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Fluctuations in the Herrings of the East Anglian Autumn Fishery, the Yield of the Ostend Spent Herring Fishery, and the Haddock of the North Sea — in the Light of relevant Wind Conditions.

By

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Herring.

The last issue of the Rapp. et Proc.-Verb. (Vol. CV, III, 1937) contained a short paper by Carruthers and Hodgson under the title: "Similar Fluctuations in the Herrings of the East Anglian Autumn Fishery and certain Physical Conditions". In it appeared a graph which showed the two following quantities plotted against each other:— the percentage of 3-year-old herrings in the catches from year to year, and the atmospheric pressure gradients controlling run of wind up the Southern Bight from the Straits of Dover during the spawning seasons concerned. Six successive year-classes of herrings were seen to have risen or fallen in strength from their immediate predecessors, in the same sense as the pressure gradients.

In other words, there was a parallelism for all the years embraced (the year-classes 1926 to 1932) when the herring fluctuations were plotted against pressure gradient.

It was desired to extend the comparison backwards in time to cover the year-classes of 1923, 1924 and 1925, but the requisite pressure data were not then available although the values for herring were.

The pressure graph has now been extended to embrace all spawning periods from that of 1923/1924 up to that of 1937/1938, and Dr. Hodgson has kindly furnished me with a value for the percentage of 3-year-old herrings in the catches of the 1936 autumn fishery.

It has consequently become possible to extend the comparison so as to cover eleven year-classes of herring. This is an extension of four steps, and the appropriate graph appears below as Fig. 1. It is seen that there is a parallelism over all ten steps, and it would seem that the spawning products in any year experience better or worse survival conditions than did those of a year earlier, according as they can be supposed to have been spread further or less far away from the neighbourhood of the Straits of Dover. It should be noted that the pressure data refer only to the months of December and January, and, concerning the obvious lack of proportionality between the two sets of data which express the fluctuations compared, the remarks made in the paper of a year ago and repeated and amplified below, should be borne in mind.

For a reason which will appear later, indications of the percentage occurrence of 3-year-old herrings in the catches of autumns 1923, 1924, and 1925 are also given in the graph — but without pressure data. This is because Dr. Hodgson regards the three herring values concerned with less confidence than attaches to his later estimates.

At the end of the paper by Carruthers and Hodgson earlier referred to, attention was paid to the yield of the Ostend fishery for spent herrings over the seasons 1927/1928 to 1935/1936.

Figures for yield were set down and inspected side by side with the pressure graph to which the fluctuations of the herrings of the East Anglian Autumn Fishery had been compared. It was seen that an inverse parallelism displayed itself for all the eight yearly steps. If the fishery had been more productive in one year than in the year before, the pressure gradient for "from-Channel" winds had been less and *vice-versa*.

In Fig. 1 I have plotted the Ostend fishery figures and, for clearness, have done so by reference to an inverted scale. An additional figure — that for season 1936/1937 has recently been communicated by Professor Gilson, and has been included. The inverse parallelism is brought out very clearly.

It seems reasonable to argue along these lines:— as from year to year, increased "from-Channel" air flow means increased "from-Channel" water flow, and this in turn means:—

(1) that the passively drifting spawning products will be distributed further afield — apparently a good survival augury for the herring, and

(2) that lately-spawned herrings in such an enfeebled condition that they drift with the water movements more or less, will be more quickly swept along the Belgian coast and will therefore remain subject to capture by the Ostend fleet for a shorter time, the converse would also hold.

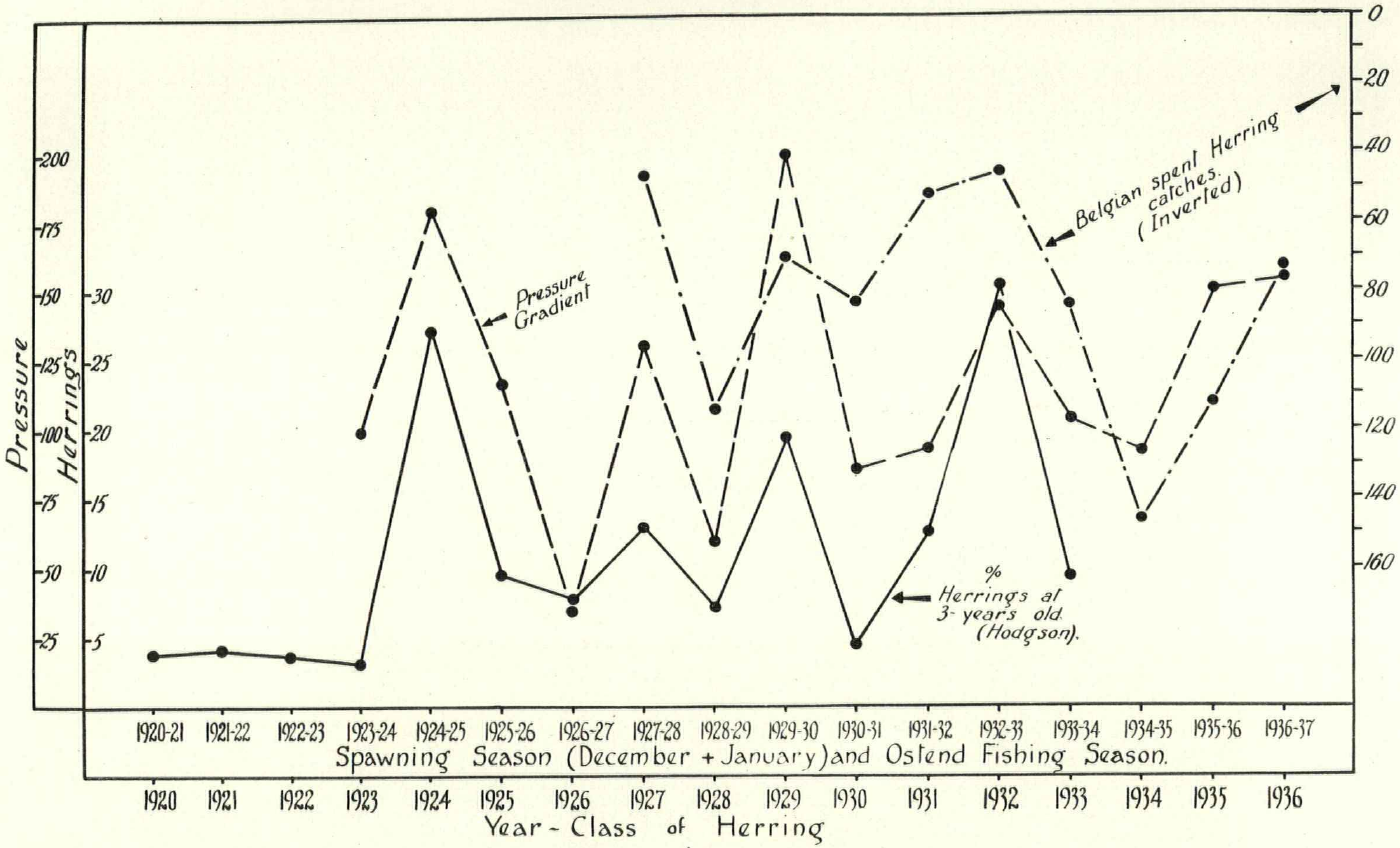

Fig. 1.

Fig. 1. Graphical Comparison of the Yearly Fluctuations in the Herrings of the East Anglian Autumn Fishery and in the yield of the Belgian Spent Herring Fishery — with those in Atmospheric Pressure Gradient controlling run of Wind northwards up the Southern Bight during December and January.

[Key to Fig. 1. Of the two scales on the left, the right-hand one measures percentage occurrence of herrings at three years old in the East Anglian catches, and the left-hand one measures atmospheric pressure gradient as explained in "Note One" in the Appendix. The inverted scale on the right refers to the yield of the Belgian Spent Herring Fishery; values read × 100 give in kilograms, GILSON's "Mean Weight of a Day's Capture".]

In such comparisons as that here made between fluctuations in herring year-class strength and pressure gradient, the presence of parallelism without proportionality calls for some comment. Does the absence of proportionality imply that the parallelism is of but little interest — that it has no real meaning? It could not justifiably be argued that such is the case unless it were at least known that:—

(1) The fish censuses were as completely reliable as a properly conducted human census.
(2) The response of water to wind is always more or less the same in the area concerned.
(3) Equal values of the pressure gradient data employed necessarily mean the same thing in terms of wind, and unequal values cannot mean the same thing.

Regarding point (1) no comment is offered. Concerning point (2), we need only point to the facts that the North Sea is not a lake and that its waters are subject to urges of Atlantic incidence. As to point (3), isopleth diagrams would surely show that a given pressure difference could exist between the two sides of the Southern Bight on different occasions, without the intervening isobar picture being exactly the same.

In view of what has been said, it seems very reasonable to seek no numerical correlation, and to contend that, such parallelism as we have displayed being all that can be hoped for, when it exists it should be regarded as being of importance. Its importance will be measured by the length of the term of years for which it holds good.

What has just been said regarding the lack of need for concern over absence of proportionality, applies with even greater force to the case of the haddock, because a much wider area of sea is involved.

Haddock.

If it were possible to display any similar kind of parallelism in the case of the haddock, it could perhaps be invested with more importance than attaches to the case of the herring. This seems reasonable on the grounds that any such parallelism would necessarily have displayed itself in spite of the fact that there must be much greater likelihood of smoothing out in view of the considerations just raised as items (1), (2), and (3), above.

In an earlier paper[1]) I found some reason to suppose that it augured well for the survival of a haddock brood if, at spawning time, the waters in the spawning area were urged to the southwards. That supposition was, however, the outcome of an indirect approach to the problem. The recent appearance of a paper by Dr. Raitt on "Stock Replenishment and Fishing Intensity in the Haddock of the North Sea"[2]), has made it possible to approach the subject of haddock fluctuations provided with a very convenient summary of the relevant facts concerning the fish; a graph from Raitt's paper is here reproduced.

It is nothing new to draw attention to the fact that to a noteworthy degree, the haddock and herring fluctuate inversely — that good years for haddock have been poor years for herring and *vice versa*. The writer discussed this matter in some detail in his paper already referred to (1935). On consulting the herring graph in Fig. 1, and the haddock curve in Fig. 2, the comparison can be very easily made for ten steps, and it is noted that:—

The fluctuations in strength have been notably opposite in sense six times, and have been definitely in the same sense twice. Of the two remaining steps, the trends of the curves were also opposite in the case of 1925 to 1926 but the slope for one fish (herring) was slight; they were in the same sense in the other case (1924 to 1925) where the slope for haddock was slight.

The "oppositeness" in strength for some of the well-known peak years is very pronounced.

There is another point well worthy of comment here, and it is one to which the writer does not remember attention having been previously drawn.

It is suggested that the reader imagine the haddock curve of Fig. 2 which portrays Raitt's data, superposed upon the herring curve of Fig. 1 which portrays Hodgson's data — and the haddock curve then shifted one step to the right. This means that the ordinate for haddock born in 1922 is pictured as lying upon that for herring born in winter 1923/24, and so on. The similarity of the two curves is now very striking. Ten steps or year-to-year slopes can be compared, and it is seen that, only in the case of the small fall for haddock from 1929 to 1930, do the two curves move in opposite sense. Moreover, there is agreement for the three slopes pre-dating pressure data — though, as earlier remarked, Dr. Hodgson is not able to be so precise about his earliest herring figures as about his later estimates.

This agreement, almost total for thirteen yearly steps, certainly seems to warrant the description "striking", and one is led to wonder whether there may not be some explanation which makes sense. Can any linkage be thought of which can account for the fact that the ups and downs of haddock fluctuations have been so strikingly reproduced by herrings born $1^1/_2$ years later? The experts are of the opinion that "nothing disastrous happens to a haddock brood after they leave the pelagic stage and take to bottom habitat — *i.e.*, at about 6 months' old".

Before commenting on the similarities of the three curves of Fig. 2, it will be well to remark that we had good reason to suppose that the cause of fluctuations in year-class strength of North Sea haddock (and cod) should be sought *within* the North Sea.

[1]) "Certain Fishery Applications of the Results of Researches on Marine Currents carried out from the Lowestoft Fisheries Laboratory". Appendix to the Ministry's series of Fishery Investigations, Ser. II, Vol. XIV, No. 4, London, 1935.

[2]) In the Council's Journal, Vol. XI, No. 2, pp. 211 *et seq.*, Copenhagen, 1936.

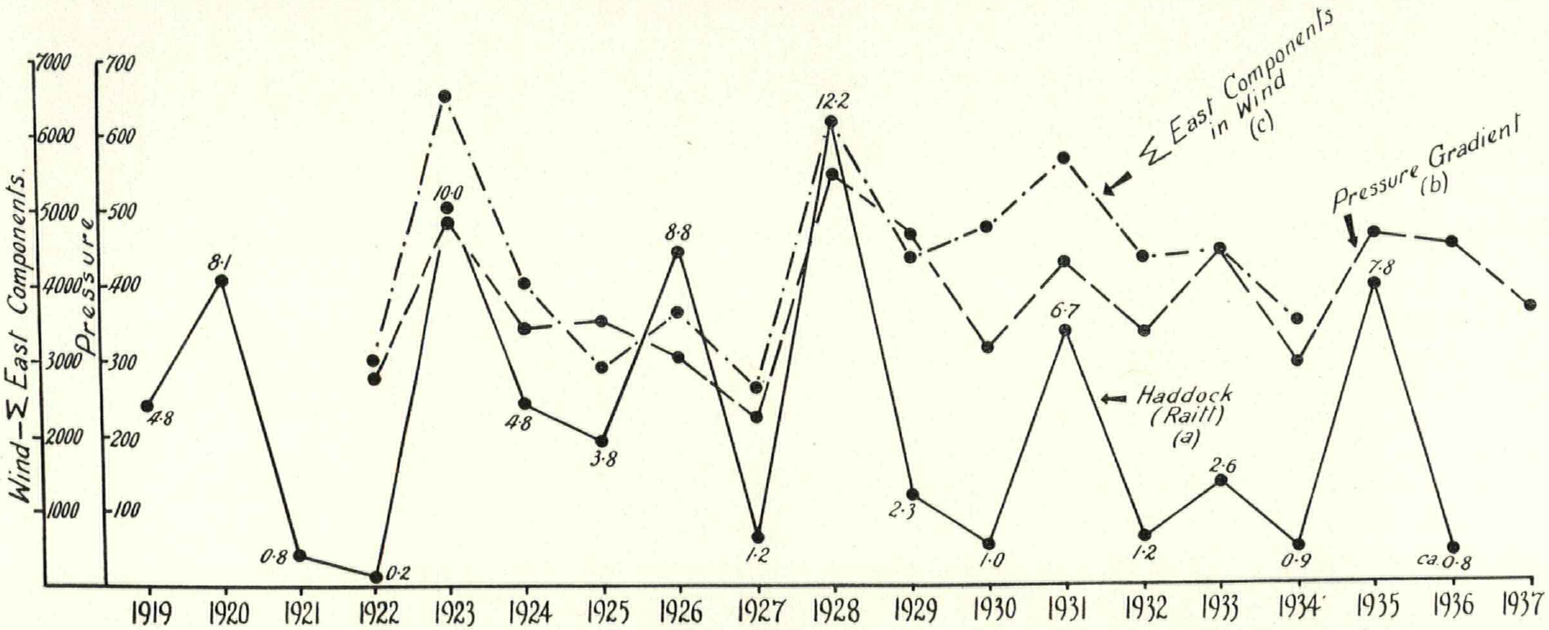

Fig. 2.

Fig. 2. Showing (a) Raitt's curve giving the "Relative Numerical Values of North Sea Haddock Broods in the First Year of Life, 1919—1934", (b) a curve portraying Pressure Gradient Values implying Wind from the SE. Quadrant during March, April and May, and (c) a curve relating to "East in the Wind" as computed from actual observations during February, March, April and May, at three appropriate Stations.

[Notes re Fig. 2. (1) For details as to curves (b) and (c) see Notes Two and Three respectively in the Appendix. (2) The 1935 and 1936 haddock values in curve (a) were kindly communicated by letter from Dr. Raitt and are to be regarded as subject to re-consideration by him.]

This impression arose some years ago as the result of certain findings concerning the two peak years for haddock, 1923 and 1928. In respect of that area of the North Sea to which interest attaches in the present connexion, it was found that the springs of those two years were very similar in certain meteorological characteristics. Also, the two respectively preceding years 1922 and 1927, alike poor years for haddock, could easily be "brought into line" meteorologically and shown to contrast with 1923 and 1928 in respect of more or less local wind conditions reigning in spring.

It only needed the belief that the influence of wind on water *could* be great enough to rule fluctuations in year-class strength, to direct detailed attention to the problem.

As the result of remarks made in my 1935 paper on the subject of cod and contemporaneous meteorological fluctuations, I was fortunate enough to receive correspondence from a high meteorological authority. Sir GILBERT WALKER, C.S.I., F.R.S., formerly Director-General of Indian Observatories and lately Professor of Meteorology in the Imperial College, displayed interest in the subject of fish fluctuations, and asked to see relevant literature. He tabulated data from 1875 onwards "of the North Atlantic Oscillation .... positive figures for which mean strong ocean winds towards northwest Europe .... with warmth there and cold in Labrador; and *vice versa*". He worked out data for March to May, June to August, September to November, December to February, and for whole years. On comparing his data with those of fish fluctuations supplied to him, he declared himself unable to see any relationship at all — rather to his surprise. The springs of 1923 and 1926 (good for haddock) were normal, but 1928 was in marked contrast and negative. He said "clearly it means, as might be expected, that it is the weather in the North Sea that matters, rather than that of the North Atlantic when the latter is not identical with it". He was, therefore, of the opinion that the right procedure in the case of the North Sea haddock and cod, was to continue seeking explanations within the North Sea.

For the months of March, April and May of the years 1922 to 1937 (and in some cases of 1919, 1920 and 1921 as well) atmospheric pressure data in the form of monthly means were procured for a number of stations judged to be suitable for the consideration of implied winds from most directions over the haddock area. Dr. C. E. P. BROOKS kindly supplied data for Deerness, Spurn, Utsire and Blaavands Huk, and thanks are offered also to Dr. SVERRE PETTERSSEN and Mr. LOMHOLT for additional data relating to Norway and Jutland respectively.

With two stations on the British side of the North Sea (more if consultation of Meteorological Office publications were undertaken) and six on the eastern side, many pressure gradients could be investigated. The data related to three separate months, and it was not known which was the best line to follow — whether to pay attention to all three, or to April and May, or to May alone. Very many trials had to be made until it became clear that the best parallelism would result if the haddock curve were compared with a curve portraying pressure gradient for wind between south and east. Eventually, out of some dozens of curves, that representing an average of the gradients: Utsire to Spurn, and Blaavands Huk to Spurn was chosen for publication. To magnify the ups and downs of this pressure curve, a step explained in "Note Two" of the Appendix was taken.

In view of the degree of resemblance between the two curves, it was decided to plot also against the haddock, certain wind data of a very comprehensive nature originally prepared for another purpose. The nature of these wind data is described in "Note Three" in the Appendix, and it is to be remarked that they would probably have been better for our present purpose if February had not been included.

Concerning both pressure and wind, it needs to be stated that we do not know whether we have dealt with the "best" months. This being so, it is to be realised that a much better parallelism than we show, *might* be forthcoming on longer investigation.

Haddock Fluctuations Compared with Fluctuations in (1) Implied Wind from the SE. Quadrant, and (2) "East in the Wind".

Reference to Fig. 2 shows that it is possible to compare the pressure and haddock curves over fourteen steps, and reveals that in twelve cases the two curves move up and down together. In one case (1925 to 1926) there is clear disagreement, and it may be remarked in passing that the 1925 to 1926 haddock change hardly ever agreed with the 1925 to 1926 pressure change in the many trial curves constructed.

The remaining step where disagreement occurs is that of 1924 to 1925, and this is of little importance because the haddock change was small and the pressure change almost nothing.

When we turn to what for brevity we have called "east in the wind", comparison is possible over twelve yearly steps and agreement is present in all but one case — that of the step 1929 to 1930.

In this latter case the wind curve does not rise a great deal and the haddock curve does not fall very steeply.

Cod and Pressure Gradient.

No particular attention has been paid to the cod in the course of this study, but the following series of figures relating to the pressure gradient Fanø to Skudesneshavn for the months of March, April and May is of some interest.

1922	*1923*	*1924*	*1925*	*1926*
+ 6·9	— 1·0	+ 5·2	+ 2·4	+ 2·7
1927	*1928*	*1929*	*1930*	*1931*
+ 2·0	— 2·9	+ 1·9	— 3·0	— 3·4

Values set down are measures of wind from a direction south of west where positive; negative values imply and are a measure of wind from north of east on the eastern side of the North Sea.

A paper by GRAHAM published in the Ministry's Fishery Investigations in 1934, gives figures for relative brood-strength for the year-classes 1922 to 1930, and an indication for 1931 has since been supplied to the writer. They are as follows:—

1922	*1923*	*1924*	*1925*	*1926*
2	7	6	6	1
1927	*1928*	*1929*	*1930*	*1931*
3	8	2	7	7++

Comparison is possible for nine steps and it is seen that in all cases but one the cod figures rise with increase of implied wind from north of east, and fall with increase of wind from south of west. The disagreement occurs with the pressure step 1924 to 1925, where a fall in pressure goes with no change in cod, but it is hardly likely that the cod figures 6 and 6 can be taken to denote precise equality. Since this pressure series was not obtained in the course of a search specially devoted to the cod, it is quite possible that further investigation would result in the discovery of a much better parallelism.

In conclusion, the reader to whom the subject matter of this paper is of interest, is enjoined to bear in mind the remarks made concerning the absence of proportionality between the sets of data expressing the fluctuations compared.

APPENDIX

Note One.

Letting each of the places Brussels, Kew, Helder and Yarmouth be denoted by its initial letter, and letting the suffixes d and j denote the mean atmospheric pressures for December and January respectively, the quantity plotted in Fig. 1 was:—

$$(B_d + B_j + H_d + H_j) \text{ minus } (Y_d + Y_j + K_d + K_j) \; .... + 100$$

all pressures having been expressed in tenth-millibars and the number 100 added to avoid the inconvenience of negative values.

Note Two.

Letting B stand for Blaavands Huk, U for Utsire, and S for Spurn, and letting the suffixes m, a, and ma stand for March, April, and May respectively, the quantity plotted in the pressure graph of Fig. 2 was:—

$$(B_m + B_a + B_{ma} + U_m + U_a + U_{ma}) \text{ minus } (S_m + S_a + S_{ma})$$

each of the nine values being the mean atmospheric pressure (expressed in tenth-millibars) at the place and for the month indicated.

This "gradient" has no real meaning in terms of implied wind such as it would have had if twice the quantity subtracted had been taken away (then it would have represented the sum of two gradients = twice the average) but the quantity indicated was plotted in order to magnify the ups and downs somewhat.

Note Three.

From the Daily Weather Report (British Section) of the Meteorological Office, the observations of wind strength and direction at Spurn, Tynemouth and Inchkeith (four observations daily) were collected into the sixteen main divisions of the compass after converting from Beaufort numbers into miles per hour. The months February + March + April + May were taken into account. At this stage values had been obtained which, if multiplied by 6, would represent the "miles of wind" from the various directions during the entire period of four months. For each year, from 1410 to 1450 observations were dealt with. Amongst other steps next taken, a summation was made of all cardinal components for each year, and the quantity plotted represents the result of resolving all the entries having east in them along the east line and adding the components so obtained. The resulting values ranged from 6,473 for 1923 and 6,094 for 1928, down to 2,602 for 1927.