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On the Recruitment Mechanism of North Sea Autumn Spawning Herring

By

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Every year virgin herring, which have left the nursery areas in the preceding winter and spring, join the various spawning concentrations in different parts of the North Sea. Some of these "recruits" are maturing early and participate in the spawning in the north-western North Sea in August, others mature later and join the spawning shoals in the central North Sea in September–October, whereas the very late maturing fish appear in the spawning concentrations in the Southern Bight, in November-January. The question arises as to the mechanism by which this separation among the group of virgin fish takes place.

A possible answer would be that the recruits tend to join the spawning concentrations on their native grounds, reinforcing the shoals from which they originate. This view was expressed in two papers some years ago (POSTUMA and ZIJLSTRA, 1958; ZIJLSTRA, 1958), based mainly on differences in sizes of otolith-nuclei and on a relationship between water temperatures during spawning and the number of vertebrae of the spawners. Differences in length and meristic characters, observed between the recruits of the various spawning grounds were thought to be due mainly to environmental factors. However, no indication could be given concerning the precise mechanism, which was responsible for the returning of the fish to their native grounds, although the use of the word "homing" indicated at least the possibility that the fish possess a sense, which guides them to their place of birth.

Since these papers were written, a new criterion for the separation of the virgin fish has been suggested (BURD, 1956, 1958; CUSHING, 1956, 1958). According to this hypothesis the separation is obtained by differences in the time when the fish reach a certain critical length, resulting in differences in the time of migration from the nurseries and in the time of the start of maturation. The larger recruits would reach the critical length at an earlier date and would consequently spawn in general more early in the season than the smaller ones.

It could be expected, however, that in this way some herring do return to their native ground, since the fish, hatched early in the season, might tend to be larger than those hatched later. A considerable degree of mixing between the herring stocks seems inevitable with this mechanism and will be dependent on the degree of overlap of the length ranges of herring born in the various seasons.

This "recruitment by length" hypothesis has the merits of giving both a criterion and a mechanism for the separation in the group of virgin fish as far as spawning time is concerned and explains at least a partial "homing", for which arguments were brought forward in our earlier papers.

If the time of spawning of the recruits depended completely upon the moment at which a critical length for the onset of maturation is reached, this would have the following consequences for length and other characters of the fish: –

1. As nearly all recruits have been 3 year-old fish in recent years, one might expect that the fish with the larger l_2 values would tend to reach the critical length earlier and consequently spawn earlier in the season. The length of the recruits, spawning at different times would depend on the amount of growth in the season preceding spawning. Information concerning the relation between l_2 and length at the time of spawning is given for the 1952 year-class in Table 1. It shows the average lengths of fish at the time of spawning for fish with the same l_2 values, in different spawning seasons.

These data indicate that growth during the last growth period has been equal for all recruits with the same initial length (l_2), irrespective of their time of spawning.

It follows that a close correlation between the two values l_2 and length at spawning does exist. Therefore the conclusion seems justified, that both l_2 and length at spawning must tend to decrease with the advancement of the spawning season, if the "recruitment by length" hypothesis is correct. As length data are much more easily obtained in sufficient numbers than l_2-values, the following analysis has been based on length data only.

Table 1.

Mean length (cm) of 3 year-old recruit spawners having different l_2 values

Spawning area	Spawning season	20 cm	21 cm	22 cm
		Average length at the time of spawning		
Dogger Bank	Sept.-Oct.....	23·6	24·4	24·9
Sandettié	Nov.	23·6	24·1	25·0
Channel	Dec.....	23·5	24·3	24·9

2. Differences in other characters, as for example otolith type and vertebral counts, between fish spawning at different times, could only be expected, if these characters were either directly or indirectly related to length. Differences in these characters would have to coincide with those in length and would tend to be gradual.

Data for herring, spawning in the period September-December were available for the years 1955–1960. The herring had been caught by commercial trawlers on the spawning grounds in the central and southern North Sea, including the English Channel. Among the spawning herring the 3 year-old fish were selected, as these fish probably represent the bulk of the recruit spawners in the years under consideration (CUSHING and BURD, 1957). By arranging the material in short periods, i. e. weeks, the changes in the characters of recruit spawners could be followed.

Length

Length data were sufficiently numerous to permit a split of the material by weeks, giving a record of the mean lengths of the recruit spawners from the beginning of September to the end of December. Due to the absence of herring in spawning condition in the landings in a period covering approximately 5 weeks in the second half of October and the first half of November the record could not be continuous. Although it is possible that the trawlers failed in that period to find existing large concentrations of spawning herring, it seems more likely that those 5 weeks represent a true gap, or at least a lull in the spawning of the herring, for in that period spawning fish are rare in samples of drift net herring too. It should be mentioned here, that with a "recruitment by length" mechanism such a gap needs a special explanation.

The mean lengths of 3 year-old, ripe herring (mat. stage VI), calculated for weekly periods, are shown in Figure 1, together with an indication about the place of capture. The data exhibit as a general trend a decreasing mean length in the course of the season, in all years considered. A more detailed examination of the data reveals, that the trend is clear and consistent in the central North Sea recruits (September–October), but does not appear in the Southern Bight

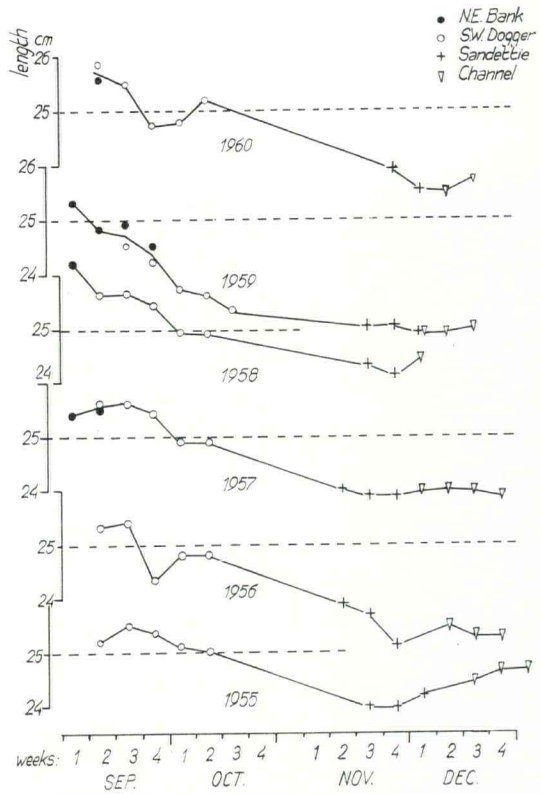

Figure 1. Mean lengths of three year-old, ripe herring calculated for weekly periods in the months September–December for the years 1955–1960.

spawners (November–December). From the material on length we may therefore conclude, that although the general trend in length seems in good agreement with the "recruitment by length" hypothesis, no satisfactory explanation can be found for the absence of this trend during the last part of the spawning season.

Vertebral counts

The material on vertebral counts was less complete than that on length, which made it sometimes necessary to combine data for 2 or 3 weeks.

Figure 2 shows the mean vertebral counts for 5 year-classes (year-class 1958 had to be omitted, due to lack of material). Means given are based on at least 30 counts. To evaluate the differences observed the analysis of variance, or sometimes the T-test, was applied.

The following conclusion could be drawn from the material: –

1. The differences, observed in the vertebral counts of all recruit year-classes in the course of the spawning season, could not be attributed to random variation ($p < 0{\cdot}001$).

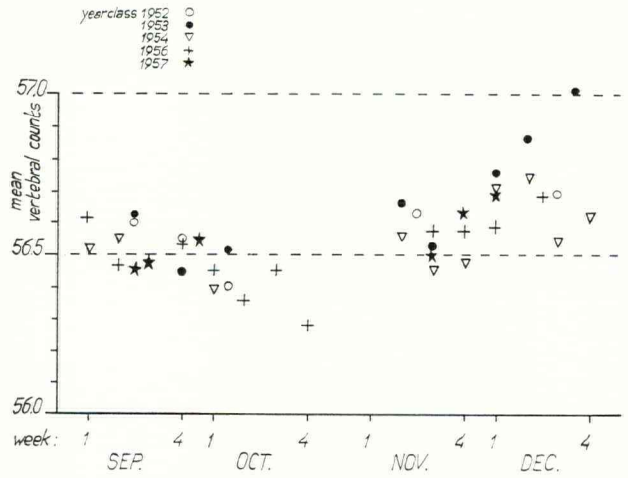

Figure 2. Mean vertebral counts of 3 year-old, ripe herring. Means are computed for weekly or 2-weekly periods and are based on at least 30 observations.

2. The differences in vertebral counts are not related with those in mean length, as is apparent from a comparison of Figures 1 and 2. Whereas the October mean lengths are intermediate between the September and November ones, the vertebral counts are lower in October than in either of the other two months. Furthermore, in the period November–December, when the mean length is changing very little, the vertebral counts show a steady rise. In fact, it seems that the differences in the vertebral counts during the spawning season are more related with spawning areas than with differences in length. Differences between the vertebral counts observed in the last 2 weeks of the central North Sea spawning and the first 2 weeks of the Southern Bight spawning were tested by a T-test; significant differences were found for the year-class 1952 ($p < 0.05$) and 1956 ($p < 0.01$) and for the combined material of year-classes 1952, 1953, 1954 ($p < 0.05$).

3. The data indicate a gradual decrease in vertebral counts for central North Sea recruits, throughout September–October. The analysis of variance showed that the observed differences in vertebral counts could not be due to random variation in the case of the year-classes 1952 and 1956 (both classes $p < 0.05$).

4. An increase in vertebral counts is indicated in the Southern Bight recruits, throughout November–December. The differences were found to be statistically significant for year-classes 1953 ($p < 0.05$) and 1954 ($p < 0.02$).

In the light of the "recruitment by length" hypothesis points 1 and 2 are of main importance. They are not in agreement with the expectation that a close correlation exists between differences in vertebral counts and those in length. The possible significance of points 3 and 4 will be discussed later.

Otolith types

The otolith types, introduced in herring research by the work of PARRISH and SHARMAN, have been shown to be related to length, especially the l_1 (PARRISH and SHARMAN, 1959). The wide type otolith seems to be the most common among the smaller fish of a year-class, the narrow type among the larger fish.

In view of the decreasing length of the recruit spawners in the course of the spawning season, a decreasing proportion of narrow type otoliths might be expected, which is, in fact, observed in the large material of the strong 1956 year-class, as shown in Table 2.

Table 2.

Percentage occurrence of narrow type otoliths in weekly samples of recruit spawners (1956 year-class) in the central and southern North Sea

Month	Sept.				Oct.					Nov.				Dec.			
Week	1	2	3	4	1	2	3	4	5	1	2	3	4	1	2	3	4
% n-type otoliths	84	80	89	85	68	72	62	–	–	–	–	47	33	33	22	24	–

When the proportion of narrow type otoliths is plotted against mean length (see Figure 3) it is noticed, however, that they are less well represented in the Southern Bight recruits than might be expected from their mean lengths, compared with the situation in central North Sea fish.

In tracing the cause of this discrepancy, the proportion of narrow type otoliths was tabulated for each cm group of length, dividing the material in periods of 2 weeks, using again data for the 1956 year-class. These data are given in Table 3.

The material in this table suggests, that: –

1. The proportion of narrow type otoliths is lower in the Southern Bight than in the central North Sea, over the whole length range.

2. The change is discontinuous and is related to the spawning areas in the central and southern North Sea.

3. The proportion of narrow type otoliths per cm group of length remains on approximately the same level in the course of the spawning season in the central North Sea, whereas a slightly decreasing proportion of "narrows" is indicated in the course of the Southern Bight spawning.

In the light of a "recruitment by length" hypothesis these points are hard to explain; one would have expected in that case a close dependence of otolith type on length.

Table 3.

% narrow type otoliths, per cm length group

(In parentheses number of observations)

Area	Period	Length, cm 21	22	23	24	25	26	27
Central North Sea								
NE Bank	30. Aug.–12. Sept.	–	–	54	69	89	89	100
		–	–	(26)	(54)	(83)	(53)	(26)
NE Bank	13. Sept.–26. Sept.	–	–	69	80	92	98	93
SW Dogger	– –	–	–	(26)	(59)	(88)	(50)	(15)
SW Dogger	27. Sept.–10. Oct.	36	49	54	83	95	100	–
		(11)	(35)	(106)	(71)	(40)	(10)	–
SW Dogger	11. Oct. –24. Oct.	–	47	49	90	95	100	–
		–	(34)	(51)	(41)	(19)	(9)	–
Southern Bight								
Sandettié	15. Nov.–28. Nov.	0	16	35	58	76	100	–
		(16)	(128)	(201)	(100)	(17)	(8)	–
Sandettié	29. Nov.–5. Dec.	8	15	25	59	70	–	–
Channel	– –	(12)	(65)	(83)	(46)	(10)	–	–
Channel	6. Dec. –19. Dec.	0	14	26	32	42	–	–
		(8)	(81)	(112)	(47)	(47)	–	–

All of the evidence on otolith type was derived from the strong 1956 year-class, which was well represented in our material. Data from other year-classes were not sufficiently numerous to permit a detailed analysis. By utilising not only the material of recruit spawners, but also of older herring it was possible to compare the relationship of otolith type on l_1 for these other year-classes. This was done for the 1952 and 1954–1957 year-classes, for both the central North Sea and Southern Bight spawners. Figure 4 displays the results in a graphical form; it shows that for all year-classes in principle the same difference in the relationship "% narrows on l_1" exists between the two areas as was observed for the 1956 year-class, for "% narrow on length", which supports the conclusions drawn from the material of this year-class.

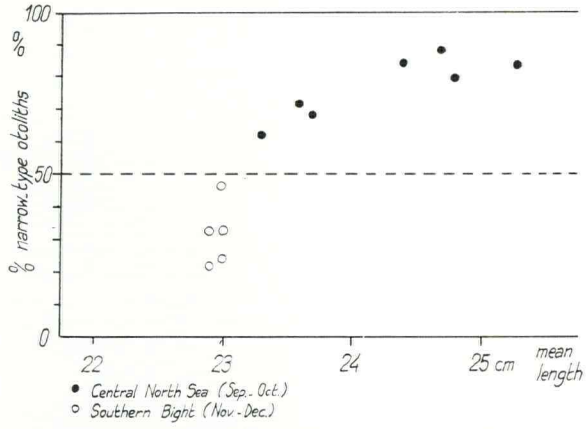

Figure 3. Relationship between % narrow type otoliths and mean length, calculated for weekly periods, in 3 year-old, ripe herring of the 1956 year-class.

Conclusions

In the light of the evidence given in the foregoing section it seems unlikely, that the timing of spawning and the distribution of the recruits over the various spawning concentrations is completely dependent on length. The evidence on length solely, especially the part concerning the spawning in the central North Sea, did agree with the "recruitment by length" hypothesis, but the data from the Southern Bight spawning were more difficult to explain. The main argument against this hypothesis is that the characters "vertebral counts" and "otolith type" vary independently of length, which must mean, that factors other than length are involved in the recruitment pattern.

With the rejection of the hypothesis of a recruitment pattern, solely determined by length, the original problem about criteria and mechanism of the recruitment, remains unsolved.

The possible significance of the material on recruit spawners, given in this paper, might be considered in the light of a "homing" hypothesis, which provides at the moment the only available alternative.

If the recruits tend to join the spawning concentrations on their native grounds, an interdependence of length, vertebral counts and otolith type throughout the spawning season would not be expected, as all these characters might at least be determined independently by environmental factors and the time of spawning, as was discussed earlier for length and vertebral counts by ZIJLSTRA (1958).

In the case of otolith types, the observations of PARRISH and SHARMAN (1959) are suggestive, indicating that in the north-western North Sea nurseries

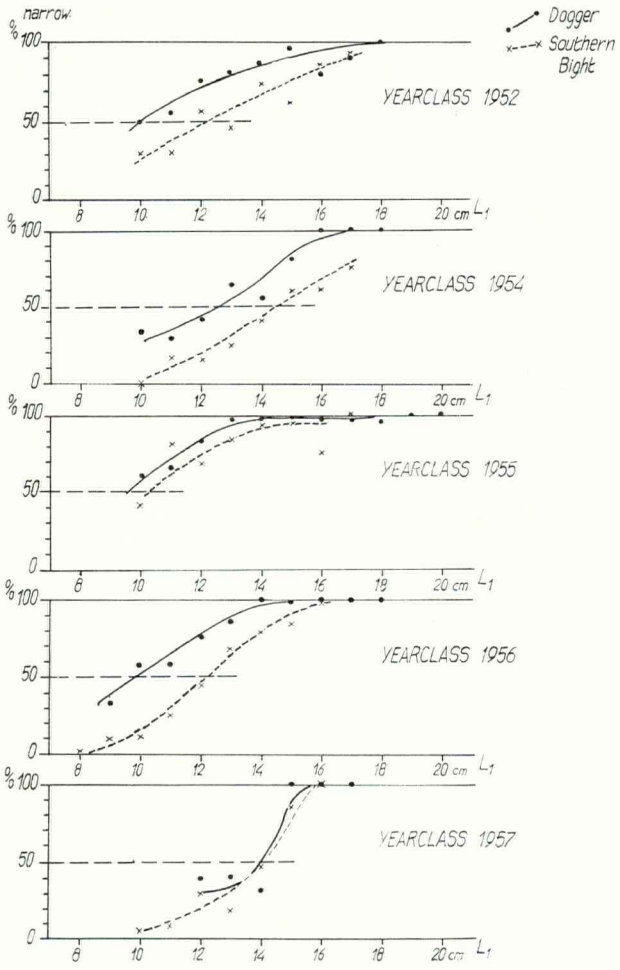

Figure 4. Relationship of % narrow type otoliths and l_1, shown for various year-classes.

almost all immature herring belong to the "narrow" type, irrespective of their length (l_1), whereas in the eastern North Sea (Bløden area) a differentiation of otolith type according to l_1 exists, small l_1's coinciding with wide type otoliths, and large l_1's with the narrow type. This might provide a basis for interpreting the observed differences in otolith type among the recruit spawners.

In relation to a "homing" hypothesis, the significance of the trend in length amongst the central North Sea recruit spawners and the (opposite) trends in vertebral counts observed in the recruits of both the central North Sea and the Southern Bight, is not clear.

The decrease in the mean length, which occurs amongst both the Dogger and the NE Bank spawners, could possibly be explained by a "recruitment by length" pattern, valid for each individual spawning; the question remains in that case why such a decrease in length is not observed in the Southern Bight recruits.

The decrease in vertebral counts amongst the central North Sea spawners, could be related to the decrease in length, because a positive correlation between length (l_1) and vertebral counts was found for the herring belonging to one spawning area (Zijlstra, 1958).

The trend in the vertebral counts amongst the Southern Bight spawners which showed an increase in the course of the season, is almost certainly due to the fact, that early Southern Bight spawners (Sandettié) have lower mean vertebral counts than the late Southern Bight spawners (Channel). It seems very likely that, in the data for the middle periods, mixtures of both groups are found, due to the fishing pattern of the trawling fleet.

It seems therefore that, without giving any direct proof, the available data could possibly be interpreted on the basis of a "homing" hypothesis.

Summary

The criterion and mechanism of recruitment of summer-autumn spawning North Sea herring were considered. Data on length, vertebral counts and otolith characters of recruit spawners, collected between September–December in the years 1955–1960 were examined in the light of the recruitment by length hypothesis. The material did not support the existence of such a mechanism, as in the course of the season the mean vertebral counts and otolith types varied, at least partly independently of length.

The possible significance of the data for the recruit spawners is discussed in the light of a "homing" hypothesis.

References

Burd, A. C., 1956. "The North Shields fishery 1949–1955". ICES, C. M. 1956, Doc. No. 56.

Burd, A. C., 1958. "Recruitment and the North Shields fishery". ICES, C. M. 1958, Doc. No. 67.

Cushing, D. H., & Burd, A. C., 1957. "On the herring of the southern North Sea". Fish Invest. Lond., Ser. 2, *20* (11).

Cushing, D. H., 1958. "Some changes in vertebral counts". Rapp. Cons. Explor. Mer, *143* (2): 126–29.

Cushing, D. H., 1958. "Recruitment to the North Sea herring stocks". ICES, C. M. 1958, Doc. No. 66.

Postuma, K. H., & Zijlstra, J. J., 1958. "On the distinction between herring races in the autumn and winter spawning herring of the southern North Sea and English Channel by means of the otoliths and an application of this method in tracing the offspring of the races along the continental coast of the North Sea". Rapp. Cons. Explor. Mer, *143* (2): 130–33.

Zijlstra, J. J., 1958. "On the herring 'races' spawning in the southern North Sea and English Channel". Rapp. Cons. Explor. Mer, *143* (2): 134–145.