|---|---|---|---|---|---|---|
| 0-Group | 5.59 | | | | | |
| 1- " | 6.00 | | | 5.73 | | |
| 2- " | | 6.26 | 6.04 | | 6.08 | 6.04 |
| 3- " | | 6.38 | 6.08 | | 6.22 | 6.07 |
| 4- " | | 6.27 | 6.01 | | 6.21 | 6.11 |
| 5- " | | 6.27 | 6.08 | | 6.18 | 6.07 |
| 6- " | | (5.96) | 6.06 | | 6.29 | (6.18) |

( ) less than ten herrings

Table 3 Differences in body lengths and otolith lengths between the two maturity groups ripening herring (r) and spent herring (s) for the two otolith types

"N a r r o w"

| | cm body length | Diff. | P | mm otolith length | Diff. | P | n |
|---|---|---|---|---|---|---|---|
| 2-Group r | 25.370 ± 0.088 | 0.729 ± 0.127 | <0.001 | 4.055 ± 0.129 | 0.028 ± 0.177 | >0.1 | 150 |
| 2-Group s | 24.641 ± 0.092 | | | 4.083 ± 0.123 | | | 119 |
| 3-Group r | 26.824 ± 0.138 | 0.490 ± 0.161 | 0.0027 | 4.207 ± 0.217 | 0.128 ± 0.251 | >0.1 | 54 |
| 3-Group s | 26.334 ± 0.076 | | | 4.335 ± 0.123 | | | 143 |
| 4-Group r | 28.071 ± 0.179 | 0.530 ± 0.222 | <0.02 | 4.495 ± 0.223 | 0.090 ± 0.333 | >0.1 | 39 |
| 4-Group s | 27.541 ± 0.126 | | | 4.585 ± 0.249 | | | 55 |

"W i d e"

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2-Group r | 22.914 ± 0.097 | 0.460 ± 0.135 | <0.001 | 3.770 ± 0.124 | 0.097 ± 0.177 | >0.1 | 110 |
| 2-Group s | 23.374 ± 0.085 | | | 3.867 ± 0.125 | | | 101 |
| 3-Group r | 25.553 ± 0.086 | 0.233 ± 0.114 | 0.05 | 4.108 ± 0.137 | 0.067 ± 0.178 | >0.1 | 114 |
| 3-Group s | 25.320 ± 0.068 | | | 4.175 ± 0.106 | | | 164 |
| 4-Group r | 26.750 ± 0.122 | 0.491 ± 0.170 | <0.005 | 4.309 ± 0.253 | 0.149 ± 0.327 | >0.1 | 43 |
| 4-Group s | 27.241 ± 0.117 | | | 4.458 ± 0.205 | | | 57 |

The significant differences are underlined

Table 5 The quotient total length / part length of otoliths

Totallength : nucleus ⟶ Rostrum

| | "Narrow" juvenile | "Narrow" ripening | "Narrow" spent | "Wide" juvenile | "Wide" ripening | "Wide" spent |
|---|---|---|---|---|---|---|
| 0-Group | 1.76 | | | | | |
| 1- " | 1.76 | | | 1.74 | | |
| 2- " | | 1.76 | 1.76 | | 1.77 | 1.75 |
| 3- " | | 1.77 | 1.76 | | 1.77 | 1.75 |
| 4- " | | 1.77 | 1.77 | | 1.77 | 1,76 |
| 5- " | | 1.76 | 1.75 | | 1.73 | 1.76 |
| 6- " | | (1.79) | 1.76 | | 1.75 | (1.75) |

totallength : nucleus ⟶ Postrostrum

| | "Narrow" | | | "Wide" | |
|---|---|---|---|---|---|
| 0-Group | 2.31 | | | | |
| 1- " | 2.32 | | 2.33 | | |
| 2- " | | 2.31 | 2.33 | 2.32 | 2.33 |
| 3- " | | 2.30 | 2.31 | 2.31 | 2.34 |
| 4- " | | 2.32 | 2.29 | 2.31 | 2.33 |
| 5- " | | 2.31 | 2.34 | 2.38 | 2.34 |
| 6- " | | (2.26) | 2.32 | 2.33 | 2.34 |

( ) less than ten herrings

Table 4 Differences in body lengths and otolith lengths between the otolith types "Narrow" (N) and "Wide" (W) for the different maturity groups

| | cm body length | Diff. | P | mm otolith length | Diff. | P | n |
|---|---|---|---|---|---|---|---|
| **juvenile Herring** | | | | | | | |
| 1-Group N | 21.353 ± 0.093 | 2.853 ± 0.127 | <0.001 | 3.577 ± 0.107 | 0.350 ± 0.163 | <0.05 | 199 |
| 1-Group W | 18.500 ± 0.092 | | | 3.227 ± 0.121 | | | 120 |
| **ripening Herring** | | | | | | | |
| 2-Group N | 25.370 ± 0.088 | 2.456 ± 0.135 | <0.001 | 4.055 ± 0.129 | 0.285 ± 0.177 | >0.1 | 150 |
| 2-Group W | 22.914 ± 0.097 | | | 3.770 ± 0.124 | | | 110 |
| 3-Group N | 26.824 ± 0.138 | 1.271 ± 0.166 | <0.001 | 4.207 ± 0.217 | 0.099 ± 0.261 | >0.1 | 54 |
| 3-Group W | 25.553 ± 0.086 | | | 4.108 ± 0.137 | | | 114 |
| 4-Group N | 28.071 ± 0.179 | 1.321 ± 0.216 | <0.001 | 4.495 ± 0.223 | 0.186 ± 0.33 | >0.1 | 39 |
| 4-Group W | 26.750 ± 0.122 | | | 4.309 ± 0.253 | | | 43 |
| **spent Herring** | | | | | | | |
| 2-Group N | 24.641 ± 0.092 | 1.267 ± 0.127 | <0.001 | 4.083 ± 0.123 | 0.216 ± 0.177 | >0.1 | 119 |
| 2-Group W | 23.374 ± 0.085 | | | 3.867 ± 0.125 | | | 101 |
| 3-Group N | 26.334 ± 0.076 | 1.014 ± 0.106 | <0.001 | 4.335 ± 0.123 | 0.160 ± 0.170 | >0.1 | 143 |
| 3-Group W | 25.320 ± 0.068 | | | 4.175 ± 0.106 | | | 164 |
| 4-Group N | 27.541 ± 0.126 | 0.300 ± 0.177 | 0.09 | 4.585 ± 0.249 | 0.127 ± 0.327 | >0.1 | 55 |
| 4-Group W | 27.241 ± 0.117 | | | 4.458 ± 0.205 | | | 57 |

The significant differences are underlined

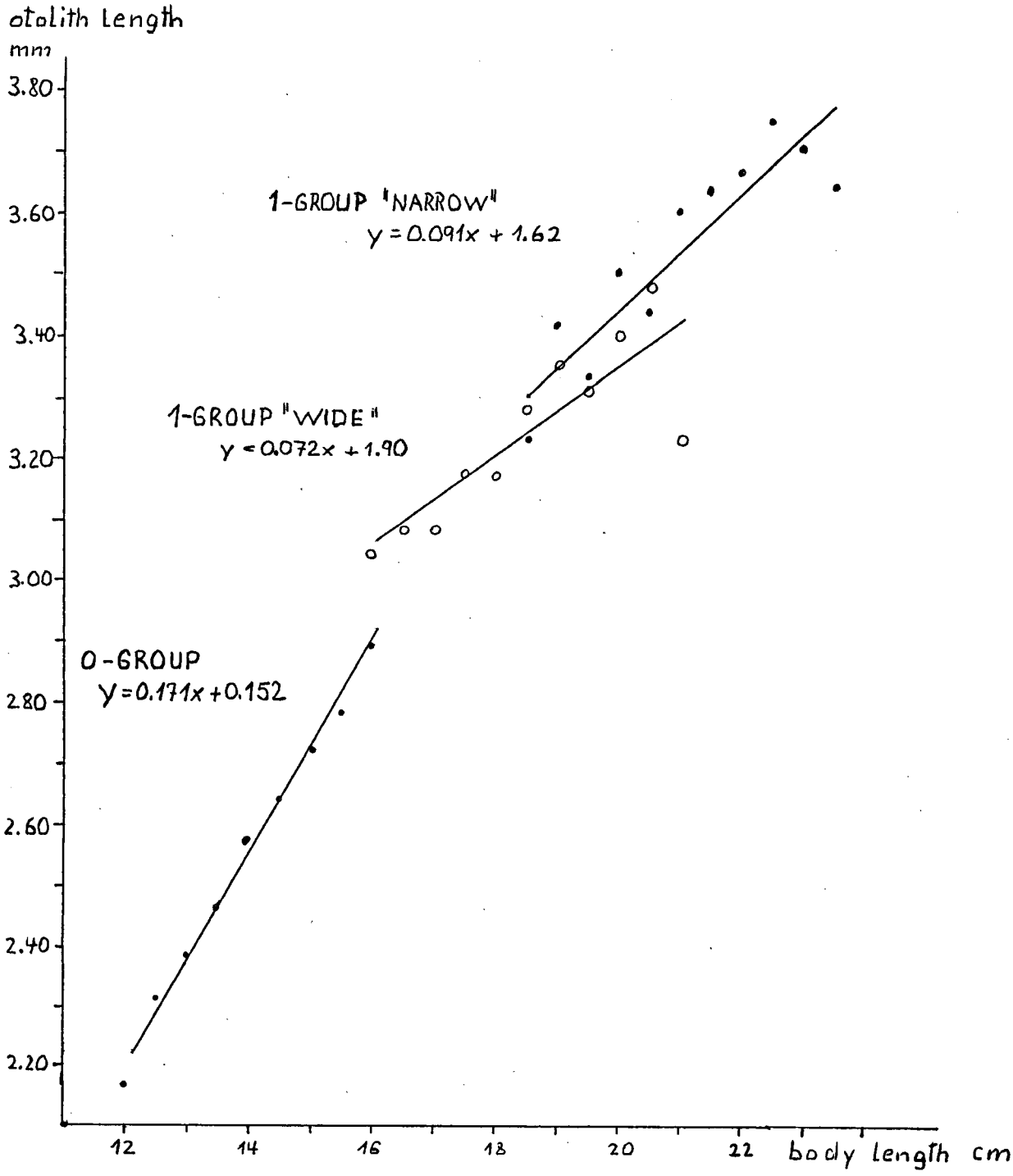


Figure 1 Relation between otolith length and body length in the 0-group and 1-group

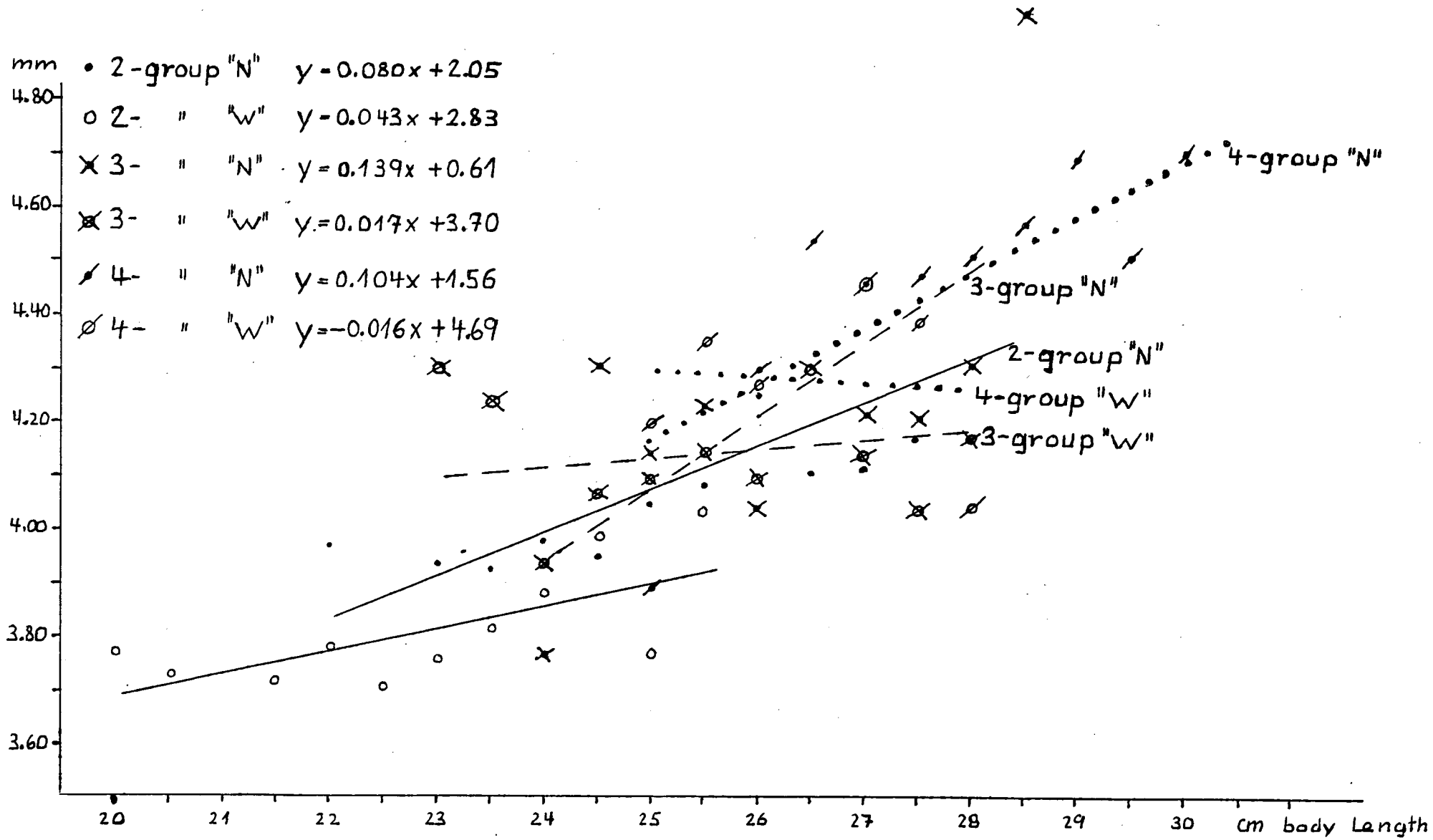


Figure 2 Relation between otolith length and body length in ripening herring of the 2-, 3- and 4-group

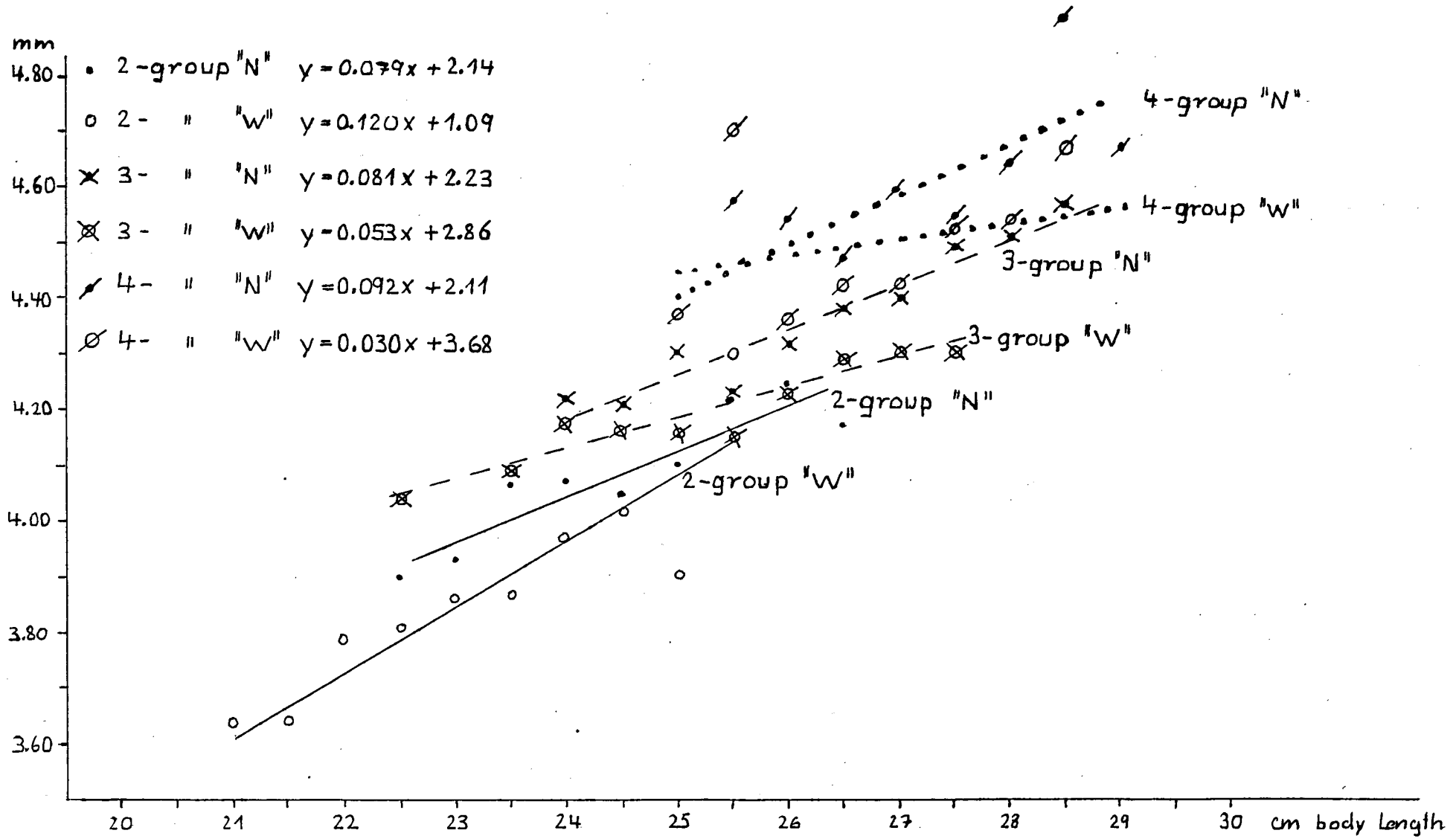


Figure 3 Relation between otolith length and body length in spent herring of the 2-, 3- and 4-group

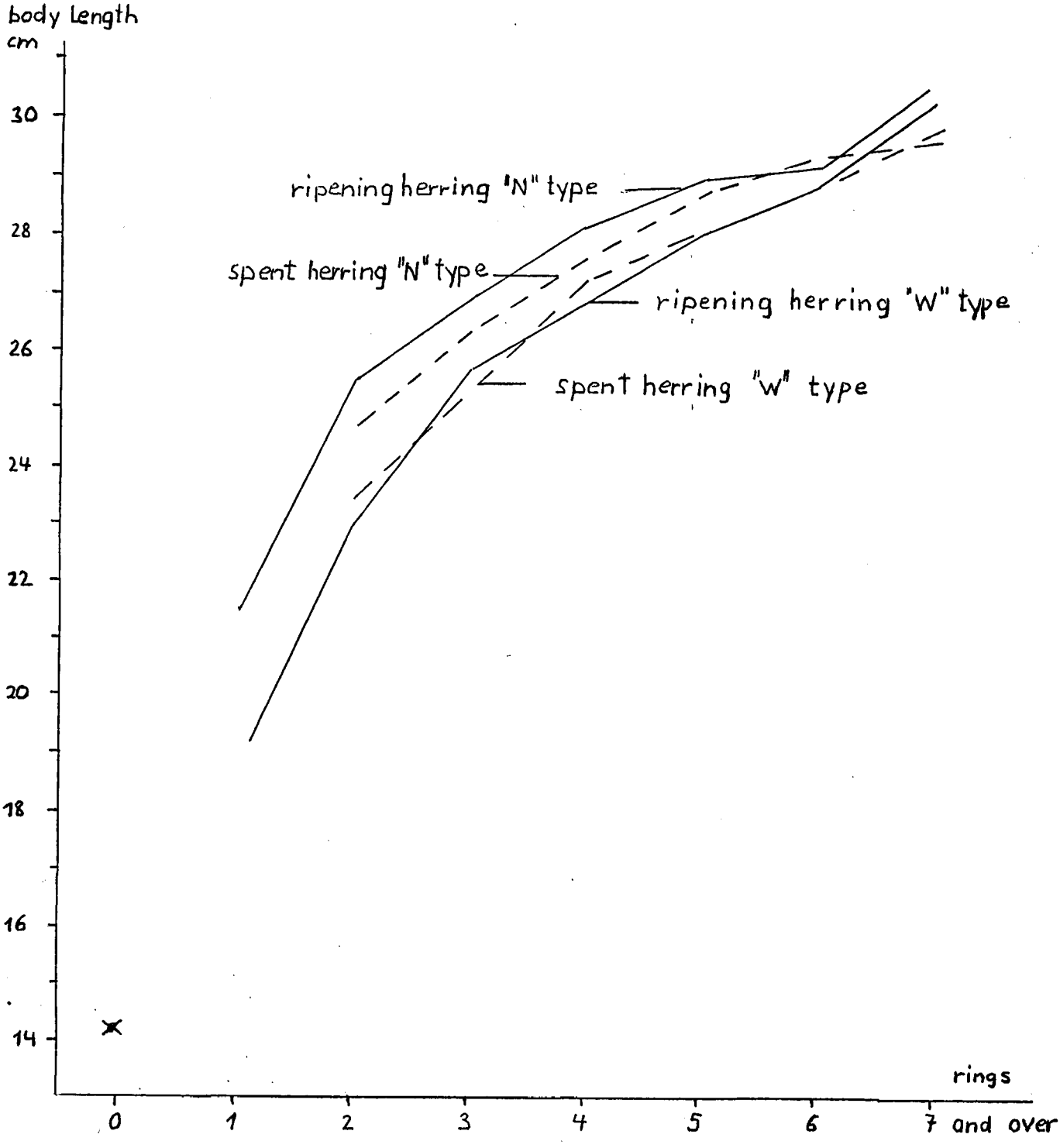


Figure 4 The growth of herring of different maturity groups and different otolith types

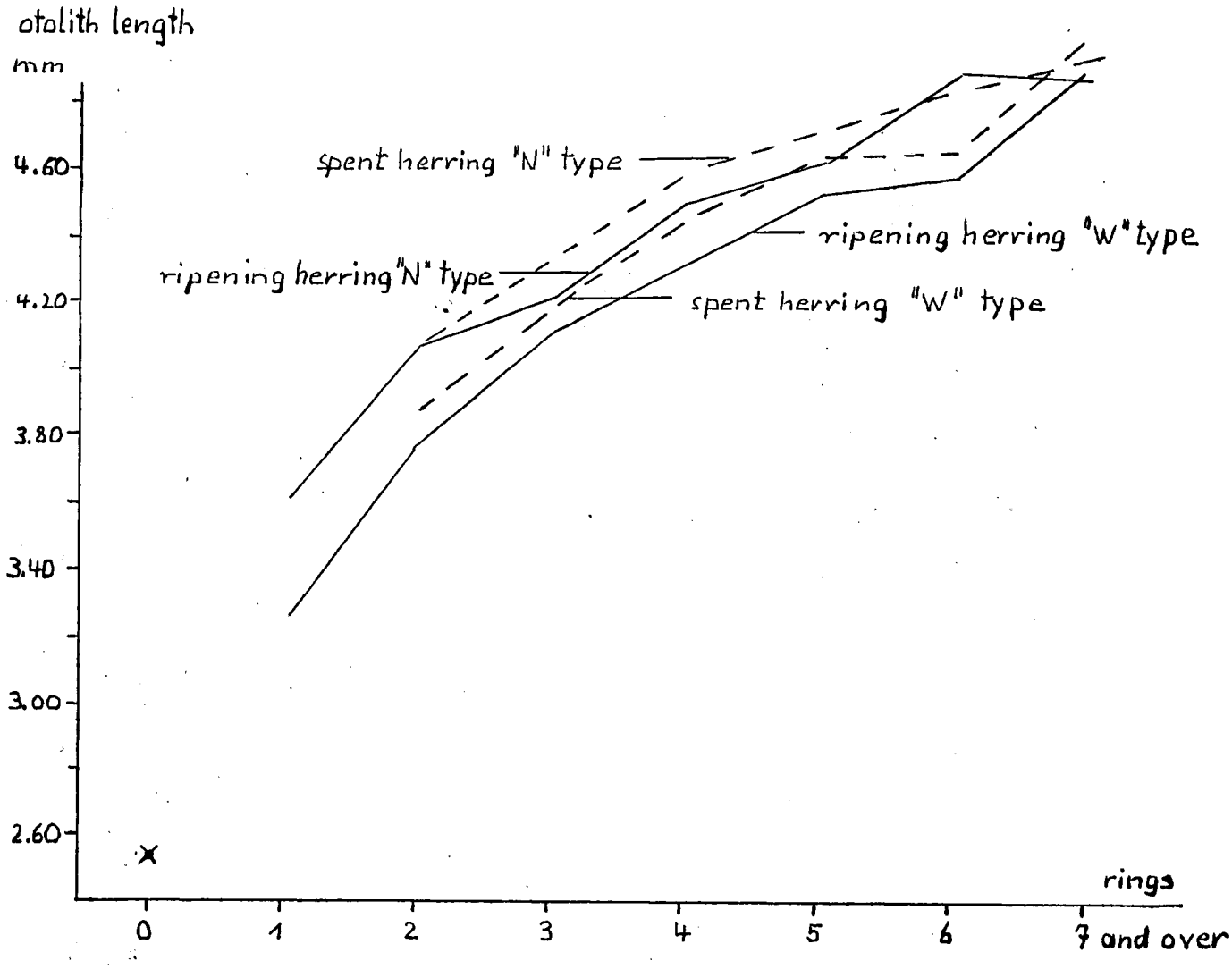


Figure 5 The growth of otoliths of different maturity groups and different otolith types

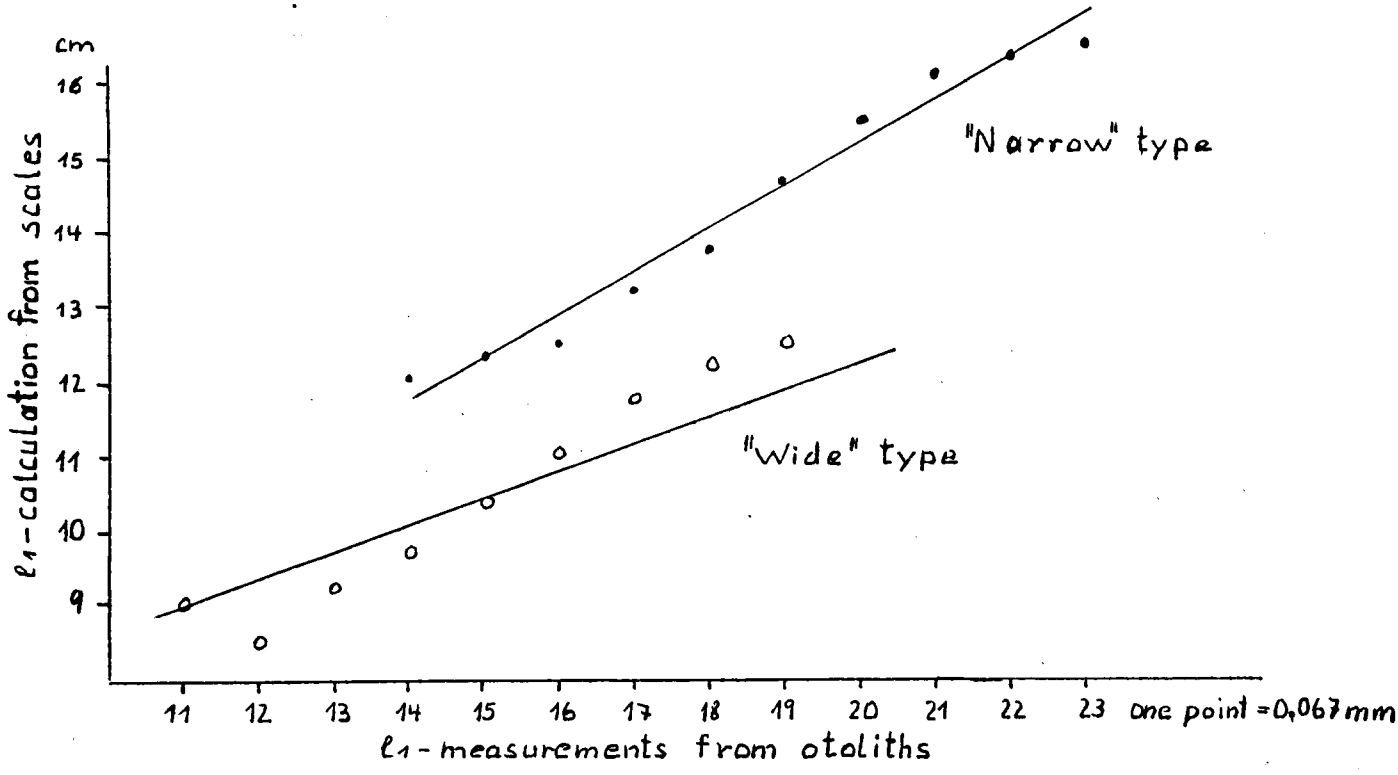


Figure 6 Mean $l_1$ and otolith measurements amongst herrings from the Doggerbank. All ages and all maturity stages