Herring Investigations at Plymouth. V. The Plymouth Winter Fishery during the Season 1927-28.

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With 7 Figures in the Text.

CONTENTS

DURING the winter of 1927–28 the progress of the herring fishing at Plymouth was followed for the fourth consecutive season. A diary of market events was again kept by Mr. A. J. Smith of the Laboratory staff, while statistics of commercial landings and of the number of visiting drifters were kindly supplied by Mr. T. Edser of the Statistical Department, Ministry of Agriculture and Fisheries, and by Mr. E. C. Nelder of the Sutton Harbour Improvement Company, respectively. In the examination of age and growth of random samples of herrings, Mr. F. J. Warren, Laboratory Assistant, again acted as recorder. Details of the methods of treatment of the data collected will be found in Part I of this series of Reports (Ford, 1).

THE WINTER FISHERY OF 1927–28.

The season was in several ways a notable one. It will be seen from the following table that in spite of a marked reduction in the number of

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boats fishing, particularly in the case of steamers, the total quantity of
herrings landed created a record :—

Season Dec.-Jan.	Number of East Country steamers.	Number of West Country (Cornish) motor drifters*	Total Quantity of Herrings landed. cwt.	Quantity landed by steamers only. cwt.	Quantity landed by motor drifters† only. cwt.
1918–19	33	139	8,624	7,628	996
1919–20	30	156	29,425	12,728	16,697
1920–21	26	182	40,263	20,973	19,290
1921–22	31	155	16,922	10,494	6,428
1922–23	68	142	54,839	40,941	13,898
1923–24	59	161	98,684	57,519	41,165
1924–25	86	176	113,585	83,647	29,938
1925–26	153	158	105,643	82,780	22,863
1926–27	129	169	63,138	45,932	17,206
1927–28	77	145	122,419	82,803	39,616

The Steam Fishery.

There has been an appreciable decline in the number of steamers
visiting Plymouth during the past two seasons, due, probably, to the
fact that the fishery had experienced several indifferent seasons in succes-
sion. In the months of December, 1927, and January, 1928, however,
the seventy-seven steamers made a total of 1789 landings of an average
weight of 46·6 cwt. This result was a welcome improvement on the
averages for the corresponding months of the seasons 1925–26 and
1926–27 (23·1 cwt. and 16·6 cwt. respectively), as well as on the average
of 26·6 cwt., covering the longer period of nine seasons from December,
1918, to January, 1927.

Whether or no the steamers, by ceasing fishing towards the end of
January, leave the district when fishing might yet prove profitable, is a
question worthy of investigation. The work of the past few years has
created the impression that to the westward of Plymouth there may be
an assemblage of well-grown, comparatively later-spawning herrings
which are not every year fully exploited. Some of the small local drifters,
when weather permits, certainly continue to make catches until well on
into March, while the study of fishes landed during February and March
has shown that an appreciable proportion of them have yet to spawn.
Wallace (**4**, p. 35), too, has shown that later spawning of considerable
intensity does occur in westerly waters in the neighbourhood of Gribbon
Head. In such a season as the one now under review, when consistently
good catches to the eastward are made, there is a decided tendency to
bring the fishery to a close as soon as the easterly shoals show signs of
exhaustion. In consequence of this, the late westerly fish are liable to
be almost entirely neglected.

* A small number of Plymouth motor drifters take part in the fishery, numbering on
average about twelve.
† These figures are inclusive of the landings by Plymouth boats.

The Motor Fishery.

The total weight of fish landed by the motor drifters during December, 1927, and January, 1928, was the heaviest since the record season of 1923–24. This satisfactory aggregate, however, in contrast with that of the steamers, was chiefly due to a considerable rise in the total number of landings made, rather than to an increase in the average weight per individual landing. Thus, although the total number of landings was the greatest recorded since the Ministry's more modern system of statistics was adopted in 1906, the average weight of 24·6 cwt. per landing did not greatly exceed the average of 22·6 cwt. for the nine-year period from December, 1918, to January, 1927.

As in past seasons, a considerable weight of fish was landed by the steamers on days when the motor drifters made no landings. Thus, on 22 days (inclusive of 6 Sundays) during December, 1927, and January, 1928, a total of 29,708 cwt. was landed by steamers, while there were no landings at all by motors.

Value of the Fishery.

The total value of the fishery during each of the past twenty-two seasons is shown in the following table, together with the average price per 1 cwt. :—

Season (Dec.–Jan.)	Total Weight landed. (cwt.)	Total Value. £	Average Price per 1 cwt. shillings and pence.	
1906–07	32,913	8,040	4	11
1907–08	23,957	6,583	5	6
1908–09	4,257	2,521	11	10
1909–10	52,544	16,105	6	1
1910–11	37,741	17,048	9	0
1911–12	39,167	18,158	9	3
1912–13	8,171	3,594	8	10
1913–14	28,886	13,933	9	8
1914–15	7,585	6,021	15	11
1915–16	11,582	13,062	22	7
1916–17	24,293	35,901	29	6
1917–18	38,108	88,453	46	5
1918–19	8,624	15,160	35	2
1919–20	29,425	40,045	27	3
1920–21	40,263	42,752	21	3
1921–22	16,922	14,792	17	6
1922–23	54,839	26,326	9	8
1923–24	98,684	65,290	13	3
1924–25	113,585	109,294	19	3
1925–26	105,643	89,334	16	11
1926–27	63,138	47,539	15	1
1927–28	122,419	65,451	10	8

It will be seen that during the season 1927–28, although a record total weight of fish was landed, the average price per 1 cwt. was, with the solitary exception of the season 1922–23, easily the lowest realised since the pre-war season of 1913–14. Thus, it is only necessary to refer back to the season 1925–26 to discover a total financial yield exceeding that of 1927–28.

It is of some local interest to note that the seasonal average price per 1 cwt. realised at Plymouth has almost always been greater than the yearly average price of herrings of British taking generally. This fact is brought out in the following table and in Fig. 1 :—

Year.	Herrings. British Taking. Average Price per 1 cwt.		Herrings. Plymouth only. Average Price per 1 cwt.		Season Dec.–Jan.
	shillings.	pence.	shillings.	pence.	
1906	8	1			
1907	5	1	4	11	1906–07
1908	5	7	5	6	1907–08
1909	6	0	11	10	1908–09
1910	7	8	6	1	1909–10
1911	5	11	9	0	1910–11
1912	6	2	9	3	1911–12
1913	6	4	8	10	1912–13
1914	6	9	9	8	1913–14
1915	16	5	15	11	1914–15
1916	21	11	22	7	1915–16
1917	22	10	29	6	1916–17
1918	24	6	46	5	1917–18
1919	14	1	35	2	1918–19
1920	11	11	27	3	1919–20
1921	4	7	21	3	1920–21
1922	7	1	17	6	1921–22
1923	7	11	9	8	1922–23
1924	11	4	13	3	1923–24
1925	10	5	19	3	1924–25
1926	8	7	16	11	1925–26
1927	9	5	15	1	1926–27
			10	8	1927–28

The daily returns of landings and market prices at Plymouth during December, 1927, provide a good illustration of the fact that the ruling price on the market is to a greater or lesser extent dependent upon the quantity of fish available. In the following table, daily landings have
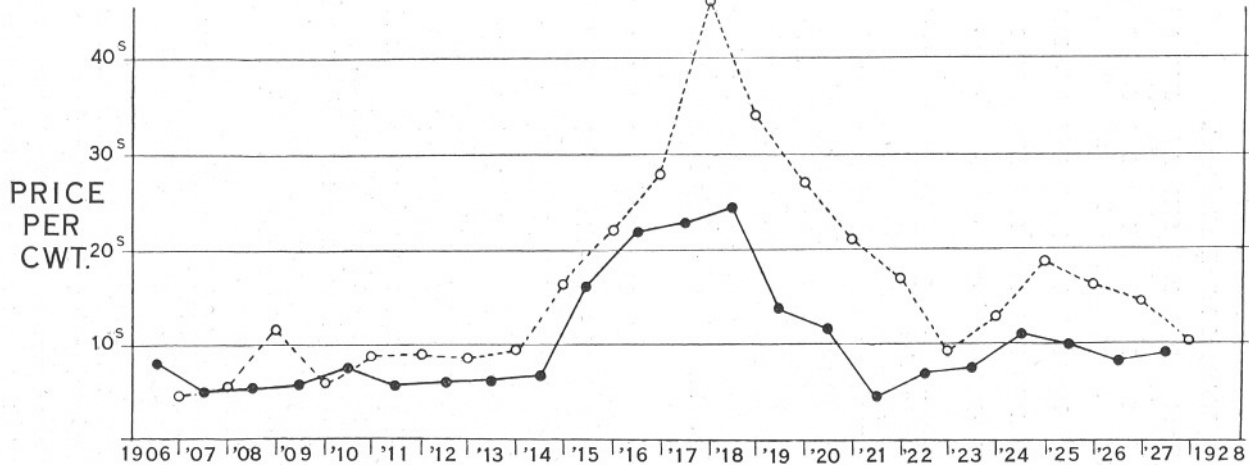
FIG. 1.—Market price per 1 cwt. of Herrings.

Continuous line —— Herrings of British taking throughout year.
Broken line .... Herrings landed at Plymouth during Dec. and Jan.

been grouped into convenient classes and the average price per 1 cwt. calculated for each class :—

Weight of Daily Landing (cwt.).

	Less than 500	500 to 999	1000 to 1499	1500 to 1999	2000 to 2499	2500 to 2999	4000 to 4499	5000 to 5499	5500 to 5999	7000 to 7499
No. of Days	5	2	3	4	7	2	2	3	1	1
Total weight landed (cwt.)	1336	1409	3581	7140	15311	5750	8600	15818	5650	7010
Average weight (cwt.) per day	267	704·5	1194	1785	2187	2875	4300	5273	5650	7010
Average price per 1 cwt. (£)	1·186	·9645	·6782	·596	·566	·433	·483	·367	·256	·320

In Fig. 2 the average price per 1 cwt. for the average weight in each class has been plotted, and the smooth curve AB drawn freehand to provide a reasonably good representation of the general downward trend of the average price as the size of the daily landing increases. It is seen that this curve falls steeply at first, but less and less rapidly later. By erecting perpendiculars from the correct points along the base line, to cut the curve AB, it is possible to read off the average price per 1 cwt. for landings of given size. The following data have been obtained in this manner :—

Weight of landing (cwt.)	500	1000	2000	3000	4000	5000	6000	7000
Approx. average price per 1 cwt. (shillings and pence)	20/–	15/–	11/6	9/11	8/6	7/4	6/3	5/4
Approx. average price per 1 lb. (pence)	2·1	1·6	1·2	1·1	·9	·8	·7	·6

It is also of interest to note that during December, 1927, on 15 out of the total of 30 days on which fish were actually landed, a total of 48,085 cwt., representing about 67% of the total weight landed throughout the month, was sold at a daily average price varying from 10s. to 5s. per 1 cwt. ; that is, at the rate of from 1d. to $\frac{1}{2}$d. per 1 lb.

In applying these statistics, however, it must be borne in mind that they are *averages ;* they smooth over those differences in price, often appreciable, between different sales on the same day. Every prospective buyer knows his own immediate requirements, and bids accordingly. One needs a given quantity of fish of the finest quality procurable for which he is prepared to pay a high price. Having secured these fish, he is indifferent to all subsequent sales. On the other hand, a second buyer is not likely to compete for fish until the price has fallen to a certain figure, but he will then buy heavily. The average figures for the day used in the foregoing considerations thus represent the mean of individual sale prices which may differ to a marked degree, so that in drawing comparisons such as that between prices at the source and those paid by the consumer these averages must be applied with great caution, if at all.

So far as actual fishing and marketing operations are concerned, however, they are instructive. By utilising the data derived from the curve AB on Fig. 2 we can determine the approximate total market value of a day's catch of given weight ; thus :—

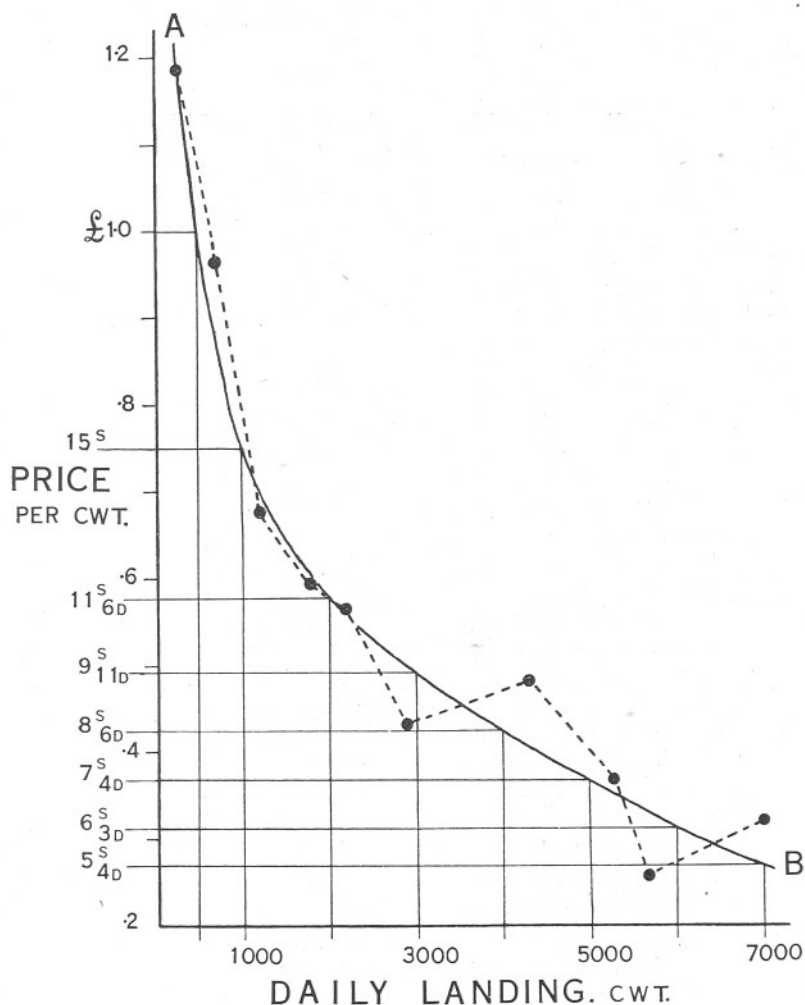| Weight of landing (cwt.)	500	1000	2000	3000	4000	5000	6000	7000
Approx. average price per 1 cwt. (shillings and pence)	20/–	15/–	11/6	9/11	8/6	7/4	6/3	5/4
Approx. total value of landing (£)	500	750	1150	1485	1700	1835	1875	1875

FIG. 2.—Market price per 1 cwt. of Herrings landed by steamers during Dec., 1927.

The continuous curve AB is drawn freehand as an approximate fit to the observed values, and from it the price per 1 cwt. for a daily landing of given size may be estimated.

To the mind of the fisherman these figures mean that during December, 1927, in increasing the total weight of fish landed in a day from 1000 cwt. to 2000 cwt., he received £400 for the additional 1000 cwt., whereas in raising the daily total from 4000 cwt. to 5000 cwt., the remuneration he received for the additional 1000 cwt. had dwindled to £135. And what is more, any amount of fish in excess of 5000 cwt. per day was literally given away.

These figures also suggest that during this period buyers were not prepared to spend much more than £1800–£1900 on daily catches aggregating 5000 cwt. or over.

The Characters of the Fishes Landed.

Eleven samples from commercial landings between October 17th, 1927, and March 3rd, 1928, were examined for length, sexual condition, age, and growth. The possession of corresponding data for the three preceding seasons undoubtedly adds to the interest and value of the present records, enabling useful comparisons to be made from which a more intelligent view of events from year to year can be obtained.

Average Length.

In Table I on page 23 the values of the median length (Q_2), the quartiles (Q_1 and Q_3), and the upper and lower limits of size for each sample are given. Corresponding data for previous seasons were given in Part III (Ford, **2**, p. 301). The means of the individual values of Q_1, Q_2, and Q_3 for each season provide a rough indication of the length distribution, and in the following table these means for the period November to January during the four consecutive seasons are shown :—

	Mean of sample values for the following seasons (Nov.–Jan.).			
	1924–25.	1925–26.	1926–27.	1927–28.
		(cm.).		
Q_1 . . .	26·4	26·4	25·6	24·7
Q_2 . . .	27·3	27·4	26·5	25·8
Q_3 . . .	28·2	28·3	27·8	27·0

It is seen that the appreciable depression of length during 1926–27 was followed by a further drop during 1927–28. It is true that considerable differences in average size can be occasioned by changes in the size of mesh in the drift-nets used (*vide* Hodgson, **3**), but in the present instance this is not thought to be the important factor. The account of the age-composition of the samples, given later, will demonstrate convincingly that the 1927–28 samples included a very much larger percentage of young fishes than those of 1925–26 or even 1924–25. Further discussion of the length data will be found on page 12 in conjunction with those on age.

Age Composition of Samples.

The age composition of the 1927–28 samples is given in the form of percentages in Table II on page 24. These results are also shown graphically in Fig. 4 on page 11, while, for convenience, the corresponding results for previous seasons have been republished in Fig. 3. It will be noticed that the principle used during the seasons 1924–25 and 1925–26, namely, of including all fishes definitely older than " 6 zones 6 rings " in a composite year-group, has been reverted to. Where interest is chiefly centred on the percentages of well-represented year-classes which either form the mainstay of a current fishery or will become increasingly important in the near future, it is hardly necessary to estimate precisely the age of a few older fishes.

By determining the mean of the individual sample percentages of each year-group, we can arrive at an average composition which will serve as a working summary for the season. Admittedly, such a summary is an approximation, but it facilitates the comparison of results from season to season ; it is not intended to stand as an accurate assessment of the age-stock on the grounds. The summary for 1927–28 is as follows :—

Season (Nov.–Jan.).	2	2–3	3	3–4	4	4–5	5	5–6	6	6–old	Older than 6
					Percentage Composition by Age.						
1927–8	—	—	16·5	0·2	19·2	1·2	30·4	1·8	11·1	1·1	18·2

As an alternative, sample age-data may also be summarised as percentages of definite year-classes, thus :—

Season (Nov.–Jan.).	1925	1924	1923	1922	1921 & earlier.
		Percentages of Year-classes.			
1927–28	16·5	19·2	30·4	11·1	18·2

It is seen that the 1923 year-class, now as 5-zoned 5-ringed fishes, definitely dominated with a percentage of 30·4. This is in accordance with the expectation expressed in Part III (Ford 2, p. 291) when the previous season's results were under review. Two other facts should be noted at this stage. In the first place, there was an unusually high percentage of 3-zoned 3-ringed fishes (1925 year-class), the significance of which will be dealt with later. Secondly, the year-class 1920, so dominant a constituent of the samples from the landings of the three previous seasons, no longer formed an important element.

The Year-class 1920.

It has previously been shown that fishes of the year-class 1920 were much in evidence during the seasons 1924–25, 1925–26, and 1926–27 (Ford, 2, p. 289). As 5-zoned 5-ringed fishes in 1924–25 they comprised
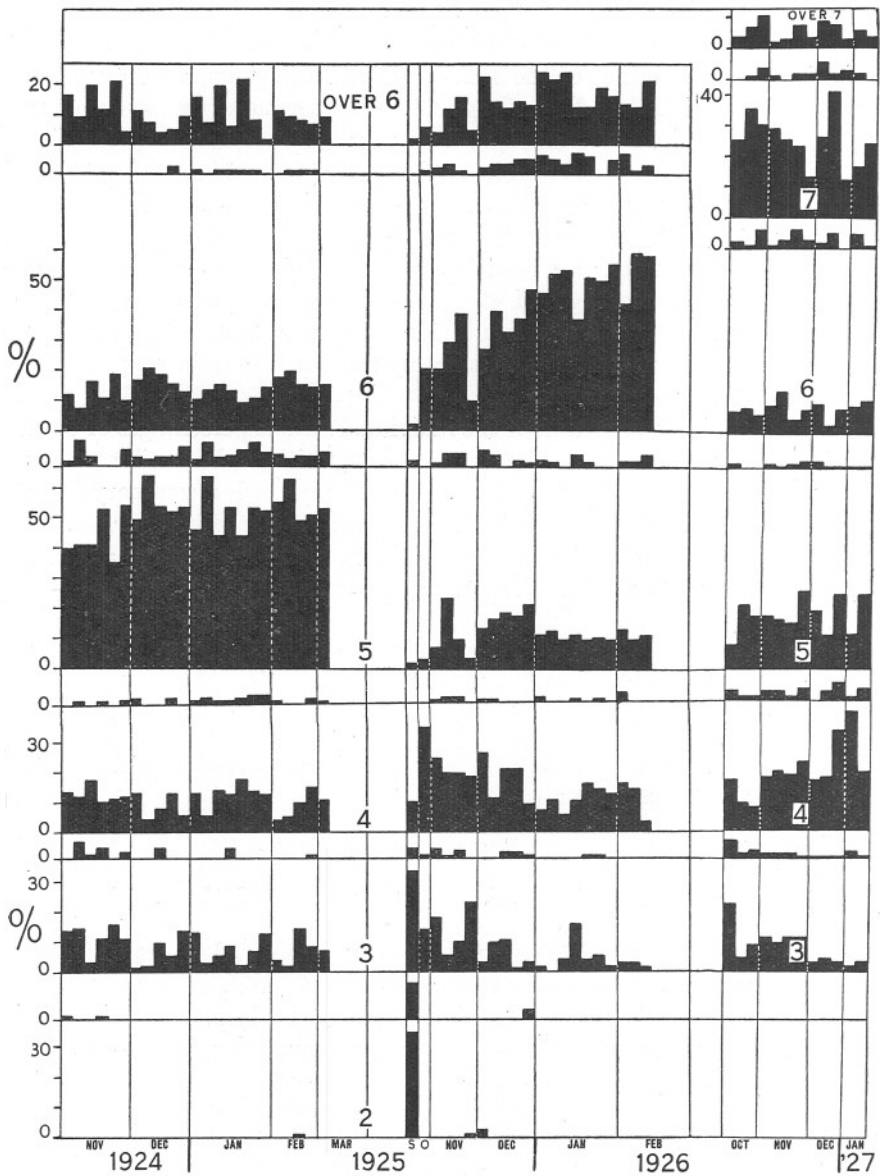
FIG. 3.—Age composition of samples of Plymouth Herrings.
Sample percentages are shown as small vertical blocks. The age-classes are as follows :

2	.	.	.	.	2-zoned 2-ringed.
3	.	.	.	.	3-zoned 3-ringed.
4	.	.	.	.	4-zoned 4-ringed.
5	.	.	.	.	5-zoned 5-ringed.
6	.	.	.	.	6-zoned 6-ringed.
7	.	.	.	.	7-zoned 7-ringed.

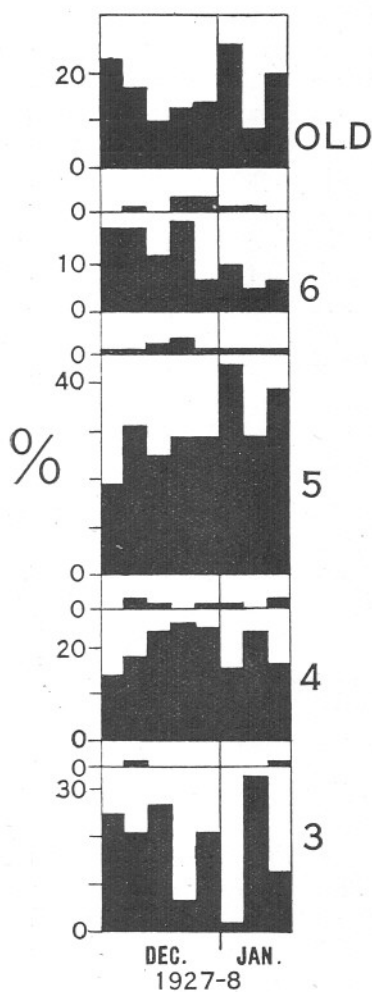The " interval " classes are obviously 2 or 3, 3 or 4, 4 or 5, etc.

Fig. 4.—Age composition of samples of Plymouth Herrings landed during season 1927–28.

Figure constructed in same way as Fig. 3. The age-class " OLD " includes all fishes definitely older than 6-zoned 6-rings.
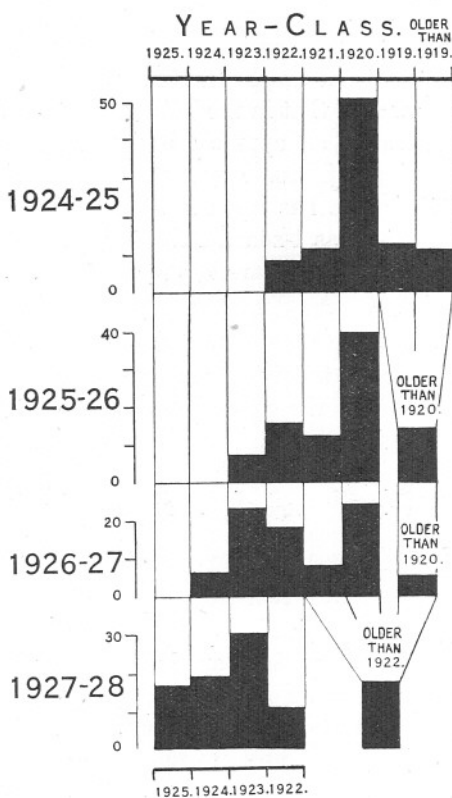
Fig. 5.—Summary of age composition during four consecutive seasons at Plymouth. The average seasonal percentage of each year-class is shown as a small vertical block.

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more than 50% of many samples ; as 6-zoned 6-ringed fishes in 1925–26
they again greatly outnumbered those of any other year-class, while as
7-zoned 7-ringed individuals in 1926–27 they were still a leading element
although not so heavily represented as in previous years. But now, in
1927–28, as 8-zoned 8-ringed fishes they no longer form a dominant con-
stituent of the samples, having been replaced by the members of younger
year-classes. It is, naturally, a little disappointing that the available data
do not go sufficiently far back actually to cover the whole period through-
out which this successful year-class 1920 had formed part of the Plymouth
catches. Judging from recent experience, it seems extremely unlikely
that more than an occasional well-grown individual of this class would
have been caught in 1921–22 as a 2-zoned 2-ringed fish. It is possible,
however, that in the following season of 1922–23, the catches would have
included an appreciable percentage of the 1920 year-class as 3-zoned
3-ringed fishes. Furthermore, when as a result of a further year's growth
their size has become well within catchable range, the percentage in
1923–24 as 4-zoned 4-ringed individuals might easily have exceeded that
of any other year-class represented.

Length for Age.

In the following table the average length and individual variation for
fishes of the year-classes represented during the season 1927–28 are
given :—

Year-class.	Age.	No. of fishes in each of 10 length-groups (cm.).										Total No.	Average length. cm.
		21	22	23	24	25	26	27	28	29	30		
1925	3-zoned 3-ringed	4	18	57	71	34	4	1	1	–	–	190	24·2
1924	4-zoned 4-ringed	–	2	26	49	66	32	9	3	1	1	189	25·3
1923	5-zoned 5-ringed	–	–	2	25	120	105	44	5	–	–	301	26·1
1922	6-zoned 6-ringed	–	–	–	7	27	31	31	8	5	–	109	26·7

These averages are lower than the corresponding ones for previous
seasons (cf. Ford, **2**, p. 293), particularly those of the 3-zoned 3-ringed
and 6-zoned 6-ringed fishes. The fact that fishing during 1927–28 was
conducted almost entirely on the more easterly grounds may account for
this (*vide* Ford, **2**, p. 287).

PREDICTIONS OF FUTURE FISHERIES.

No one with any practical experience of the annual fluctuations to
which the herring fisheries are subject, will be likely to underestimate
the difficulties which have to be overcome before there can be any hope
of giving reliable forecasts of future fisheries. In the pages which follow
an attempt has been made to indicate how the results of the investigations
during the past few seasons may be brought to bear directly upon this

practical question. In the face of so formidable a problem, any worker might reasonably hesitate to advance suggestions after such a short period of study ; it should, therefore, in fairness to the present writer, be clearly recognised that the attempted forecasts are given primarily as illustrations of the way in which the limited data may prove helpful, and, secondarily, as trial predictions which can ultimately be substantiated or disproved. Even if such forecasts do eventually prove poor, they should not necessarily be regarded as a condemnation of the whole work ; the discrepancies between forecast and reality ought rather to be examined most carefully in an endeavour to discover why they have arisen.

If we examine the data of landings by steamers over a period of years at Plymouth we are at once impressed by three facts :—

1. The average weight per landing varies greatly from one season to the next.

2. In some years the heaviest landings are made in December, whereas in others, in January.

3. Fishing operations are adversely influenced by bad weather conditions.

Of these three facts, the present work can only deal with the first two ; the influence of meteorological conditions is outside its scope, important as it may be. We have thus to discuss how the systematic study of the fishes landed during the past four seasons, and of a set of temperature records in the Plymouth area over the same period, can help us to predict the yield of a future fishery, as well as the " earliness " or " lateness " of the fishery in that season.

We have already seen that the 1920 year-class of fish formed a marked percentage of the landings in recent years. Let us, therefore, first notice the state of the fishery during those seasons when this year-class was represented in the landings. In the following table, the values of the average weight per landing by steamers are shown against the corresponding age and percentage of fishes of the 1920 year-class :—

| Season (Nov.–Jan.). | 1920 Year-class. | | | Average Weight per Landing by Steamers. cwt. |
| | Age. | | | |
	Zones.	Rings.	Percentage.	
1921–22	2	2	Practically unrepresented	13·8
1922–23	3	3	No data available	25·8
1923–24	4	4	No data available	37·8
1924–25	5	5	50·5	40·0
1925–26	6	6	39·6	23·0
1926–27	7	7	24·2	16·0
1927–28	8	8	< 10	46·6

We see that the average weight per landing rose each season from 1921–22 to 1924–25, but then fell away for two seasons in succession. During the same period the percentage of the 1920 year-class rose and fell in a corresponding manner. It is not unreasonable to argue that this is no mere coincidence and that the high average landings during 1923–24 and 1924–25 were the result of the maximum representation of a highly successful year-class 1920. From this observation we could reasonably contend that had we in 1922–23 appreciated the coming importance of this year-class we could have predicted the good catches in 1924–25 and 1925–26.

Clearly, then, as an initial step towards forecasting, we must examine our data on age composition, in order to get as much information as possible concerning the various year-classes represented.

Age Composition of Samples during the four Seasons from 1924–25 to 1927–28.

In the following table, and in Fig. 5 on page 11, the average age composition for each of the four seasons 1924–25 to 1927–28 is given.   The seasonal averages are in each case the mean of all the sample percentages of that season, and they are tabulated according to the year-class :—

| Season (Nov.–Jan.) | Average Percentage of different Year-classes. | | | | | | | Earlier than |
	1925	1924	1923	1922	1921	1920	1919	1919
1924–25	—	—	—	8·2	11·8	50·5	12·8	11·0
1925–26	—	0·25	7·2	15·7	12·6	39·6	14·2	
1926–27	—	6·3	23·2	18·9	8·6	24·2	5·2	
1927–28	16·5	19·2	30·4	11·1		18·2		

3-zoned 3-ringed   4-zoned 4-ringed   5-zoned 5-ringed   6-zoned 6-ringed

Before proceeding to examine the actual data given in the above table, it will be helpful to point out the three leading ways in which the data may be read :—

1. By reading along a horizontal line we obtain the percentage of each year-class during the same season.
2. By reading down a vertical column we learn how the percentage of a given year-class changes from one season to the next.
3. By reading across the diagonal rows we learn the percentage of fishes in each season having a given number of zones and rings.

Turning now to the data themselves, we see, in the first place, that a year-class usually makes its initial appearance in the samples when 3-zoned 3-ringed. The 1924 year-class was an exception, but even then only an occasional 2-zoned 2-ringed fish occurred in 1925–26. Bearing in mind the relatively small size of fishes when 3-zoned 3-ringed, it is probable that as yet only the bigger representatives are caught, the smaller ones avoiding capture by passing through the mesh of the net.

In the second place, the percentage of a year-class tends to rise until its members have become 5-zoned 5-ringed. For example, in 1925–26, the percentage of year-class 1923, then 3-zoned 3-ringed, was 7·2% ; in the following season, when the fishes were 4-zoned 4-ringed, the percentage rose to 23·2% ; in 1927–28, when the fishes had become 5-zoned 5-ringed, the percentage had again risen to 30·4%. Year-classes 1921, 1922, and 1924 show a similar tendency (see Fig. 5 on p. 11).

Thirdly, the percentage of a year-class tends to decline when its members have passed the age of 5-zones 5-rings. Thus, in 1924–25, the percentage of year-class 1920 was 50·5%, the fishes being 5-zoned 5-ringed ; in 1925–26 the percentage of the same year-class, now 6-zoned 6-ringed, had dropped to 39·6% ; in 1926–27, when the fishes were 7-zoned 7-ringed, the percentage had dropped still farther to the low level of 24·2% ; in 1927–28 the percentage of year-class 1920 had become so reduced that by including with it the percentages of all older year-classes, as well as that of year-class 1921, the aggregate was only 18·2%. The percentages of year-classes 1919, 1921, and 1922 also showed a decline after the age of 5-zones 5-rings was reached (see Fig. 5, p. 11).

Let us now return to the 1927–28 data. Five distinct age-groups are concerned, viz. : the four year-classes 1925, 1924, 1923, and 1922, and the composite group which includes all fishes of the years prior to 1922. Arguing on the indications arrived at above, we can make some progress if asked to predict what will happen during the next few seasons. We will consider each age-group in turn :—

(A) Year-class 1925.

Members of this class, as 3-zoned 3-ringed individuals, formed 16·5% during the season 1927–28. It will be observed that this percentage was

considerably greater than that for similar-aged fish in any of the preceding
seasons, indicating that the year-class 1925 is likely to prove a highly
successful one. We should expect that during the season 1928–29, when
the fish will be 4-zoned 4-ringed, the percentage will prove appreciably
higher—perhaps from two to three times that shown in 1927–28. In the
following season of 1929–30, when the members of this same year-class
will be 5-zoned 5-ringed, we may look for a percentage greater even than
that of 1928–29—perhaps amounting to 50% of the total sample. In the
next season (1930–31), when an age of 6-zones 6-rings will be reached, we
may expect to witness the beginning of a decline in importance, which
decline will in subsequent seasons become more and more pronounced.

(B) Year-class 1924.

Members of this class, as 4-zoned 4-ringed individuals, formed 19·2%
during the season 1927–28, a value which compared fairly favourably with
that for fishes of corresponding age in previous seasons. We should expect
in 1928–29 a somewhat increased percentage, say approaching 25%. In
the following season (1929–30) the first evidence of a falling-off in numbers
would be anticipated, for the fishes will then have become 6-zoned
6-ringed. In the next season (1930–31) the percentage will probably have
become reduced to an amount hardly large enough to be considered an
important element of the catches.

(C) Year-class 1923.

Fishes of this class, as 5-zoned 5-ringed individuals, comprised 30·4%
during the season 1927–28. This percentage must be regarded as the
highest likely to be reached by this year-class. The first signs of depletion
are to be looked for in 1928–29, although the percentage then reached
should still form an appreciable constituent of the samples. In 1929–30,
a further reduction would be expected, while in 1930–31 this year-class
will probably cease to be more than nominally represented.

(D) Year-class 1922.

This year-class had already passed its zenith in 1927–28, so that in
1928–29 it cannot be expected to enter much into the landings.

(E) Year-classes of 1921 and earlier years.

As with year-class 1922, these year-classes had in 1927–28 already
passed out of the stage when they could be considered likely to continue
as important constituents of the landings.

If we take as a criterion of relative importance a percentage of 10%,
we can, from the observations made under (A) to (E), suggest the future

season during which each of the year-classes represented in 1927–28 will cease to be an important element of the samples :—

Year-classes of 1921 and earlier years   During season 1928–29
Year-class 1922   .   .   .   .   ,,   ,,   1928–29
Year-class 1923   .   .   .   .   ,,   ,,   1929–30 or 1930–31
Year-class 1924   .   .   .   .   ,,   ,,   1930–31
Year-class 1925   .   .   .   .   ,,   ,,   1931–32 or 1932–33

Thus by 1932–33, i.e. five seasons hence, practically the whole of the stock represented in this season of 1927–28 will have been replaced by new stock.

It is important to realise, however, that no consideration of the sample data for any given season can yield the slightest information concerning the proportion of new year-classes which will appear in the future. But, by watching the actual percentage of 3-zoned 3-ringed fishes in each season, we can obtain advanced warning of the part likely to be played by a newly arrived year-class. If the percentage of 3-zoned 3-ringed fishes is unusually high, we may expect fishes of that year-class to become a leading constituent of the landings during the next two seasons at least ; if, on the other hand, 3-zoned 3-ringed fishes are relatively few, we shall not expect great subsequent yield from that year-class.

Age Composition in Relation to Density of Landings.

In the preceding section we endeavoured to predict the proportions of the different year-classes in samples of future seasons. We have next to discuss the probable effects of these changes in proportion on the density of commercial landings. At this stage it is necessary for us to recall that in our age-estimates we are dealing with percentages and not absolute values. Thus to determine the numerical abundance of fishes of a given year-class in a particular season, we must interpret our age-percentages in terms of the absolute density of fish—in our case, the average weight per landing by the steamers. With these two sets of data available, let us try first to sum up the situation during the season 1927–28, when the average weight per landing rose to a new high level. (See table on p. 13.) We can safely conclude that the good landings in that season were not due to the year-classes 1920 and 1921, for the former had at that time become seriously depleted, while the latter had been poorly represented during the two previous seasons when most would be expected from it. Evidence seems in favour of the view also, that year-class 1922 was of minor importance ; had it been one of appreciable success we should not have expected the average weight per landing in 1926–27, when fishes of this class were 5-zoned 5-ringed, to have fallen so low as 16 cwt. Our

attention is thus attracted particularly to year-classes 1923, 1924, and 1925. Of these three, year-class 1923 had already given promise in 1926–27 of being a more important one than its immediate predecessors of 1921 and 1922, and the possibility of an increase in its significance in 1927–28 was suggested in an earlier Report. (Ford, **2**, p. 291.) Here again, however, the low average landing in 1926–27 does not support the view that year-class 1923 was an outstanding success like that of 1920, although it must be regarded as a considerable improvement on year-classes 1922 and 1921 on account of its importance during 1927–28.

Turning next to year-class 1924, we note that its members, as 4-zoned 4-ringed fishes during the season 1927–28, contributed 19·2% towards the high average landing of 46·6 cwt. We must therefore regard this year-class as of at least average importance, and expect it to yield a satisfactory quota to catches of the immediate future. The percentage of 6·3 in 1926–27 when the fishes of the class were 3-zoned 3-ringed, however, did not arouse unusually high expectations.

The third of the classes to be considered is that of 1925 which appeared for the first time in appreciable numbers in 1927–28. Here we have very real hopes of a new highly successful group which in the first year of appearance constitutes a percentage of 16·5% of a high seasonal yield.

We are now in a position to attempt a forecast for the forthcoming season of 1928–29. On the indications considered above, we should expect the following :—

1. A decline in the abundance of the fairly rich year-class 1923.
2. An increase in the fairly rich year-class 1924.
3. An increase in the rich year-class 1925.

We should, under the circumstances noted, expect that the total increase resulting from (2) and (3) would more than counterbalance the decrease due to (1). That is to say, so far as the old stock is concerned, there should be a better available supply of fish in 1928–29 than in 1927–28. Furthermore, an additional new element, the 1926 year-class, should appear as 3-zoned 3-ringed fishes, but no forecast can, at present, be offered concerning the extent to which this may be expected. Altogether, then, so far as the available supply of fish is concerned, the prospects for the season 1928–29 would appear favourable.

Early and Late Seasons.

It is well known that at Plymouth, as elsewhere, the season is sometimes early, sometimes late. Any form of observation which would give a reliable indication of the time at which good fishing might be expected in an impending season, would, therefore, be of material practical utility.

We know that, at Plymouth, the shoals which arrive in the winter are concentrating for spawning. It is reasonable to think that such a physical factor as the temperature of the sea will influence the development and ultimate maturation of the roes and milts, and, in consequence, will have its effect on the time at which the fishes approach the spawning-grounds. Since the year 1921, regular observations of temperature at certain hydrographical stations in the Plymouth area have been made by Dr. Atkins and Mr. Harvey of the Laboratory Staff. We may safely use the data on temperature at a depth of 10 metres at Station E_1
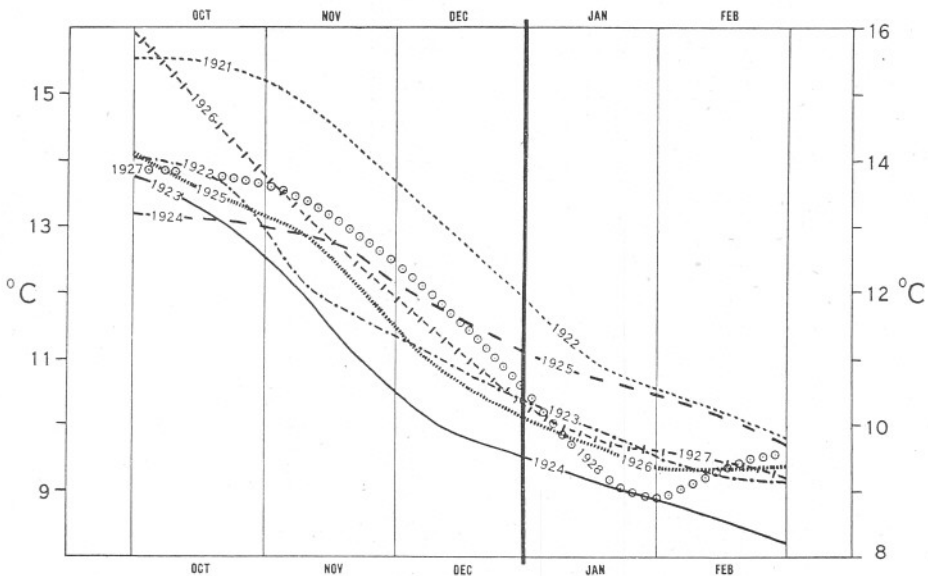

FIG. 6.—Temperatures at 10 metres depth at Hydrographical Station E_1.

(ca. 10 miles S.W. of the Eddystone) as an approximation to the temperature conditions prevailing over the Plymouth herring fishing-grounds (*vide* Ford, **2**, p. 287). In Fig. 6 the temperatures during the winter months are expressed in the form of smoothed curves drawn to fit the data.

From the curves in Fig. 6, the following average values for the seven seasons have been determined :—

Date.	Nov. 1st.	Dec. 1st,	Jan. 1st.	Feb. 1st.
Average temp. (°C)	13·5	11·9	10·5	9·6

Comparing the records for individual seasons with the above averages, we see at once that during 1921–22 the temperatures were much above the normal throughout the months of November, December, and January,

whereas during 1923–24 they were consistently below the normal. It is of immediate interest to examine the monthly landings of herrings during these two markedly abnormal years. For this purpose, the landings by motor-drifters are the more convenient, for these vessels are at work during November, whereas the steamers rarely arrive in numbers until December. Here are the data of landings by motor-drifters during the two seasons 1921–22 and 1923–24 :—

Season.	Total Weight of Fish Landed by Motor-Drifters. (Cwt.)		
	November.	December.	January.
1921–22	293	2,103	4,325
1923–24	23,492	23,840	17,325

The contrast between these two sets of data is striking. In the first place it is seen that the total landed during November was almost negligible in 1921–22 but of real importance in 1923–24. This observation becomes of additional interest when it is realised that in the month of November, during each of the remaining five of the series of seven seasons, the total weight landed never once exceeded 9000 cwt., nor was it less than 4000 cwt. In the second place it is seen that in 1921–22 the greatest quantity of fish was landed as late as January, whereas in 1923–24 the best catches were taken in November and December.

There appears to be no evidence that these two facts can be entirely explained by differences in intensity of fishing due to the number of vessels working in the two seasons, or to varying weather conditions. Turning to the temperature records, therefore, it is interesting to notice that the temperature range during January, 1922, corresponded with that prevailing during the greater part of November, 1923. From this we may well suppose that catches are likely to be considerably better in waters *below* 12° C. than in waters *above* 12° C. in temperature.

Referring once more to Fig. 6, we see that the temperatures prevailing during the season 1924–25 are interesting in that the curve, like those for 1921–22 and 1923–24, is a departure from the normal, although of a different character. The water during late December and the whole of January was appreciably warmer than usual. Thus on January 1st, 1924, the temperature was about 11·1° C. compared with the normal of 10·5° C., and on February 1st it was still as high as 10·5° C., compared with the normal of 9·6° C. Comparing the average weight of fish per landing by the steamers during December, 1924, and January, 1925, we find that the average was higher during the latter month (Dec., 1924=20·3 cwt., Jan., 1925=50·7 cwt).. That is to say, superior catches coincided with a temperature lower than about 11·1° C.

From these observations concerning three seasons abnormal so far as temperature is concerned we may, therefore, draw up an experimental

progress report regarding the yield of the fishery with respect to the temperature of the sea :—

Temperature °C.						Expected Yield.
Above 13	.	.	.	.	.	. poor.
13–12 .	.	.	.	.	.	. improving.
12–11 .	.	.	.	.	.	. fair.
Below 11	.	.	.	.	.	. good.

Assuming that this report is sound, we can, from the temperatures representing the average conditions for the seven seasons (given on p. 19),
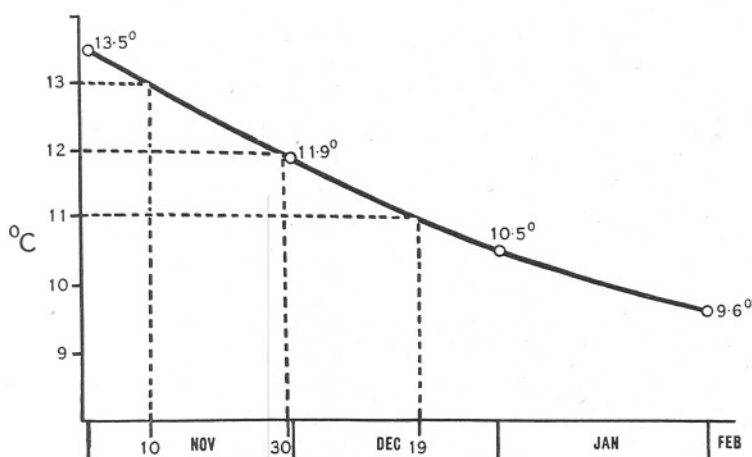

FIG. 7.—Average temperatures at 10 metres depth at Hydrographical Station E₁, based on the seven seasons' data given in Fig. 6. The dates at which 13° C., 12° C. and 11° C. are reached are indicated.

deduce a hypothetical " normal " time table of fishing. In Fig. 7, a smooth curve has been drawn to pass through the calculated average temperatures, from which we can determine the dates at which the criterion temperatures are reached :—

13° C.	12° C.	11° C.
November 10th.	November 30th.	December 19th.

We should therefore expect fishing normally to be poor until November 10th ; improving from November 11th to November 30th ; fair from December 1st to December 19th, and to become really satisfactory on December 20th.

Future Investigations.

In the above sections an attempt has been made to demonstrate the application of the study of the age of herrings, and the temperature conditions on the fishing-grounds to the question of the prediction of

future fisheries. It has been shown that advanced knowledge of the probable abundance of fish in a future season can be obtained by the study of the age of fishes in earlier years in conjunction with statistical data on market landings. Clearly, then, similar work should be carried out in the seasons which are to come in order to verify or improve upon the conclusions so far reached. With regard to the prediction of a " time table " of fishing, there is good reason to advocate the observation of temperature over the fishing-grounds at short intervals, from, say, the beginning of November onwards, so that more precise data may be obtained concerning the coincidence of fishing results with water temperature.

It is hardly necessary to point out that there are factors likely seriously to influence local fishing which in these pages have not been taken into account at all, such as variations in strength and direction of winds ; the changing tides, or the phases of the moon. While we know with certainty that gales frequently prevent the smaller vessels from leaving harbour, and that wind and tide materially affect actual fishing operations, we do not, as yet, possess much knowledge concerning the effect of such factors on the fish themselves. Conceivably, it is possible that fish may be present in the vicinity in good quantity, although few can be caught. For instance, do fish react to a period of calm sea over the time of " dead " tides ?—Do they, as one experienced skipper suggests, keep to the bottom owing to the resulting clearness of the water ? If a wind now arises, will it " stir the fish " and so cause better fishing ? Is an offshore (north-easterly) wind bad for fishing ? Does the light of a full moon induce the fish to take to the deeper layers ? Such questions as these remain to be solved, but the solutions will be hard to accomplish on account of the practical difficulties in observation.

There is also the question of the particular local grounds on which fish are plentiful in one year, or during one part of the season, and not in another. Why, for example, are fish located comparatively far up Channel towards Brixham, in one season, and away down Channel to the westward of Plymouth in another ? Can these variations be accounted for and thus predicted ? It is suggested that the study of growth from scale-measurements, and the comparisons between fishes from different parts of the Channel and south-western district will lead to a fuller knowledge of the origin and movements of the herring shoals visiting Plymouth, and that this information should ultimately indicate the particular local grounds likely to be frequented by shoals of known character. This accomplished, the further work of anticipating the future stock for these particular grounds can be undertaken. In this connection the study of fishes landed at Brighton, Brixham, Mevagissey, Newlyn, Padstow, and Milford, during the past few years has provided data of immediate value.

Finally, there remains the study of the circumstances which control the survival of the yearly broods of young herrings resulting from the spawning of the visiting shoals, for until we are fully acquainted with these facts, we cannot foretell what amount of new stock will arrive in a future season. This necessitates the detailed investigation of the history of the fish from the egg until the age of three years is reached, and, also, of the physical and other conditions which determine the number of fishes which will survive to enter the adult shoals. It is only in this way that we can arrive at an explanation of the amazing success of some year-classes and the complete failure of others; while, as has already been shown, knowledge in advance of outstanding year-classes is also knowledge in advance of fishing prospects.

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TABLE I.

LENGTH DISTRIBUTION (cm.).

Sample.	Date. 1927	Total No. of Fishes	Lower Limit.	Lower Quartile Q_1	Median Q_2	Upper Quartile Q_3	Upper Limit.
1	Oct. 17	100	23·5	24·6	25·4	26·2	28·5
2	Nov. 10	110	24·5	26·0	26·6	27·5	30·5
3	Dec. 2	110	21·5	25·0	26·0	27·1	30·5
4	Dec. 8	110	23·5	24·9	25·9	27·4	29·5
5	Dec. 14	100	22·5	24·4	25·6	26·6	29·5
6	Dec. 21	100	22·5	24·1	25·2	26·5	29·5
7	Dec. 30	100	22·5	24·4	25·3	26·6	30·5
	1928						
8	Jan. 2	110	24·5	25·9	26·7	27·6	29·5
9	Jan. 17	100	21·5	23·5	24·7	26·1	30·5
10	Jan. 28	100	22·5	24·1	26·0	27·4	29·5
11	Mar. 3	100	22·5	25·2	26·4	28·1	31·5

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TABLE II.

PERCENTAGE AGE COMPOSITION.

Sample.	Date. 1927	2	3	3–4	4	4–5	5	5–6	6	6-old.	Older than 6	?	Total No. of Fish in Sample.
1	Oct. 17	4	41	–	14	–	23	1	8	–	9	–	100
2	Nov. 10	–	–	–	15	4	29	5	14	–	32	1	100
3	Dec. 2	–	25	–	14	–	19	1	18	–	23	–	100
4	Dec. 8	–	21	1	18	2	31	1	8	1	17	–	100
5	Dec. 14	–	27	–	23	1	25	2	12	–	10	–	100
6	Dec. 21	–	7	–	25	–	29	3	19	3	13	1	100
7	Dec. 30	–	21	–	24	1	29	1	7	3	14	–	100
	1928												
8	Jan. 2	–	1·8	–	15·5	0·9	43·6	0·9	10·0	0·9	26·3	–	110
9	Jan. 17	–	33	–	23	–	29	1	5	1	8	–	100
10	Jan. 28	–	13	1	16	2	39	1	7	–	20	1	100
11	Mar. 3	–	11	–	12	–	36	1	8	4	27	1	100