REPORT

ON THE

AGE AND GROWTH-RATE OF PLAICE

IN THE

SOUTHERN NORTH SEA,

AS DETERMINED BY THE INVESTIGATION OF OTOLITHS,

BY

WILLIAM WALLACE, D.Sc.,

Assistant Naturalist on the Staff.

With Diagrams (Figs. 1–13) in Text, Synoptic Table, Tables I–IX, and Plates I–V at end.

CONTENTS.

Page.

I.—General Considerations:

§ 1. Introduction 3

§ 2. Nature of Results obtained 3

§ 3. Earlier Method of Research 4

§ 4. Advantages of Otolith Method 5

§ 5. Evidences of Reliability of Otolith Method 5

§ 6. Age Nomenclature 7

§ 7. Tabulation of the Data 7

II.—Distribution and Size of Age Groups:

§ 1. Distribution of the Age Groups 8

§ 2. Relation of Size to Age on the English Inshore Grounds 13

§ 3. Relation of Size to Age in the Region between the Leman Banks and the Dutch Coast 18

§ 4. Relation of Size to Age on the Central Grounds 26

III.—Average Rate of Growth in the Southern North Sea 30

IV.—Note on the Relative Mortality of Males and Females at Different Ages 33

I.—GENERAL CONSIDERATIONS.

§ 1. Introduction.

It has been recognised, ever since scientific methods of investigation have been directed to the solution of practical fishery questions, that amongst the first and most essential problems to be attacked are those of the age of fishes of particular sizes, of the rate of growth of fishes, and of the average duration of life of fishes of both sexes. An accurate knowledge of these matters is necessary for the proper understanding both of the life-histories of the fishes and of the changes produced in the fish population by the operations of the fishermen. A ready means of ascertaining the exact age of any individual fish is clearly, therefore, of much practical value, and fortunately such a means has been discovered in the recently developed method of examining the number of rings shown by the otoliths or ear-stones.

The data with which this Report deals consist of determinations of age (as inferred from the number of yearly rings in the otoliths), combined with measurements of length, in 7,863 plaice.

In addition, a large amount of material including the otoliths of over 7,200 plaice collected during the current year (1906) on various grounds exists but has not been worked up.

In the collection of all this material my colleagues, Mr. J. O. Borley, Mr. R. A. Todd, and Mr. A. E. Hefford, have kindly co-operated, while Mr. G. T. Atkinson has been of great assistance in dealing with the fishes at sea. I would also record here my indebtedness to Dr. Garstang for his valuable criticism; to Mr. Todd for his fine photographs of otoliths and plaice reproduced in Plates I., II., and III.; and to Mr. Hefford for undertaking an independent investigation of a large collection of otoliths (Leman ground to the Texel, September, 1905) with the view of determining to what extent the "personal equation" enters into these observations.

In the discussion of results, I have limited my remarks to the quantitative distribution and average size of the age groups of plaice, neglecting for the present the range of size which will be an important consideration when we come to convert statistics of length into those of age. My arrangement of the raw material in the Age-Group Tables at the end of this Report should however materially facilitate this process.

§ 2. Nature of the Results obtained.

The analysis of the material so far examined has yielded a considerable amount of definite information in regard to the following important points:—

(1.) The distribution of the various age groups of plaice over the Southern North Sea.*

(2.) The Average Age of the Plaice on different grounds.

(3.) The relation of Size to Age in various parts of this region.

(4.) The Average Annual growth of plaice in the Southern North Sea.

(5.) The relative mortality of males and females at different ages.

(6.) The Age and Size of Plaice at maturity.†

These matters will be somewhat briefly discussed, my object being to call attention only to those general results which clearly emerge from the first analysis of the data at present available.

---

* By Southern North Sea I mean the area lying to the South and S.E. of the 30-fathom line. This includes the Dogger Bank and Flamborough off grounds, &c., as well as the whole of the "Flemish Bight."

† This will form the subject of a separate Report.

§ 3. Earlier Method of Research.

Prior to Reibisch's* discovery of annual rings in the otoliths of plaice, the only method of inferring the average rate of growth of fishes was the method of frequency-curves, often known as Dr. Petersen's method, from having been adopted as the basis of an elaborate research by Dr. Petersen† on the growth of plaice in the Baltic, Belts, and Kattegat. The method was later employed by other investigators, and the most extensive researches in regard to the plaice were made in Scotland by Dannevig‡ and Fulton,§ the work of the latter especially being on a very large scale. Still more recently Johansen‖ and Cligny¶ have used this method to determine the growth-rate of plaice on the Danish and French coasts respectively.

This method is founded on the following well-known facts :—

(1.) The plaice (and other fishes) spawn but once a year.

(2.) The spawning period is strictly limited to a definite small portion of the year.

Now, assuming, for simplicity, that all plaice are hatched at exactly the same date** in each year, it follows that at any given moment, two plaice, if they differ at all in age, will do so either by one whole year, or by two whole years, or three years, &c., but not by intervals involving fractions of a year. Again, the size of fishes of a given age may be expected to vary according to the normal law—in the absence of disturbing factors, and always provided we are dealing with homogeneous material (of the same race, &c.). In other words the length-frequencies of fishes all of the same age will form a simple "probability curve" with a single mode.

Consequently if we make at one and the same time a large and representative collection of plaice, and plot out the frequencies of different lengths, the gross curve thus formed will exhibit a succession of undulations, each undulation representing one generation, the product of one season's spawning ; and the peaks of the curve—the crests, so to speak, of the waves of growth—will correspond to sizes which may be taken as the average sizes of successive years. Then the differences between these average sizes will give the rate of growth from year to year.

The chief difficulties experienced in the use of this method are as follows :—††

(1.) It is impossible from a mere study of length-frequencies to determine whether a given size group is caused by the predominance of fishes all of one age or of several ages.

(2.) It is impossible to tell whether two successive size groups are of the same year of age or of two successive years (as the method *assumes*), or finally whether the interval between them is more than one year, since an intermediate year might for one reason or another be missing.

(3.) Even when it is highly probable that two successive size groups represent two successive years of age, it must always be uncertain what these ages are ; at least in the absence of the youngest group—the 0 group, the size of which, however, is generally fairly certain.

(4.) Even assuming the size groups to represent age groups it is impossible by this method to ascertain, with any degree of accuracy, the range of size of fishes of a given age, as the amount of overlapping of the sizes of adjacent age groups cannot be certainly calculated.

(5.) Finally, a large collection of specimens is required to give a frequency-curve showing definite size groups, and therefore the method is inconvenient as well as uncertain, especially in dealing with the older fishes.

---

* Reibisch, 1899 ; *Wissensch. Meeresunters. K. Kommission, Kiel, Bd.* 4 (pp. 233–248).

† Petersen, 1893 ; *Report of the Danish Biological Station*, IV. (pp. 2–29).

‡ Dannevig, 1899 ; 17*th Ann. Rept., Fishery Board for Scotland*, Part III. (pp. 232–247).

§ Fulton, 1902 ; 20*th Ann. Rept., Fishery Board for Scotland*, Part III. (pp. 337–360).

‖ Johansen, 1905 ; *Medd. fra Kom. for Havunders, Série Fiskeri*, Bd. 1, Nr. 2.

¶ Cligny, 1905 ; *Ann. de la Stat. Aquic. Boulogne, Nouv. Sér.*, Vol. I. (pp. 101–122).

** As we know that this is not the case, but that the spawning period extends over three months or so, the variations of a given size group will be partly due to *slight* differences of age.

†† (1) to (3) have been recently stated by Johansen (1905, pp. 3–5).

§ 4. Advantages of the Otolith Method.

The obvious advantages of the otolith method, if reliable, are as follows :—

(1.) It gives us directly the age of individual fishes.

(2.) To determine with sufficient accuracy the average size of a given age group, it is not necessary to measure a very large number of specimens as is the case if we employ Petersen's original method.

(3.) The method gives us not only the *average* size of an age group, which, in favourable circumstances (*e.g.*, a large enough collection), may be inferred from measurements alone (*see* Fig. 4), but also the *range* of size which it is impossible to infer accurately from the measurements, since the amount of overlapping cannot be certainly calculated.

Advantages (2) and (3) follow of course from (1).

§ 5. Evidences of Reliability of Otolith Method.

This method has been independently found to be reliable by Heincke,* Redeke,† Johansen,‡ and myself, and may now be stated to have superseded, for the reasons already mentioned, the older method of dependence on frequency-curves.

The method depends on the periodic growth and seasonal differentiation in the otoliths and other skeletal structures—in a word, the phenomenon of "rings of growth."

Owing to the kindness and skill of my colleague, Mr. R. A. Todd, I am enabled to present in Plates I. to IV. a very instructive series of photographs, which besides showing very clearly the nature of the objects with which we have to deal, affords visual evidence of :—

(1.) The seasonal periodicity in the production of white and dark rings : white in Spring–Summer ; dark in Autumn–Winter.

(2.) The facility with which the number of significant rings can be definitely stated in the great majority of cases.

(3.) The regular (average) relation between the number of rings and the length of the fish.

These are three important considerations upon which the reliability and success of the method depends. I shall briefly refer to these points in order, and illustrate them by a reference to the figures in Plates I. to IV.

The Figs. 1 to 7 represent seven groups of otoliths, each otolith representing a single fish.§ All the otoliths in each group (Figure) were taken from plaice of the same centimetre length. For example, Fig. 1 represents 36 otoliths of 36 plaice all of 16 cm. length (16·0—16·9 cm.). These otoliths were not selected in any way, but simply taken at random from a heap of otoliths from 16 cm. plaice collected during the Leman to Texel cruise in May, 1905. They were arranged for photography by *reflected light* by placing on a dead-black background immersed in water, such a number being taken in each case as could be conveniently photographed simultaneously to the desired magnification. The same general explanation applies to the other figures.

(1.) The seasonal periodicity of the white and dark rings is well illustrated by the series of Figs. 1–7.

---

* Heincke, 1905 ; "*Rapports et Procès-Verbaux du Conseil Permanent International pour l'Exploration de la Mer.*" Vol. III., App. E. (pp. 1–39).

† Redeke, 1905 ; "*Rapports et Procès-Verbaux*," &c. Vol. III., App. H^1 (pp. 1–9).

‡ Johansen, 1906 ; "*Rapports et Procès-Verbaux*," &c. Vol. V., Rapport de la Commission C_2 (pp. 87–107).

§ The otolith of the right (upper) side of the plaice in each case.

Figs. 1–3 represent the otoliths of 81 plaice caught in May. It will be observed that they all show a white ring at the margins. This white ring has as yet evidently not attained its full thickness. It is narrow in comparison with any of the inner white rings.

Fig. 4 shows the otoliths of 32 plaice caught in July. In these the white ring at the margins is distinctly broader than in the case of the May-caught plaice.

Figs. 5–7 represent the otoliths of 67 plaice caught in September. Here there is a broad dark ring which extends up to the edges of the otoliths.*

(2.) The facility with which the number of significant rings can be counted in the great majority of cases will be admitted after glancing at Figs. 1–8. Only in a small minority of cases occur faint, narrow, or partial white or dark rings of doubtful significance. Now one has either to reject such doubtful cases or to make an approximate estimate of the number of true annual rings. I have consistently adopted the latter course.

Further, it must be remembered, as Reibisch pointed out (1899), three zones can usually be made out more or less clearly in the white centre or nucleus of the otolith, so that, starting from the very centre, we have (1) a dense white dot occupying the very centre ; (2) a very narrow dark ring ; (3) a narrow white ring. These all belong to the first Spring–Summer growths and are doubtless the expression of phases in the early life history (metamorphosis, &c.) of the fish.

(3.) The regular relation between the number of otolith rings and the length of the fish is very apparent in all the examples illustrated by Figs. 1–7. Each of these figures, as has been stated, represents the otoliths of a collection of plaice of the same centimetre length ; and although the otoliths were not in any way selected, the lengths were chosen so as to approximate to the average length of age groups II., III., and IV., in May, and of groups I., II., and III., in September (*see* p. 26). It is clear that the nearer the length chosen to the average size of a given age group, the larger will be the majority of otoliths showing the number of rings proper to the age group in question.

We may now examine the otoliths depicted in Figs. 1–7, noting the number of *white* rings in each case, and in the few doubtful cases estimating the probable number.

Fig. 1.—Otoliths of 36 plaice : length 16 centimetres. 28 with two rings, 7 with three rings, 1 (?) with one ring.

Fig. 2.—Otoliths of 25 plaice : length 21 centimetres. 3 with two rings, 19 with three rings, 2 with four rings.

Fig. 3.—Otoliths of 20 plaice : length 27 centimetres. 7 with three rings, 13 with four rings.

All the plaice of which the otoliths are shown in these three figures (Figs. 1–3) were captured in the region between the Leman ground and the Texel in May, 1905. The sizes of the plaice, viz., 16 cm., 21 cm., and 27 cm., are approximately the average sizes of two-year-old, three-year-old, and four-year-old fishes respectively, and we see that in the first case the large majority (78 per cent.) of the otoliths had *two* rings ; in the second 71 per cent. had *three* rings ; in the third 65 per cent. had *four* rings.

Fig. 4.—Otoliths of 32 plaice : length 16 centimetres. 19 with two rings, 13 with three rings.

The plaice of which the otoliths are shown in this figure were caught in Bridlington Bay in July, 1905. The majority (60 per cent.) show two rings. The age of these plaice would be two and a half years.

Fig. 5.—Otoliths of 24 plaice : length 14 centimetres. 20 show one ring, 4 show two rings.

---

* The *extreme* edge of these otoliths (Figs. 5–7) appears whitish, but a minute examination and comparison of these figures with Figs. 1–3 will show (what is certainly the case) that in the former the whiteness at the margin is not in the substance of the otolith, but is simply due to reflection from the slightly bevelled edges.

Fig. 6.—Otoliths of 25 plaice : length 20 centimetres. 22 show two rings, 3 show three rings.

Fig. 7.—Otoliths of 18 plaice : length 24 centimetres. 5 show two rings, 12 show three rings, 1 shows four rings.

The plaice of which the otoliths are shown in these three figures (Figs. 5–7) were caught in the Leman to Texel region in September, 1905. The sizes selected, viz., 14 cm., 20 cm., and 24 cm., are approximate to (but do not quite coincide with) the average sizes of age groups I., II., and III. (*see* p. 26). We see that of the otoliths of 14 cm. plaice the large majority (83 per cent.) have *one* ring. These plaice would be about $1\frac{3}{4}$ years old. Again, the otoliths of 20 cm. plaice show in 88 per cent. of cases *two* rings. Finally, of the otoliths of 24 cm. plaice the majority (67 per cent.) showed *three* rings.

Apart from the above demonstration, there is in the present Report abundant statistical evidence of the regular relation between the size of a plaice and the number of rings in its otoliths.

For example, an examination of Fig. 3, p. 14, and Figs. 8 and 9, p. 24 will show that :—

(1.) When the length-frequencies of a large collection of plaice plotted out show well-defined size groups, each of these groups is due to the preponderance of fishes having the same number of otolith rings.

(2.) Where we have two successive size groups *a* and *b*, of which *b* has a higher mode than *a*, the fishes preponderating in size group *b* have *just one more* otolith ring than the plaice which preponderate in size group *a*.

In regard to foreign researches the only *details* of otolith-analysis which have so far been published are those of Heincke (1905) and Johansen (1906). Redeke (1905) does not give details but simply states that he has used the method (which he has found "quite indispensable") to check the results of the graphic method. He says (p. 8), "the determination of age from the otoliths has enabled us to draw limits where the ordinary graphic method is not sufficient to show the two different year groups, just because the one-year group is always but imperfectly represented in the hauls, and, as it were, fused with the other."

§ 6. Age Nomenclature.

I have adopted Dr. Petersen's (1893) Nomenclature, according to which :—

the 0 group = fishes under *one* year old,
the I group = fishes fully *one* but less than *two* years old,
and so on.

A plaice's year is assumed to commence at the beginning of April.

§ 7. Tabulation of the Data.

In the arrangement of the data regarding the relation of size to age in the plaice, the *primary grouping* is according to the period of the year. This grouping seemed the most natural and least liable to lead to confusion in comparing different grounds. In accordance with this arrangement, October to March, during which the largest number of samples from separate localities were obtained, is treated as one period. The growth during this period, according to the marking experiments, is very slight ; not more than a quarter of the entire annual growth. In the winter proper growth appears to be more or less at a standstill. Various observations of other investigators, *e.g.*, Fulton (1902, p. 342) and Redeke (1905) lend support to this assertion.

Finally, Mr. Todd's interesting observation of the absence of food in the stomachs of the majority of plaice during the winter months* provides the reason why these fishes add little, if anything, to their growth during the cold season.

* 100 per cent. in November according to samples (*see* Mr. Todd's Report in this volume).

The *secondary grouping* of the data in the tables is according to the geographical position of the localities or grounds. Within each period the particulars for the more northerly grounds will be found towards the top, and those for the more southerly towards the foot of the tables.

These arrangements apply both to the detailed tables (Tables I–IX) at the end of this report, and also to the Synoptic Table, pp. 36 and 37.

Tables I–IX contain the original data, viz., the measurements of plaice which had 1, 2, 3.....9 + *white* otolith rings respectively in the various samples.

A separate table is devoted to each age group.

This arrangement together with the primary grouping according to season, facilitates a comparison of the size of plaice of the same age on different grounds.

The older fishes of nine years and upwards are combined in a single group (IX +) owing to the small numbers in the individual age groups and the difficulty in determining the exact numbers of rings in the case of some of the largest plaice.

The Synoptic Table contains :—(1) the necessary particulars in regard to the trawl hauls in which the various samples were obtained, and (2) the numbers and average sizes of plaice of different ages in these samples, separate data being given for the two sexes where—as in most cases—these were distinguished.

For the actual courses of the trawl hauls in which the samples for otolith-analysis were obtained, the reader is referred, by means of the reference numbers of the hauls, to the charts in the reports on " Trawling Investigations."

II.—DISTRIBUTION AND SIZE OF AGE GROUPS.

§ 1. Distribution of the Age Groups.

Our observations of the age of plaice on the English Inshore grounds within the 10-fathom line have so far been limited to the summer months.

In the Wash (2–7/viii/05) the plaice population in August was found to be mainly composed of groups O. and I. (*see* Fig. 4). Relatively few of the II. group were present and the III. group was found to be scarce although the Estuary was very thoroughly investigated. Off Mablethorpe (23–24/viii/05) on the adjacent Lincolnshire coast, however, the II. group was very abundant but the III. group, although more plentiful than in the Wash, was represented by but few specimens. Off Lowestoft (1–4/v/05) in Spring the I. and II. groups were relatively abundant (*see* Fig. 3), but the III. group was poorly represented and much below the average size (*see* Fig. 3). No plaice older than three years were found in the Thames Estuary (16/vii/04).

In Bridlington Bay, however (7–11/vii/04), fairly large numbers of the older plaice, even up to six years, were caught. These older fishes in the Bay were further remarkable for their very small average size as compared with their size on such offshore grounds as the Dogger, &c. (*see* Synoptic Table and Age Group Tables III.–VI.).

Of all the localities so far examined within the 10-fathom line Bridlington Bay is the only place where these older fishes have been found.*

From these observations it appears that before they are two years old (*see* Fig. 4) the great bulk of the plaice leave the Wash. The two-year-old plaice are very abundant within the 10-fathom line off the open coast in summer, but the three-year-old fishes are relatively infrequent within this zone. From this as well as from the small size of these groups, we may conclude that there is a migration of the great bulk of the II. group to the offshore grounds later in the season. This in fact is indicated by the analysis of samples collected on the Leman Ground in September, 1905 (*see* p. 21).

* Trawling is greatly restricted in this Bay, and is limited to small boats. *See* also footnote to p. 20.

Leman to Texel Region.—The distribution of the age groups in the region between the Leman Banks and the Dutch Coast (Leman Ground to the Texel) in September, 1905, will now be briefly described.

The accompanying Table 1. gives the number of plaice of the different age groups caught *per hour** with the otter trawl at different distances along the Leman-to-Texel line.

TABLE 1.—Showing the approximate Number of Plaice of different Ages caught per hour with the Otter Trawl in a series of hauls from the Leman Ground to the Dutch Coast (the Texel) made in September, 1905 (5–14/ix/05).

No. of Haul.	Reference No.	No. of Miles from Dutch Coast.	Depth in Fathoms.	Age Goups.					Average No. of Otolith Rings.
				I.	II.	III.	IV.	V.+	
O. 343, 344	9^1	90–80	15½–17	1·5	3·5	6·0	5·2	1·1	...
O. 345	9^2	80–70	17–16	1·2	3·7	2·5	3·7	2·5	...
O. 346	9^3	70–60	16–15½	2·2	3·2	6·2	3·7	1·2	...
Mean C.P.H.† on Leman Ground (O. 343–346)				**1·6**	**3·5**	**5·2**	**4·5**	**1·5**	**3·1**
O. 347	10^1	60–50	15½–16	1·3	11·4	15·7	10·1	1·3	...
O. 352	10^2	50–40	16–14½	0·4	11·0	17·8	5·4	0·2	...
O. 351	10^3	40–24	14½–14	0·4	22·8	17·4	8·6	1·0	...
Mean C.P.H. on Brown Bank Ground (O. 347, 352, 351)				**0·7**	**15·5**	**17·0**	**8·0**	**0·8**	**2·8**
O. 350	11^1	24–15	14–14	0·5	51·3	33·4	9·0	...	...
O. 349	11^2	15–6	13–12	2·0	50·1	9·3	0·2	...	...
O. 348	11^3	6–3	12–8	16·2	68·2	9·6	2·5	...	...
Mean C.P.H. on the Texel (O. 350, 349, 348)				**4·2**	**54·2**	**19·0**	**4·2**	...	**2·0**

The broad general features of the distribution of the ages of plaice in this region can best be recognised by considering the products of certain combinations of hauls representing the three following grounds; viz., *Leman Ground*, *Brown Bank Ground*, and *The Texel*. Of these the first is the most offshore and the last the most inshore ground. Three or four hauls were made on each of these grounds in September, 1905. The results of the age analysis of the samples thus obtained will be found in the Synoptic Table.

The chief results of this analysis as regards the distribution of the age groups on the Leman, Brown Bank, and Texel Grounds, are shown graphically in Fig. 1.

Both on the Brown Bank Ground and on the Texel over 75 per cent. of the plaice consisted of groups II. and III., but, whereas on the Texel the II. group greatly predominated; on the Brown Bank Ground II. and III. were nearly equally abundant, but III. was slightly in excess.

* In cases where the number of fishes in the sample examined fell short of the total catch, the *proportions* of the various age groups in the total catch were assumed to be the same as in the sample. The Catch per Hour was then estimated by multiplying the number in each age group by the following factor :—

$$\frac{\text{Total catch.}}{\text{No. in sample} \times \text{No. of hours.}}$$

† C.P.H. = Catch per Hour.

On the Leman Ground about 80 per cent. consisted of groups II., III. and IV., the III. group being rather more abundant than the other two.

Off the Dutch Coast, the I. group, as we should expect, was most abundant on the furthest inshore station on which the "Huxley" was able to trawl, viz., in 7–12 fathoms (O. 348). In a parallel haul (B. 377) with the Beam trawl covered with finer meshing, in the same depth of water, the I. group just equalled the II. group in numbers. From this it is clear that the bulk of the I. group was in shallower water than 7 fathoms at this time.

The I. group was somewhat more abundant and had a lower average size on the Leman Ground than on the Brown Bank Ground. This probably means that the I. group on the Leman Ground was partly, at least, derived from the English Coast, whereas the Brown Bank Ground could only be reached by the largest members of the group from the Dutch Coast.

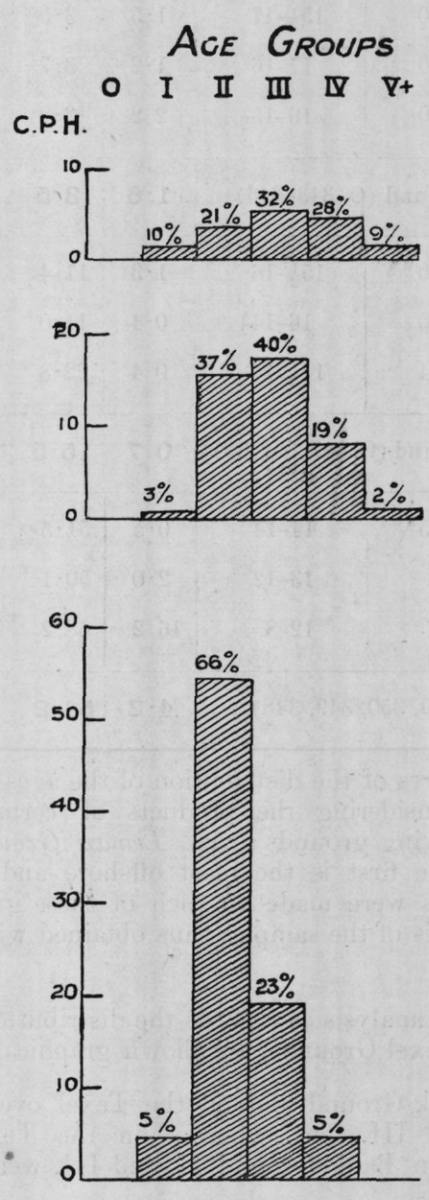


FIG. 1. Showing average catch per hour (c.p.h.) (with the otter trawl) of different ages on the Leman Ground (upper diagram), Brown Bank Ground (middle diagram), and the Texel (lower diagram), in September, 1905. To illustrate Table 1, p. 9.

The IV. group was scarce on the Texel. It was absolutely (c.p.h.) more abundant on the Brown Bank Ground than on the Leman Ground, but formed a larger proportion (percentage) of the population on the latter ground.

The V. group and older fishes (V.+ group) were with very few exceptions caught on the Leman Ground.

It thus appears that in September, 1905, according to these observations, the zones of greatest density (c.p.h.) of the various age groups of plaice in this region occurred in the following situations (*see* Table 1).

The I. group; within 3 miles of the Dutch Coast; in less than 8 fathoms.

The II. group; between 3–6 miles off the Dutch Coast; in 8–12 fathoms.

The III. group; between 15–24 miles off the Dutch Coast; in 14 fathoms.

The IV. group; between 50–60 miles off the Dutch Coast; in 15–16 fathoms.

The V.+ groups; between 70–80 miles off the Dutch Coast; in 16–17 fathoms.

Central Grounds of the Southern North Sea.—Table 2 gives the approximate number of plaice of different ages caught per hour* in certain hauls on the more central grounds up to the end of 1905.

Of these Central grounds we may distinguish a Southern group (South of 53° 30′ N.L.), including Sandette Bank and the Leman and Botney Grounds, from a Northern group (North of 54° N.L.), including the Dogger Bank and Flamborough Off Ground.

Up to the end of 1905, the ages of plaice caught in twenty-two hauls (with the large trawls) on the Northern grounds and eleven hauls on the Southern grounds were determined.

TABLE 2.—Showing approximate Catch per hour of Age Groups and Average Age on various Central Grounds in the North Sea.

Date.	Numbers of Hauls.	Ground.	Age Groups.					Average Age in Years. (No. of Otolith Rings.)
			I.	II.	III.	IV.	V.+	
12/x/05	O. 360, 361	Clay Deep, edge of Dogger	...	...	1·7	8·6	2·5	4·1
11/x/05	O. 358, 359	South Dogger	...	0·5	0·6	2·3	1·0	4·0
22/i/05	O, 270–272	„ „	...	...	1·2	1·6	0·2	3·6
11/iii/04	O. 160–164, 166.	„ „	...	0·1	4·1	3·3	3·4	4·2
19–20/x/05	O. 362–366, B. 397.	Flamborough Off	...	0·4	1·3	3·2	2·5	4·3
20/i/05	O. 268	„ „	0·5	0·2	3·5	5·5	3·9	4·0
13–14/i/05	O. 266, 267	Flamborough Head ...	0·2	0·4	1·6	4·0	8·8	4·6
		(Southern Grounds.)						
27–29/ix/04	B. 213, 214, 220.	Leman Ground	...	1·1	3·1	4·4	2·2	3·9
5–6/ix/05	O. 343–346	„ „	1·6	3·5	5·2	4·5	1·5	3·1
24/x/05	O. 368	„ „	4·5	16·2	12·5	16·0	7·2	3·2
25/i/05	O. 276	Botney Ground, South ...	0·2	0·9	8·7	2·3	1·8	3·6
26/xi/04	B. 247, 248	Sandette Bank	2·6	9·7	28·4	40·6	9·7	3·5

Although from a mere examination of the data displayed in Table 2 it would be hard to say whether the older groups, IV. and V.+, were in general more numerous on the Northern or on the Southern grounds, we find, as we should naturally expect, that

* *See* footnote to p. 9.

the density (catch per hour) of I., II. and III. was decidedly greater on the more inshore Southern grounds than on the more distant Northern grounds. The same thing is shown by the average age (meaning really the average number of otolith rings), since, out of the seven Northern samples, only one averaged less than four years, whereas out of the five Southern samples none attained that age.

Leman Ground in September, 1904 *and* 1905.—If we refer to Table 2, and examine the relative abundance of different ages on the Leman ground (1) in September, 1904, and, (2) in September, 1905, we shall observe certain well-marked differences in the age-composition which seem to indicate that the movements of the plaice in this region were not quite the same in 1904 as in 1905.

The differences are as follows :—

(1.) The I., II., and III. groups were both absolutely and relatively more abundant in 1905 than in 1904.
(2.) The IV. group predominated in 1904, the III. group in 1905.
(3.) The older plaice (V.+) were relatively and (though to a less extent) absolutely more abundant in 1904 than in 1905.

Further, if we turn to the Synoptic Table or refer to p. 27, we shall find that (for either sex) the average sizes of groups III. and IV. were considerably higher in September, 1904, than in September, 1905 (*see* p. 27).

When the trawling data and results of the marking experiments for 1905 have been published and compared with those for 1904 we shall possibly be in a position to state the probable cause of these yearly differences. As suggested by Dr. Garstang, the higher average age in 1904 as compared with 1905 may well have been due to the comparative failure of the summer migration of young plaice from the Dutch coast in 1904.

The higher average *size* for a given age in 1904 may have been due to reduced competition for food resulting from the same cause.

We may now point to *certain seasonal differences in the age composition of the population on the South part of the Dogger Bank* as indicated by the otolith analysis of samples obtained in autumn (11/x/05), winter (22/i/05), and spring (11/iii/04).

The age composition of these three samples from the Dogger is indicated graphically in the accompanying Fig. 2, from an inspection of which the main features can be recognised at a glance. In these diagrams, however, the various older groups (V.+) are not separately distinguished, but the details will be found in the Synoptic Table.

We note the following differences in the age composition of these three samples :—

(1.) Passing over the II. group, which is of little consequence on the Dogger (merely noting its entire absence in the January hauls), we see that the III. group shows an increase in January as compared with October and a still greater increase in March as compared with January.
(2.) We note a slight decrease of the IV. group in January as compared with October and a decided increase again in March, the numbers of this group caught in March considerably exceeding the number caught in October.
(3.) The V.+ group (including all the older fishes) shows a decided decrease in January as compared with October. In fact, in January (*see* Synoptic Table), no fish older than five years was taken. In March again there is a great increase in the numbers of these older fishes, which also constitute a much larger proportion (percentage) of the total in this than in either of the other two samples.

Assuming that these differences in the age composition of these three samples represent regular seasonal changes on the South Dogger, we may provisionally interpret them as due to regular seasonal *migrations* of two kinds (not necessarily occurring at precisely the same time in every year).

The gradual increase of the III. group in January as compared with October and in March as compared with January points to a gradual migration of the III. group on to the Bank from more inshore grounds. That such a migration must occur is obvious since the numbers of the II. group on the South Dogger (judging from these samples) is insignificant. That the migration is gradual, leading to a gradual accumulation of this group on the Bank during winter is indicated by the present evidence—so far as it goes.

Changes (2) and (3) are most readily interpreted as due to a clearing off the Bank, during autumn and winter, of ripe plaice, and their return in spring (when spent). Our researches into the maturity of plaice* in this region show that, in regard to the females, which preponderate on the Bank,

(1) a *part only* of the IV. group (nearly five-year-old plaice), but *most* of the V. group, and *practically all* the older plaice are sexually mature, and it is just these groups which show a decrease in January and an increase again in March.

(2) in October (1905), 58 per cent. of the females in the samples from South Dogger were mature (ripening) ; in January, only 16 per cent. ; in March, 37 per cent. (spent).

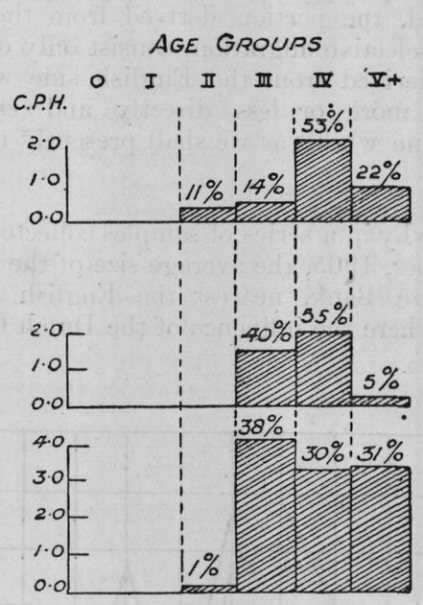


FIG. 2. Showing catch per hour (c.p.h.) of different ages on the South part of the Dogger in October, 1905 (upper diagram), January, 1905 (middle diagram), and March, 1904 (lower diagram). To illustrate Table 2, p. 11.

§ 2. RELATION OF SIZE TO AGE ON ENGLISH IN-SHORE GROUNDS, SOUTH OF FLAMBOROUGH HEAD.

A glance at a Chart of the North Sea will show that on the continental side the conditions favourable to the life and growth of young plaice (*viz.*, shallow water and a sandy bottom) extend over a much greater area than on the English side. This is partly indicated by the positions of the 10-fathom and 20-fathom contour lines which are situated in general further from shore on the continental side, so that there is a greater extent of shallow water in direct relation to the coast. On the English side, on the other hand, the area suitable as a rearing ground for young plaice is in comparison greatly restricted. Not only are the gradients steeper, but there are large tracts of "rough" (stony, &c.) and often muddy ground extending from the near neighbourhood of the coast to a considerable distance from land. There is an especial development of such rough ground opposite the mouths of the Humber and Wash. On our coasts, therefore, the plaice are mainly restricted during the first two years of their life to certain estuaries like the Humber, Wash, and Thames and to certain small shallow Bays of which Bridlington Bay may be taken as a type. In the estuaries themselves, moreover, the young plaice are by no means *generally* distributed. They are absent or very scarce in the deeper parts of the channels where mud is mixed with the sand, and are practically confined to the shallow sandy margins of the shore and slopes of the sand banks.

* *See* forthcoming Report.

Briefly stated, then, the English side of the North Sea is characterised by (1), the relatively small extent of the area within the 10-fathom line, and (2), the presence of rough ground between this zone and the central part of the Sea.

The effect of the presence of this rough ground must be to interfere to a large extent with the distribution of plaice according to size which is so characteristic of the species on the continental side (*see* pp. 21–23), assuming that distribution to be due to the "selective migration" of the larger fishes of a given age.

We have noted (p. 8) that while the II. group was numerous, the III. group was relatively scarce within the 10-fathom line on our shores in summer. This means that the bulk of the II. group must migrate to the off-shore grounds later in the year. Now on a given off-shore ground situated between the English and Dutch Coasts the population is probably derived partly from one and partly from the other side. Of the II. group on such a ground, the portion derived from the Dutch Coast will, on the above-mentioned theory of selective migration, consist only of the *largest* plaice of that year, whereas the portion derived from the English side will, owing to the barrier of rough ground, have come more or less directly and *en masse* from the narrow zone within the 10-fathom line where, as we shall presently notice, it has a relatively low average size.

This possibly explains why in a series of samples collected between the Leman Banks and Dutch Coast in September, 1905, the average size of the II. group was smaller in the neighbourhood of the Swarte Bank, nearest the English Coast, than on the Leman ground further to the S.E. where the influence of the Dutch Coast probably predominated (*see* Fig. 7, p. 22).

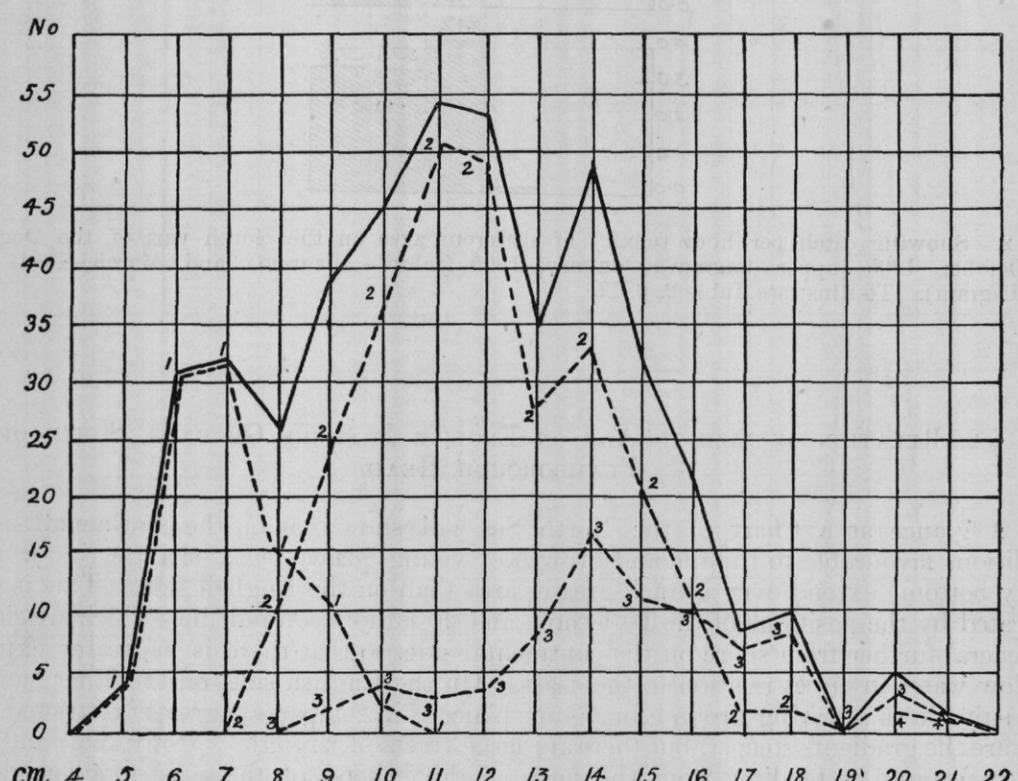


FIG. 3. Age Analysis of Plaice caught in Shrimp Trawls off Lowestoft, 1–4/v/05.
———— = Size-Frequencies of Total Catch.
--1---1--- } Size-Frequencies of Age-Groups I., II., and III., *i.e.*, of Plaice
--2---2--- } having one, two, and three white otolith rings respectively.
--3---3--- }

Our inferences as to the growth of plaice within the 10-fathom line on the English shores of the North Sea, south of Flamborough Head, are based on the following samples from different parts of the coast:—Bridlington Bay (7–11/vii/04 and 7/vii/05), off Mablethorpe (23–24/viii/05), The Wash (2–7/viii/05), off Lowestoft (1–4/v/05), and the Thames Estuary (16/vii/04).

The analysis of the samples collected in the Thames Estuary and Bridlington Bay in July, 1904, was discussed in my previous paper (1905, pp. 206–208).

A comparison and combination of the data furnished by these samples enables a sufficiently accurate estimate of the rate of growth on our shores to be made. The details of the analysis of the various samples will be found in the synoptic and detailed tables. It will suffice here to state the chief results and deductions.

The curve shown in Fig. 3 represents the combined catches of several hauls with the shrimp trawl on the shrimping grounds abreast of Lowestoft at the beginning of May, 1905. The otoliths of all these plaice were examined, and the figure shows the analysis of the catch by this method into its component age groups.

We see that the three cusps of the gross curve of length frequencies are identical with the cusps of the curves of the component age groups I., II., and III. The average sizes of these age groups are respectively 7·6 cm., 12·4 cm., and 15·2 cm. ("amended" by the addition of ·5 cm.*).

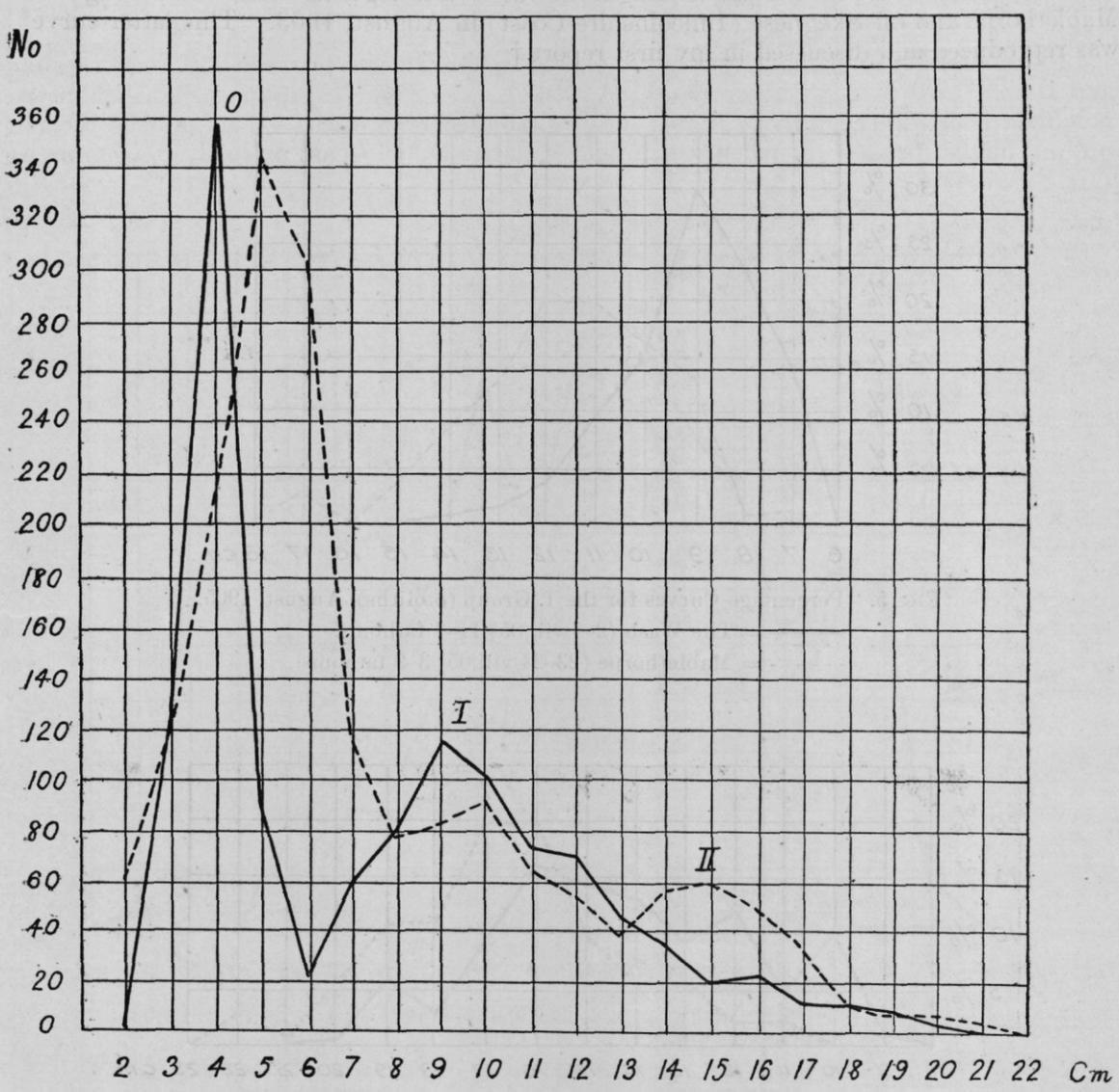


FIG. 4. Length-Frequencies of Plaice caught with Shrimp Trawls in the Wash and off the Lincolnshire Coast.
——— = all Plaice caught within the Wash in August, 1905.
- - - - - - = all Plaice caught in the Wash and off Skegness and Mablethorpe, August, 1903.

* Necessary owing to the international method of measurements, according to which for example all fishes from 2·0 cm. to 2·9 cm. inclusive are classed as 2 cm.

In the third cusp at 14 cm. both the II. and III. groups take part. This probably means that the plaice represented by the third elevation in the curve were caught in deeper water than the rest of the catch, the intermediate depths not having been sampled in due proportion.

It is evident from the form of its curve and its fusion with that of the II. group, that the III. group is not duly represented in this collection, and that we have only here the smaller fishes of this age whose chief habitat is further off shore. On the other hand, the curve for the II. group, if the secondary elevation at 14 cm. were smoothed away (as it doubtless would have been if a larger number of specimens had been obtained) is a fairly symmetrical one.

We can say therefore that 7·5 cm. and 12·5 cm. represent approximately the average sizes of one-year-old and two-year-old plaice on this part of the coast in May, 1905. This gives an average rate of growth during the second year of 5 cm.

The length-frequencies of all the plaice caught within *The Wash* in August, 1905, are shown in Fig. 4, in the form of a curve. Placed alongside of this curve in the same figure is the curve for all the plaice caught in the Wash together with those caught off Mablethorpe and off Skegness (Lincolnshire Coast) in August, 1903. This latter curve* was reproduced and discussed in my first report.†

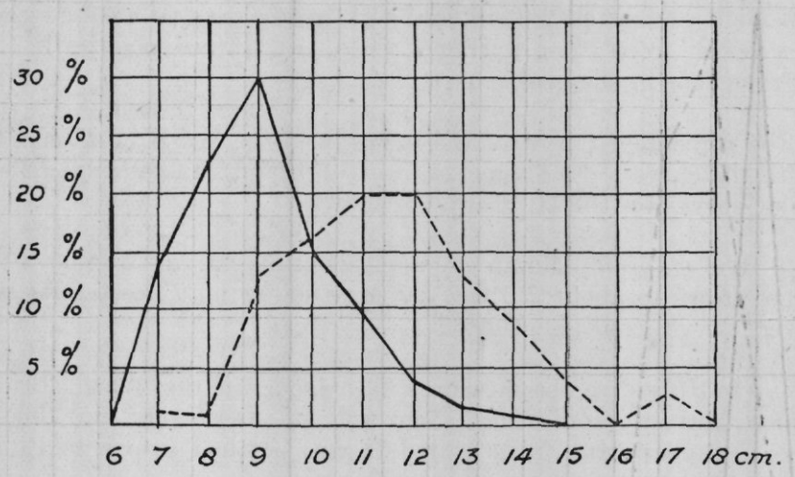


FIG. 5. Percentage Curves for the I. Group (otoliths), August, 1905.
——— = The Wash (2–7/viii/05) 1½–7 fathoms.
- - - - - - = Mablethorpe (23–24/viii/05) 3–9 fathoms.

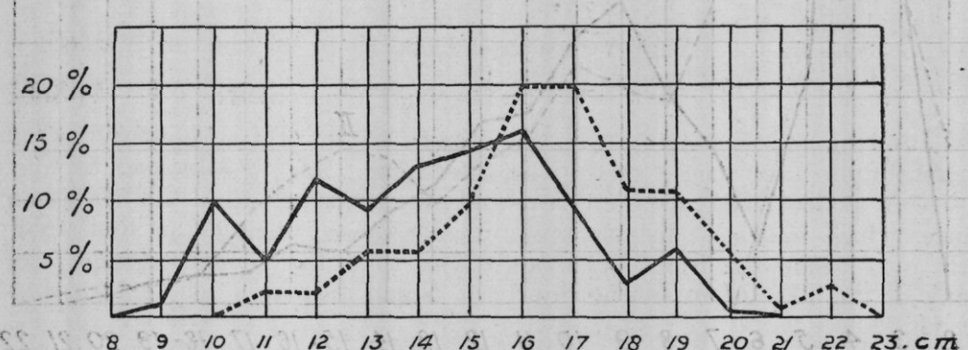


FIG. 6. Percentage Curves for the II. Group (otoliths), August, 1905.
——— = The Wash (2–7/viii/05) 1½–7 fathoms.
- - - - - - = Mablethorpe (23–24/viii/05) 3–9 fathoms.

* *See* Table IV., Trawling Investigations. App. B. *International Investigations. Mar. Biol. Association Report, I. 1902–03, p. 105.*

† *International Investigations. Mar. Biol. Association. Report, I. 1902–03, p. 208.*

It will be noticed on inspecting these curves that the first two cusps of the 1903 curve representing the modal sizes of the yearling (O. group) and year-old (I. group) plaice occur at 5 cm. and 10 cm., whereas the two cusps in the 1905 curve correspond to 4 cm. and 9 cm. The difference is due to the fact that in the 1903 curve the catches off Skegness and Mablethorpe are included ; whereas in the 1905 curve only the plaice caught within the limits of the Wash proper are represented. Further, the presence of a third cusp in the 1903 curve corresponding to the II. group and its absence in the 1905 curve is due to the inclusion of Mablethorpe plaice in the former case.

The examination of the otoliths in a sample from the Wash in August, 1905 (2–7/viii/05) revealed a *I. Group* having an average size of 9·6 cm. and a II. group with an average size of 14·6 cm. indicating, as in Bridlington Bay, a growth of 5 cm. in the second year.

The fishing off Mablethorpe in August, 1905, took place in somewhat deeper water than was the case in August, 1903. On the first occasion the plaice were all caught at a distance of one-third of a mile from shore (exact depth somewhat uncertain) and the curve of sizes showed distinct cusps at 5 cm., 11 cm., and 15 cm.* corresponding to the O., I. and II. groups.

In August, 1905, the plaice were fished in 3½ to 9 fathoms and the curve for the total catch shows cusps at 11·5 cm. and 16·5 cm. corresponding to the I. and II. groups, but the O. group was not caught. The otolith analysis of this catch yielded a I. group with an average size of 12·0 cm. and a II. group with an average size of 17·1 cm. If we subtract ·5 cm. from these averages we obtain values practically identical with the position of the cusps in the gross curve.

In Fig. 5 the percentage curve for the I. group in the Wash (2–7/viii/05) is shown side by side with the curve for the same group caught off Mablethorpe (23–24/viii/05). In Fig. 6, similar curves for the II. group are shown.

Summary.—The *O. group* had an average size of 5 cm. in August (Wash). This group apparently grows to about 7·5 cm. by May following (Lowestoft) when the fish become just over one year old (I. group).

The *I. group* in July–August measured 9–9·5 cm. in the Wash, Bridlington Bay, and the Thames Estuary, indicating a growth of 4–4·5 cm. in the second year. At Mablethorpe, in deeper water, it measured 12 cm. It had grown to 12·5 cm. by May at Lowestoft (II. group).

The *II. group* in July–August measured from 13·5 to 14·5 cm. in the Wash, Thames, and Bridlington Bay, indicating a growth of about 4–5 cm. in the third year, but at Mablethorpe it measured 17 cm. indicating about the same annual growth (17 − 12 = 5 cm.)

The *III. group* in July–August measured from 19 to 20 cm. off Mablethorpe and in Bridlington Bay and the Thames.

Now, allowing another 3 cm. for the growth of the III. group by the following Spring (an ample allowance), this gives 22–23 cm. (about 9-inches) as about the average size of plaice when just four years old on our coasts within the 10-fathom line. This figure, which indicates an average annual growth during the first four years of slightly over 5 cm., is lower by about 6 cm. than the general average size (*viz.*, 27–28 cm.) of the IV. group in the Southern North Sea as a whole (*see* p. 31 and Figs. 12 and 13).

Previous Investigations on other Coasts.—For the sake of reference and comparison with my own results, I have summarised in Table 3 appended here some of the chief results of the work of other investigators on the size and age of plaice in different localities. With the exception of Redeke, who has made use of the otoliths in his

* *See* Table IV. App. B. *Report* I. *1902–03, p. 105.*

researches, all the authors whose results are quoted, based their estimations of age solely on Petersen's method of measurements.

TABLE 3.—Showing Average Sizes (in cm.) of Age Groups O., I. and II., in various Inshore Waters (O–5½ fathoms) according to other Investigators.

Month.	Locality.	Depth (fms.)	Age Groups.			Author and Reference.*
			O.	I.	II.	
VII	Boulogne	Beach	5·3	—	—	Cligny (05) p. 105.
„	Zuyder Zee	„	5·0	—	—	Redeke (05) p. 4.
VIII	Boulogne	0–4½	5·9	9·7	—	Cligny (05) pp. 105 & 121.
„	Dunbar	0–4	5·6	13·6	21·4	Dannevig (99) p. 237.
„	Solway Firth... ...	0–5½	5·8	10·7	—	Fulton (02) pp. 340, 346.
X–XII	Zuyder Zee	—	6	11	—	Redeke (05) p. 4 &c.
„	Esbjerg	0–½	8	11	—	Johansen (05) p. 8 &c.
„	Boulogne	0–4½	7·0	10·2	—	Cligny (05) pp. 105–121.
„	Solway Firth... ...	0–5½	6·1	10·0	—	Fulton (02) pp. 340–346.
„	Dunbar	1½–5	6·0	15·5	22·1	Dannevig (99) p. 237.

* For full reference see pp. 4 and 5.

From an inspection of this table we gather that the rate of growth during the first year is much the same in all localities examined, the average size of a plaice when *one year old* being between 6 and 8 cm.

Within the 5-fathom line along the various coasts and in the estuaries, the *two-year-old* plaice have been found to average 10–11 cm. (except apparently at Dunbar, according to Dannevig's researches). The values for the average size of the two-year-old plaice given respectively by Cligny for Boulogne, Redeke for the Zuyder Zee, Fulton for the Solway, Johansen for Esbjerg, and myself for the Wash, Thames, Bridlington Bay and Lowestoft, agree almost perfectly (allowing where necessary for difference of date).

It should, however, be clearly understood that these values for the I. group represent mainly the selective action of depth on size. The geographical range on the I. group (*see* p. 9) is not limited to the narrow strip of coast within the 5-fathom line: consequently the average size of the group in this zone of depth is considerably below the true average size of the group, viz., about 14 cm. at the end of the year (*see* p. 31 and Fig. 12). The same reasoning applies to the older age groups.

§ 3. Relation of Size to Age in the Region between the Leman Banks and the Dutch Coast.

The results of this part of the investigation are based on the Age Analysis of plaice caught in two continuous linear series of trawlings between the Leman Ground and "The Texel," up to a distance of about three miles from the Dutch Coast. The direction of these lines is roughly N.W. and S.E. One series was carried out in May, 1905 (9–12/v/05), and another in September, 1905 (5–14/ix/05).†

† The data for these series are given in thick type in the Synoptic and Age Group Tables (at the end).

The May series comprised the hauls:—O. 301–309 and B. 300. The September series comprised hauls O. 343–352, and B. 374, 375, and 377.

The actual courses of these hauls will be shown on Charts in the Reports on Trawling Investigations.

Importance of Continuous Radial Series.—The object of determining the ages and sizes of plaice caught in continuous series of hauls between the Leman Ground and the Dutch Coast was to arrive at an estimate—as accurate as possible—of the average annual growth of plaice in this part of the North Sea.

As is now well-known, plaice of all sizes and ages are not found in any one spot. Accordingly the analysis of samples from isolated localities in the North Sea or even a combination of such samples, is not likely to yield accurate values for the average sizes of different age groups. There is in fact* a gradual change of habitat with growth, so that the larger plaice of a given age are found further from shore. Illustrations of this law, based on the otolith investigation of plaice caught at varying distances from the Dutch Coast, are given below (*see* pp. 20–23, Fig. 7).

This zonal distribution of plaice according to *size* depends on *age* only apparently in so far as size itself depends on age; and since the variation in size of a given age is often very considerable (*see* Figs. 10 and 11 and Age Group Tables I.–IX. at end), so also is the geographical range of a given age group. Hence the importance, first urged by Dannevig (1902) of carrying out radial lines of trawlings from the coast into the middle of the sea; since only in this way can we be sure that all sizes of each age are duly represented in our calculations.

This particular line from the Leman Ground to the Dutch Coast (the Texel) was selected for investigation at Dr. Garstang's suggestion, because the trawling investigations and marking experiments indicated that such a line forms the main axis, so to speak, of the waves of summer migration from the Dutch Coast. The Leman Ground, as Dr. Garstang has shown, is mainly populated by plaice which have migrated there in the course of the summer from the Dutch Coast (Garstang *op. cit.* "Trawling Investigations 1902–1903, p. 93).

Material.—The material for age analysis was collected chiefly by means of the Commercial Otter trawl,† but partly (in 7–12-fathoms off the Dutch Coast) by means of the Beam trawl provided with a small-mesh covering net (B. 300 in May; B. 377 in September).

The material collected in *May*, 1905, consisted of 2,561 otoliths. This does not represent *all* the plaice caught along the Leman to Texel line on this occasion. It really represents all the plaice caught on the Leman and Brown Bank Grounds plus a *portion* of the plaice caught on the Texel. Moreover, in May the products of the individual hauls along this line were not separately distinguished, that is to say, the otoliths were

* Johansen (1906 *op. cit.*) gives numerous examples referring to the Danish Coast.

† The recently published results of Redeke's experiments in regard to the numbers of plaice of different sizes which pass through the meshes of the cod-end of a commercial otter trawl show that up to about 16 cm. in length large numbers may escape. (*Verhandelingen uit het Rijksinstitut voor het Onderzoek der Zee. Eerste Deel. I.–II., 1906.*) Now in our Leman-to-Texel samples the I. group had an extreme range of 7–12 cm. in May (Reference No. 2) and of 11–18 cm. in September (No. 12), and the II. group had an extreme range of 10–25 cm. in May and of 13–29 cm. in September. It follows that if the smaller fishes of these two groups were present in appreciable quantities outside the 12-fathom line (within which the small mesh was actually employed) they would not be caught in their natural proportions; in which case the average lengths of these groups in the total collections must be somewhat too high. On the other hand, if we compare the average sizes of the I. and II. groups in O. 348 (No. 11^3) and B. 377 (No. 11^4), two parallel hauls, one with and the other without the small mesh, we shall find that only in regard to the I. group is the difference important. (Tables 1 and 2 at end.)

grouped according to the length and sex of the fishes, but otoliths from the different hauls were combined so as to form one large sample (9–12/v/05).

In *September* the work was done more thoroughly ; that is to say, the otoliths from the individual hauls along the line were preserved separately, so that in this case, we have material for analysis in regard both to the quantitative distribution of the age groups in this region (p. 9) and the relation of size to age in different parts of this region (*see* below p. 21). Altogether 1,960 otoliths were collected ; representing all the plaice (with one or two accidental omissions) caught in the first ten hauls starting from the Leman Ground, and nearly half the number (257 out of 525) caught in the eleventh haul, B. 377. In obtaining this last sample the number of each cm. length in the total catch was as nearly as possible halved so that the proportional frequencies were the same in the sample as in the total catch. By doubling the length-frequencies of each age group in the last sample previous to combining with the other samples, we obtain a result which ought to be approximately the same as if we had determined the ages of *all* the fish caught in the entire series of hauls (*see* Figs. 8 and 9, p. 24).

In May of the current year (1906) otoliths were collected along the same line and along a line further to the South. 4,074 otoliths were collected along these lines. On these occasions the beam trawl with small-mesh covered cod-end was used consistently throughout. The results will be published in my next report.

The law according to which the length of plaice *of the same age* varies with distance from shore* is very definitely shown by the otolith-analysis of the September series of samples.

The positions along the Leman-to-Texel line of the hauls in which these eleven samples were obtained, are given below :—

Reference Number.	Equivalent Number of Haul.	Number of Miles from Dutch Coast.	Depth in Fathoms.	Ground.
9^1	O. 343, 344	90 to 80	$15\frac{1}{2}$–17	Leman.
9^2	O. 345	80 to 70	17–16	„
9^3	O. 346	70 to 60	16–$15\frac{1}{2}$	„
9^4	B. 374, 375	70 to 60	16–$15\frac{1}{2}$	„
10^1	O. 347	60 to 50	$15\frac{1}{2}$–16	North of Brown Ridge.
10^2	O. 352	50 to 40	16–$14\frac{1}{2}$	Brown Bank Ground.
10^3	O. 351	40 to 24	$14\frac{1}{2}$–14	Brown Bank Ground (E. part).
11^1	O. 350	24 to 15	14–14	Between Brown Bank and Texel Grounds.
11^2	O. 349	15 to 6	13–12	The Texel.
11^3	O. 348	6 to 3	12–8	„
11^4	B. 377	6 to 3	12–7	„

* The primary fact, viz., that the increase in size of plaice corresponds in general to increase in depth of water and distance from shore, has been known for some time. It seems to have been first pointed out, so far as home waters are concerned, by Professor McIntosh in his Report to the Trawling Commission, published in 1884, and is mentioned by him ("Resources of the Sea," 1899) as an argument against the "gradual-accumulation-theory" of those who advocated the closure of shallow inshore areas like St. Andrews Bay. In this connection it is interesting to note, as mentioned on p. 8, that in Bridlington Bay, where trawling is greatly restricted, considerable numbers of older plaice up to six years are found. No advantage, however, is apparently gained by their accumulation (if due to this cause) since the size of these older plaice is far below the average (*see* Synoptic Table and Age Group Tables III–VI).

TABLE 4.—Showing Average Lengths (cm.) of Age Groups II., III., and IV., at different distances from the Dutch Coast, along a line (N.W.—S.E.), between "the Texel" and the Leman Bank. Index figures give the numbers of fish on which the averages are based. B.* = Beam trawl with small mesh covering.

Reference Number.	Number of Hauls.	Number of Miles from Dutch Coast.	Age Groups.					
			II.		III.		IV.	
			Males.	Females.	Males.	Females.	Males.	Females.
9^{1}	O. 343. 344	90–80	$23{\cdot}23^{15}$	$24{\cdot}58^{13}$	$26{\cdot}56^{31}$	$27{\cdot}00^{17}$	$31{\cdot}57^{24}$	$32{\cdot}55^{18}$
9^{2}	O. 345	80–70	$24{\cdot}16^{9}$	$26{\cdot}16^{6}$	$28{\cdot}66^{6}$	$27{\cdot}00^{4}$	$30{\cdot}50^{9}$	$31{\cdot}00^{6}$
9^{3}	O. 346	70–60	$23{\cdot}35^{7}$	$25{\cdot}00^{6}$	$27{\cdot}07^{14}$	$26{\cdot}59^{11}$	$30{\cdot}35^{7}$	$32{\cdot}25^{8}$
9^{4}	B.* 374, 375	70–60	$20{\cdot}0^{3}$	$22{\cdot}16^{6}$	$25{\cdot}95^{11}$	$26{\cdot}26^{26}$	$29{\cdot}74^{4}$	$33{\cdot}33^{6}$
10^{1}	O. 347	60–50	$23{\cdot}36^{15}$	$23{\cdot}43^{30}$	$26{\cdot}05^{34}$	$27{\cdot}14^{28}$	$28{\cdot}68^{16}$	$31{\cdot}41^{24}$
10^{2}	O. 352	50–40	$21{\cdot}77^{18}$	$23{\cdot}23^{31}$	$26{\cdot}26^{34}$	$26{\cdot}32^{45}$	$29{\cdot}05^{9}$	$29{\cdot}96^{15}$
10^{3}	O. 351	40–24	$21{\cdot}18^{63}$	$22{\cdot}10^{51}$	$25{\cdot}96^{47}$	$26{\cdot}35^{40}$	$29{\cdot}50^{25}$	$30{\cdot}00^{18}$
11^{1}	O. 350	24–15	$20{\cdot}86^{93}$	$21{\cdot}80^{111}$	$24{\cdot}51^{64}$	$25{\cdot}41^{69}$	$27{\cdot}91^{23}$	$28{\cdot}96^{13}$
11^{2}	O. 349	15–6	$19{\cdot}72^{113}$	$19{\cdot}89^{86}$	$23{\cdot}09^{22}$	$23{\cdot}26^{15}$	$32{\cdot}5^{1}$	—
11^{3}	O. 348	6–3	$17{\cdot}26^{67}$	$18{\cdot}26^{64}$	$21{\cdot}90^{5}$	$23{\cdot}65^{13}$	$25{\cdot}0^{2}$	$25{\cdot}50^{1}$
11^{4}	B.* 377	6–3	$17{\cdot}02^{53}$	$18{\cdot}26^{68}$	$18{\cdot}50^{6}$	$23{\cdot}28^{14}$	$23{\cdot}83^{3}$	$30{\cdot}16^{3}$

Explanation of Fig. 7.—The variations in the average sizes of age groups II., III., and IV., according to their distance from the Dutch Coast are shown in Fig. 7 in the form of three pairs of curves. These curves were constructed in the following manner :—Divisions at equal intervals along the horizontal line forming the base of the diagram are numbered from left to right according to the distance from the Dutch Coast. Equal divisions along the vertical scale to the left are equivalent to lengths of a centimetre. Taking each age and each sex separately the value of the average size in each sample is marked by a point placed opposite the proper divisions of the horizontal and vertical scales. By joining these points we obtain for each age and sex a curve which shows the variations in the average length in the different samples.

Neglecting the irregular fluctuations which are obviously errors due to small numbers, we may recognise at once the general trend of these curves and their meaning :—

(1.) In general the curves all slope towards the right ; that is to say the average size (whether of the II. group, III. group, or IV. group) decreases as we approach the Dutch Coast.

(2.) In general the separate curves for males and females maintain more or less parallel courses, the females at a higher level than the males. The average distance between the two curves of a pair is greatest in the case of the IV. group as we should naturally expect.

(3.) The curves for the II. group do not rise consistently to the left, but there is a descent (in the case of both sexes) at the left end, representing a decrease in the average size of this group as we approach the Swarte Bank. This may be due to an admixture of plaice of English origin with those derived from the Dutch Coast. Owing as explained above (p. 14) to the rough ground opposite the English Coast interfering with "selective migration according to size," the II. group from the English side has probably come more or less directly from the coastal zone within the ten-fathom line where the average size of the group is relatively small (*see* p. 14, &c.).

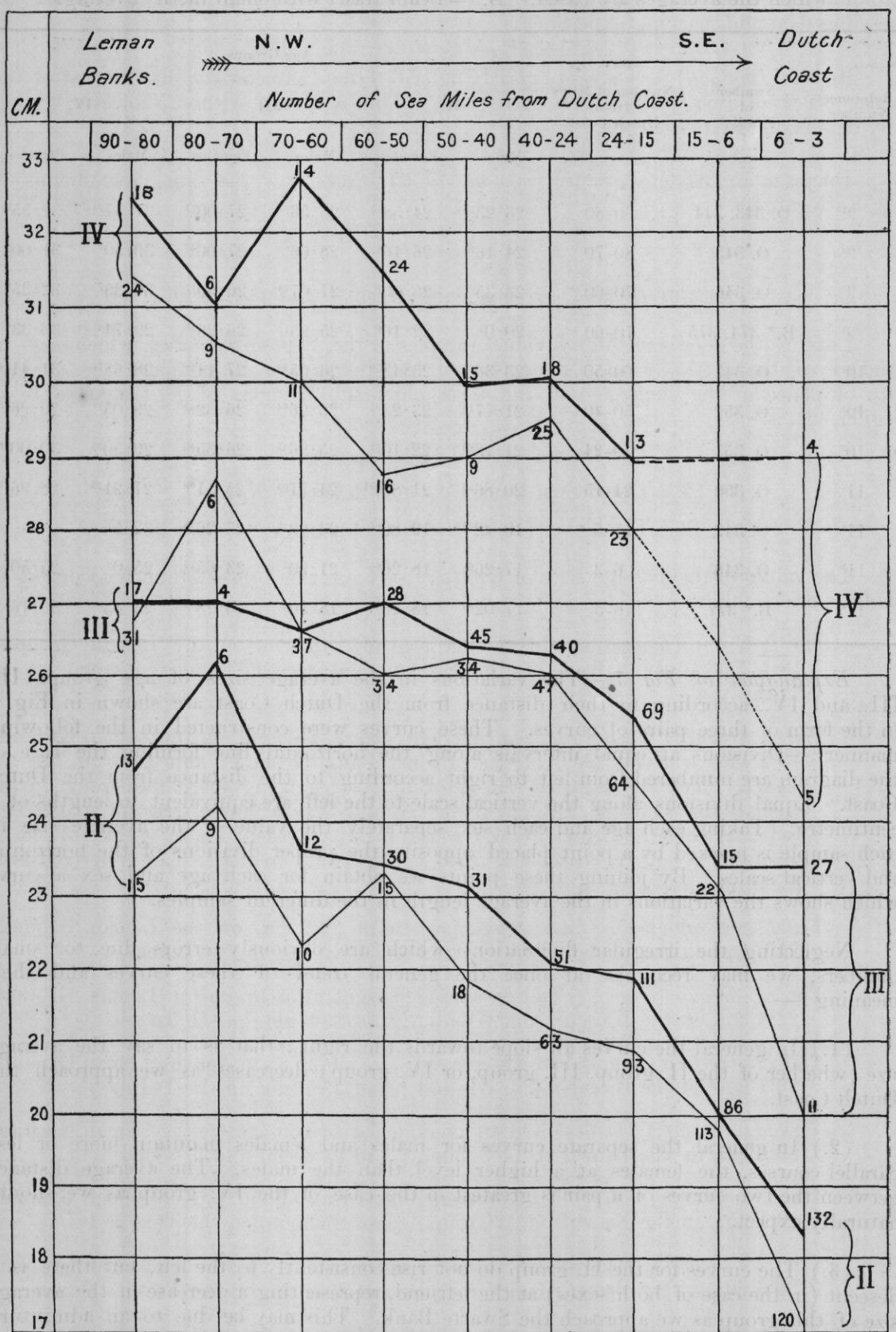


FIG. 7. Curves showing (for males and females separately) the variations in the Average Length of Age Groups II., III., and IV., in a series of samples collected at different distances along a line joining the Swarte Bank to the Dutch Coast (the Texel), 5–11/ix/05. To illustrate Table 4.

Thick line = Females. Thin line = Males.

Figures opposite the points in the curves give the numbers of specimens on which the averages were based.

The general feature common to all these curves, however, is the gradual ascent to the left, which, besides affording a striking illustration of the law of distribution according to size, clearly points to the Dutch origin of the bulk of the population on the Leman ground, thus confirming inferences which have already been drawn from a study of the trawling data and marking experiments.

Redeke (*op. cit.*) has already clearly described the characteristic distribution of the plaice off the Dutch Coast (1), in Spring and (2) in Autumn, without, however, giving any details of otolith analysis.

Johansen in his latest paper (*op. cit.* 1906) shows how the same law obtains in the Kattegat, &c.

Leman Ground, Brown Bank Ground and the Texel.

Leaving the details of the individual samples of the September series, which may be studied in the Age Group Tables, it will be instructive to compare the average size of plaice of the same age in the three chief sub-divisions of the Leman to Texel region, viz. :—

(1.) The Leman Ground (Reference No. 9).

(2.) The Brown Bank Ground (Reference No. 10).

(3.) The Texel (Reference No. 11).

The values of the average sizes of Groups I.–IV. on these three grounds according to samples are as follows :—

The *I. Group* (*males*) had an average size of 16·7 cm. on the Leman Ground ; 18·1 cm. (only 5 fish) on the Brown Bank Ground ; and 14·5 cm. on the Texel.

The *I. Group* (*females*) had an average size of 15·9 cm. on the Leman Ground ; 19·2 cm. (only 4 fish) on the Brown Bank Ground ; and 14·6 cm. on the Texel. We thus see that the I. group, besides being more numerous on the Leman than on the Brown Bank Ground, has a lower average size. This indicates that the Brown Bank Ground is out of reach, so to speak, of the I. group from either coast, and that the I. group on the Leman is derived from the English Coast.

The *II. Group* (*males*) had an average size of 23·2 cm. on the Leman Ground ; 21·6 cm. on the Brown Bank Ground and 19·1 cm. on the Texel.

The *II. Group* (*females*) had an average size of 24·5 cm. on the Leman Ground ; 22·8 cm. on the Brown Bank Ground ; and 19·8 cm. on the Texel.

The *III. Group* (*males*) had an average size of 26·8 cm. on the Leman Ground ; 26·1 cm. on the Brown Bank Ground ; and 23·7 cm. on the Texel.

The *III. Group* (*females*) had an average size of 26·6 cm. on the Leman Ground ; 26·5 cm. on the Brown Bank Ground ; and 24·6 cm. on the Texel.

The *IV. Group* (*males*) had an average size of 30·9 cm. on the Leman Ground ; 29·1 cm. on the Brown Bank Ground ; and 27·3 cm. on the Texel.

The *IV. Group* (*females*) had an average size of 32·4 cm. on the Leman Ground ; 30·6 cm. on the Brown Bank Ground ; and 29·2 cm. on the Texel.

The values for the average size of the II. group given here agree perfectly with those quoted by Redeke (1905 pp. 6–8) for the same region ; viz., 18–23 cm. in Autumn according to distance from the Dutch Coast. For example, he gives 23 cm. as the size of this group on the Brown Ridge in November, 1903. This was also the value in my Sample No. 10[1] from the north part of the Brown Ridges.

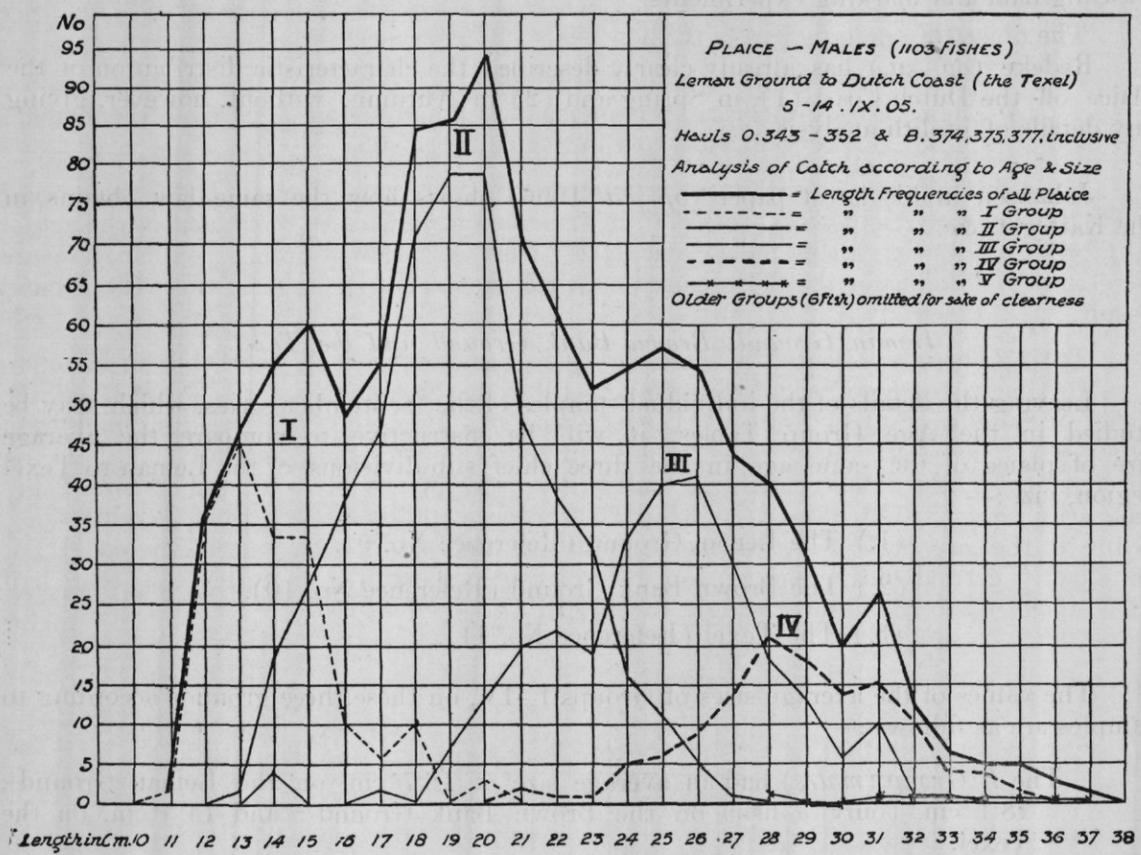

No
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
PLAICE — MALES (1103 FISHES)
Leman Ground to Dutch Coast (the Texel)
5 - 14 . IX . 05.
Hauls 0.343 - 352 & B. 374, 375, 377, inclusive
Analysis of Catch according to Age & Size
= Length Frequencies of all Plaice
= " " " I Group
= " " " II Group
= " " " III Group
= " " " IV Group
= " " " V Group
Older Groups (6 Fish) omitted for sake of clearness
I
II
III
IV
Length in Cm. 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38

FIG. 8.

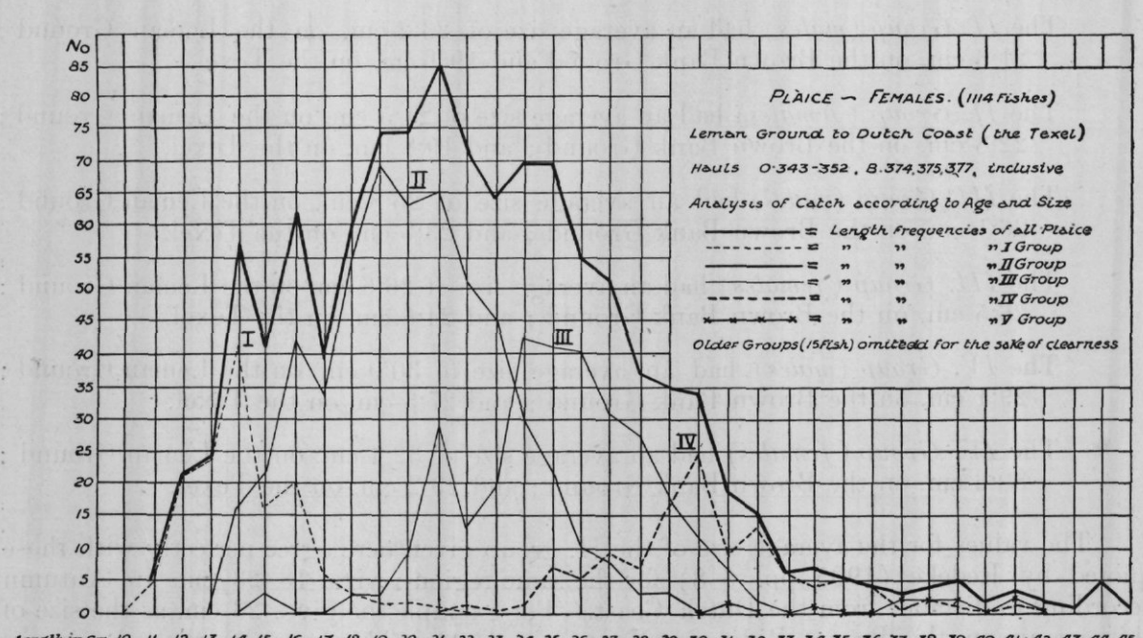

No
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
PLAICE — FEMALES. (1114 Fishes)
Leman Ground to Dutch Coast (the Texel)
Hauls 0·343-352, B. 374, 375, 377, inclusive
Analysis of Catch according to Age and Size
= Length Frequencies of all Plaice
= " " " I Group
= " " " II Group
= " " " III Group
= " " " IV Group
= " " " V Group
Older Groups (15 Fish) omitted for the sake of clearness
I
II
III
IV
Length in Cm. 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45

FIG. 9.

Explanation of Figs. 8 *and* 9.—The age analysis, by means of the otolith method of the entire catch of plaice between the Leman Banks and Dutch Coast in September, 1905, is shown graphically in Figs. 8 and 9. In these figures we see the gross frequency curve resolved, so to speak, into separate curves for the various age groups.

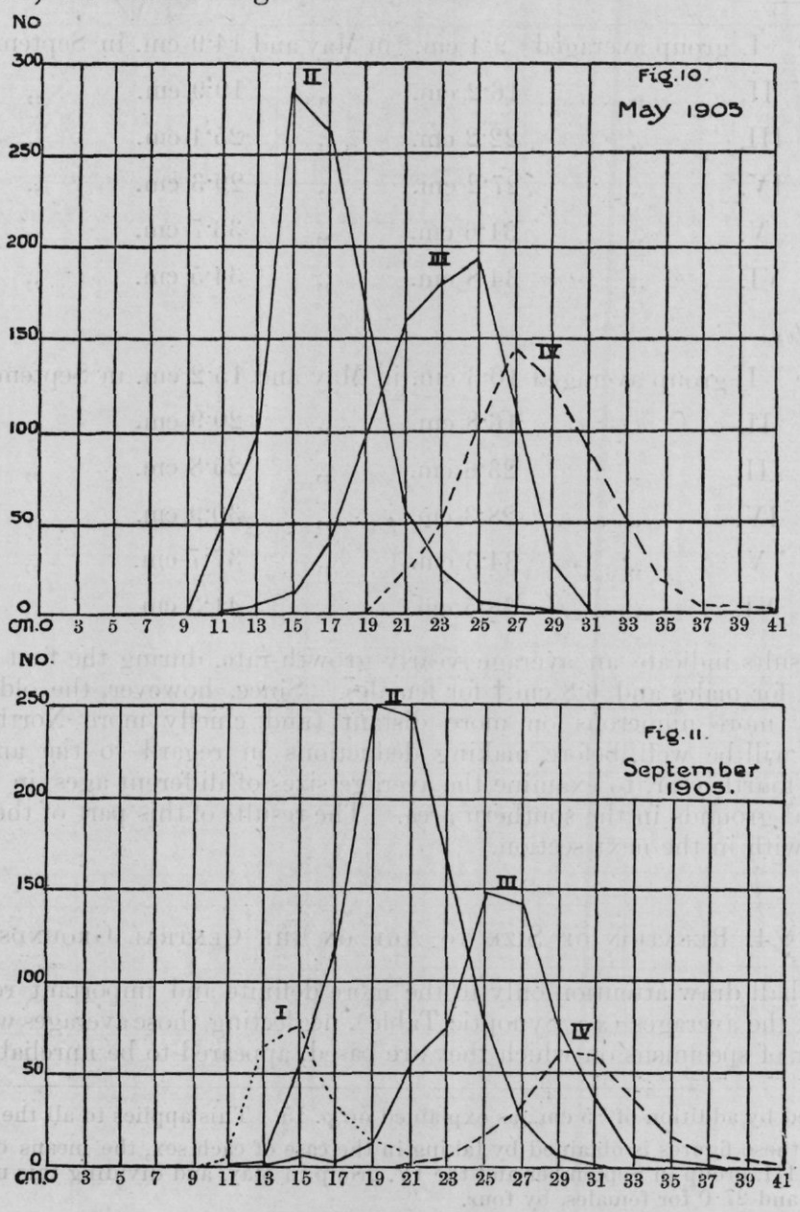
The object of these figures is to show :—

(1.) The relation of size to age in either sex.

(2.) The relative numerical proportions of the different ages over the Leman-to-Texel section as a whole in September, 1905.

Since the numbers of specimens represented in these curves, viz., 1,103 males and 1,114 females differ somewhat from and, in the case of the females, fall short of the actual numbers caught, viz., 1,100 males and 1,147 females, a few words of explanation are necessary to account for the discrepancy which, however, is too slight to affect the general result.

The numbers represented in these curves, in fact, comprise all the fishes in Samples 1 to 10 (inclusive) together with *double* the fishes in Sample No. 11^4. Now if *all* the fishes in Samples 9^1 to 11^3 were all that had been *caught* in the corresponding hauls, and Sample 11^4 just half the number caught in haul B. 377, there would have been no discrepancy in the final result. Actually, however, the otoliths of one or two fishes caught in hauls O. 343–352 and B. 374, 375 were accidentally omitted from the collections, while, in the case of B. 377, the halving of the number at each centimetre could not be exactly carried out. Sample No. 11^4 consisted, therefore, of rather less than half (257 out of 528) the number caught in haul B. 377.



FIGS. 10 AND 11.

Figs. 10 *and* 11 show in graphic form the distribution of the length frequencies of the otolith or age groups, I. to V., in the entire collections made along the Leman-to-Texel line in May and September, 1905. In the construction of these figures a 2 cm. grouping has been adopted and the sexes combined so as to give larger numbers and smoother curves.

These diagrams appear to need little explanation. They show at a glance the growth of the fishes in the interval between May and September, the great range of size of fishes of the same age over this section of the North Sea, and the great extent to which the age groups overlap.

The numerical proportions of the various age groups are not indicated in Figs. 10 and 11. In the case of groups I. and II., only a fraction of the numbers actually *caught* is represented, since the ages of only a portion of the plaice captured on "the Texel" (where these groups were chiefly found) were determined, and it is this portion which is represented in the diagrams. The original data from which these curves were constructed will be found in the Age Group Tables at the end.

General Age Group Averages for the whole Leman-to-Texel Region.—I refer here to the collective averages for May (9–12/v/05) and September (5–14/ix/05). Only the averages of age groups I.–IV. need be mentioned. These averages, with the exception of the VI. group, and (in September) the V. group also, are based on large numbers (*see* Synoptic Table) amounting, in the case of each of the groups II., III., and IV., to several hundred specimens.

1. *Males*—

The	I.	group averaged	9·4 cm.*	in May and	14·9 cm.	in September.
„	II.	„	16·2 cm.	„	19·9 cm.	„
„	III.	„	22·2 cm.	„	25·4 cm.	„
„	IV.	„	27·2 cm.	„	29·3 cm.	„
„	V.	„	31·6 cm.	„	33·7 cm.	„
„	VI.	„	34·8 cm.	„	34·5 cm.	„

2. *Females*—

The	I.	group averaged	10·3 cm.	in May and	15·2 cm.	in September.
„	II.	„	16·8 cm.	„	20·9 cm.	„
„	III.	„	23·6 cm.	„	25·8 cm.	„
„	IV.	„	28·3 cm.	„	30·9 cm.	„
„	V.	„	34·3 cm.	„	37·7 cm.	„
„	VI.	„	38·5 cm.	„	41·3 cm.	„

These results indicate an average yearly growth-rate, during the first four years, of about 6·6 cm. for males and 6·8 cm.† for females. Since, however, the older groups are proportionally more numerous on more distant (and chiefly more Northern) grounds (*see* p. 11) it will be well, before making deductions in regard to the annual growth-rate *after* the fourth year, to examine the average sizes of different ages in samples from various central grounds in the southern area. The results of this part of the investigation will be dealt with in the next section.

§ 4. Relation of Size to Age on the Central Grounds.

Here I shall draw attention only to the more definite and important results afforded by a study of the averages (*see* Synoptic Table), neglecting those averages which, from the small number of specimens on which they are based, appeared to be unreliable.

---

* Amended by addition of ·5 cm., as explained on p. 15. This applies to all the other values.

† Each of these figures is obtained by taking in the case of each sex, the means of two averages, *i.e.*, that of the III. group in September and the IV. group in May, and dividing this mean value, viz., 26·3 for males and 27·0 for females, by four.

September, 1904, *and September*, 1905—*Leman Ground.*

We have already seen (p. 12) that the *Average Age* of the plaice on the Leman Ground was decidedly higher in September, 1904, than in September, 1905, and this we thought might be attributed to a comparative failure of the summer migration from the Dutch Coast in the former year, or to other causes at present obscure.

Here I wish to point out the distinctly higher average size in 1904 of those age-groups which are sufficiently well represented in both samples to render the comparison valid. Thus we find:—

The III. Group (*males*) averaged 28·8 cm. in 1904 and 26·8 cm. in 1905.

The III. Group (*females*) averaged 30·5 cm. in 1904 and 26·6 cm. in 1905.

The IV. Group (*males*) averaged 31·7 cm. in 1904 and 30·9 cm. in 1905.

The IV. Group (*females*) averaged 35 cm. in 1904 and 32·4 cm. in 1905.

The fact that in 1904 the hauls were made on September 27–29 and in 1905 on September 5–6, or just over three weeks earlier in the year, is clearly insufficient to account for more than a small part* of these considerable differences.

September, 1905, *and October*, 1905—*Leman Ground.*

The dates of the two samples under consideration are 5–6/ix/05 and 24/x/05. The difference is thus about seven weeks.

Comparing only the well-represented age-groups, we find:—

The II. Group (*males*) averaged 23·2 cm. (34 fish) in September and 24·9 cm. (32 fish) in October, a difference of 1·7 cm.

The II. Group (*females*) averaged 24·5 cm. (31 fish) in September and 25·3 cm. (33 fish) in October, a difference of 0·8 cm.

The III. Group (*males*) averaged 26·8 cm. (62 fish) in September and 28·4 cm. (25 fish) in October, a difference of 1·6 cm.

The III. Group (*females*) averaged 26·6 cm. (58 fish) in September and 30·3 cm. (25 fish) in October, a difference of 3·7 cm.

The IV. Group (*males*) averaged 30·9 cm. (44 fish) in September and 31·7 cm. (21 fish) in October, a difference of 0·8 cm.

The IV. Group (*females*) averaged 32·4 cm. (38 fish) in September and 33·9 cm. (43 fish) in October, a difference of 1·5 cm.

These differences are somewhat irregular, but, except in the case of the III. Group, (females) are not great, and are doubtless due partly to growth in the seven-weeks interval, possibly complicated by migrations, the exact nature of which is at present obscure.

October to March—Various Grounds.

The allowance to be made for growth during this period is slight. Only one sample, *viz.*, from the south part of the Dogger was obtained in March, the rest in October, November and January

N.B.—In speaking of the III. group, IV. group, V. group, &c., in autumn and winter it is important to remember that the fishes belonging to the III. group have practically completed *four* years' growth, those of the IV. group are practically *five* years old, and so on.

* Marking experiments (T. 4 + 5; 1905–6) with plaice transplanted to the Leman Banks showed an average growth of only ·3 cm. during the whole month of September.

In the following synopsis only the *approximate* length (*e.g.*, 27 cm. = 27·0 to 27·9 cm.) is quoted.

The III. Group (*males*) had an average size of:—

27 cm.	...	(12 fish)	on the	Botney Ground (January, 1905).
		(7 „)	„	Clay Deep edge of the Dogger (October, 1905).
28 cm.	...	(19 „)	„	Flamborough Off Ground (October, 1905).
		(25 „)	„	Leman „ (October, 1905).
		(39 „)	„	Sandette Bank (November, 1904).
29 cm.	...	(9 „)	„	Flamborough Off Ground (January, 1905).
		(8 „)	„	South Dogger (January, 1905).
30 cm.	...	(12 „)	„	„ (March, 1904).

The III. Group (*females*) had an average size of:—

28 cm.	...	(10 fish)	on the	Clay Deep edge of the Dogger (October, 1905).
		(26 „)	„	Botney Ground (January, 1905).
29–30 cm.	...	(18 „)	„	Flamborough Off Ground (October, 1905).
		(14 „)	„	South Dogger (January, 1905).
		(50 „)	„	„ (March, 1905).
		(25 „)	„	Leman Ground (October, 1905).

The IV. Group (*males*) had an average size of:—

31 cm.	...	(32 fish)	on the	Clay Deep edge of the Dogger (October, 1905).
		(21 „)	„	Leman Ground (October, 1905).
32 cm.	...	(54 „)	„	Sandette Bank (November, 1904).
		(20 „)	„	Flamborough Off Ground (January, 1905).
		(9 „)	„	South Dogger (October, 1905).
33 cm.	...	(6 „)	„	„ (January, 1905).
		(25 „)	„	Flamborough Off (October, 1905).
35 cm.	...	(17 „)	„	South Dogger (March, 1904).
36 cm.	...	(16 „)	„	Flamborough *Head* Ground (January, 1905).

The IV. Group (*females*) had an average size of:—

32 cm.	...	(54 fish)	on the	Clay Deep edge of the Dogger (October, 1905)
		(7 „)	„	Botney Ground (January, 1905).
33 cm.	...	(10 „)	„	South Dogger (October, 1905).
		(43 „)	„	Leman Ground (October, 1905).
35 cm.	...	(24 „)	„	South Dogger (January, 1905).
36 cm.	...	(62 „)	„	Flamborough Off Ground (October, 1905).
		(33 „)	„	South Dogger (March, 1904).
		(9 „)	„	Sandette Bank (November, 1904).

The V. Group (*males*) had an average size of:—

34 cm.	...	(12 fish)	on the	Sandette Bank (November, 1904).
35 cm.	...	(8 „)	„	Clay Deep edge of the Dogger (October, 1905).
36 cm.	...	(19 „)	„	Flamborough Off Ground (October, 1905).
		(7 „)	„	Leman Ground (October, 1905).
38 cm.	...	(29 „)	„	Flamborough *Head* Ground (January, 1905).

The V. Group (*females*) had an average size of:—

37 cm.	...	(10 fish)	on the	Leman Ground (October, 1905).
40 cm.	...	(10 „)	„	Clay Deep edge of the Dogger (October, 1905).
41 cm.	...	(19 „)	„	Flamborough Off Ground (October, 1905).
41 cm.	...	(24 „)	„	South Dogger (March, 1904).

Provisional Deductions.

Generally speaking, the plaice were largest for their age on the South Dogger and Flamborough Off Grounds. It is as yet impossible to decide definitely whether, or to what extent, this is due to:—(1) the existence of a more rapidly growing race inhabiting the north part of the North Sea,* (2) more rapid growth on the Dogger Bank due to greater abundance of food and less competition for it,† or (3) selective migration according to size.

The average sizes of the III. and IV. groups on the Clay Deep edge of the Dogger and on the South Botney Ground were distinctly lower than on the south part of the Dogger, the Flamborough Off Ground and the Leman Ground. On the whole, we should expect this to be so, since the first-named grounds are nearer the Danish and Dutch Coasts, respectively, than the last-named. In regard to the Flamborough Ground, we have the effects of greater depth of water and perhaps the presence of a more rapidly-growing northern race to consider. In any case, the number of plaice reared on the adjoining English Coast (*e.g.*, Bridlington Bay) is insignificant compared to the number on the Eastern Grounds.

The fact that in October, 1905, the average size of the III. and IV. groups was lower on the Clay Deep edge of the Dogger than on the Leman Ground in spite of the greater proximity of the latter to the coast, may perhaps be taken as an indirect indication that the rate of growth on the Eastern Grounds proper (Danish and German "nurseries") is slightly less than on the Dutch Coast. Such a result is what we should expect from our knowledge that the density of the plaice population is greater on the Danish than on the Dutch "nurseries."

In October, 1905, and November, 1904, respectively, the average size of the IV. group (females) was distinctly larger (viz., 36·5–36·6 cm.) on the Flamborough Off Ground and Sandette Bank, which we know to be spawning grounds, than on the south part of the Dogger and Leman Ground, which are not spawning grounds. Here the size was only 33·9 cm. In March (1904), however, on the South Dogger, the size of this group (females) was about the same as on the Flamborough Off Ground and Sandette Bank in autumn, viz., 36·9 cm.

These local and seasonal differences in the average size of the IV. group (females) may be provisionally correlated with the fact that, according to our observations, only the larger members of this group attain maturity. This involves the temporary migration (in winter) of the larger fishes of this age and sex to the spawning grounds such as the Flamborough Off Ground and Sandette Bank (thereby raising the average size of the group on these grounds) and leaving the smaller plaice of the same age behind on grounds such as the Dogger Bank and Leman Ground. These spawned fishes of the IV. group return to the Bank in spring and so raise the average length again in this region.

The results of analysis of two samples: (1) from the Flamborough Off Ground in October, 1905, and (2) from the South Dogger in March, 1904, furnish an almost identical series of age group averages in the case of the female sex.

The two series are as follows:—

1. Flamborough Off Ground—19–20/x./05.

Age Groups	III.	IV.	V.
Years old	$3\frac{3}{4}$	$4\frac{3}{4}$	$5\frac{3}{4}$
Average Length (cm.)	30·2	36·6	41·2

2. South Dogger—11/iii./04.

Age Groups	III.	IV.	V.
Years old (nearly)	4	5	6
Average Length (cm.)	30·4	36·9	41·9

* Fulton's exhaustive researches, based on Petersen's method (*op. cit.* 1902), indicate more or less clearly a more rapid growth-rate off the East Coast of Scotland than in the Southern North Sea according to the present observations.

† *See* Garstang, "Transplantation Experiments."

The two series of values approximate so closely as to suggest an interchange between the plaice population on the two grounds.

Another case of remarkably close agreement between the average size for a given age in two widely separated localities is furnished by the analyses of two samples, viz., (1) from the Leman Ground in October, 1905, and (2) from the Sandette Bank in November, 1904, in which the average sizes of groups II., III., and IV. (males) were almost identical, the November being slightly higher than the October values, as we should naturally expect.

The two series are as follows :—

1. Leman Ground—24/x./05.

Age Groups	II.	...	III.	...	IV.
Average Length (cm.) ...	24·9	...	28·4	...	31·7

2. Sandette Bank—26/xi./04.

Age Groups	II.	...	III.	...	IV.
Average Length (cm.) ...	25·1	...	28·5	...	32·0

This result suggests a common origin of the plaice population on the Sandette Bank (near the Straits of Dover) and the Leman Ground (between the Norfolk and Dutch Coasts). Coupled with the results of marking experiments which show a southward migration from the Leman Ground in autumn, this remarkably close agreement between the average lengths of plaice of the same age on those two grounds suggests that the population on Sandette Bank in autumn may be directly derived from the Leman Ground, and since the Sandette sample entirely or almost entirely consisted of actually spawning fishes (of which the vast majority were males) it seems probable that the Southward migration is (partly at least) for the purpose of spawning.

III.—AVERAGE GROWTH-RATE IN THE SOUTHERN NORTH SEA.

In the preceding pages I have indicated and partially attempted to account for certain differences in the average lengths of the age-groups of plaice in samples from various parts of the Southern North Sea. It now remains to deduce from the available data a general estimate of the average growth-rate of male and female plaice in the Southern North Sea as a whole.

The importance of samples collected along the lines of migration as necessarily affording the best material on which to base such estimates has already been pointed out (p. 19). The entire collections made in a continuous series of trawlings between the Leman Banks and the Dutch Coast in May and September, 1905 (*see* p. 26), furnish us with the required data so far as the first four or five years are concerned. These samples are, however, deficient in the older groups which are proportionally more numerous on more distant grounds (p. 11).

For purposes of "control" it is important to ascertain whether our estimate of the growth-rate based on the analysis of one collection (which we may call A) is confirmed by the results of analysis of another and entirely distinct collection (which we may call B). In other words we wish to obtain by independent analyses, two series of values for the average lengths of the various age-groups so as to check our results.

One such series (*see* Table 5) has been obtained by combining in one large collection (A) all the samples which were collected in autumn and winter. This combination seems legitimate since the amount of growth during the whole of this period is relatively slight.

Collection A, therefore, consists of (1) the Leman-to-Texel samples collected in September, 1905, together with (2) the various samples from the central grounds collected during the period September–March. The latter samples supplement the above-mentioned deficiencies in the former by furnishing examples of the older groups.

Collection B consists exclusively of the material collected along the Leman–to–Texel line in May, 1905.

If our methods are sound and our samples representative, the curves of growth (*see* Figs. 12 and 13) constructed on the basis of these two sets of data will agree as to their general orientation and trend, at least up to the fifth year.

Comparing the data themselves (Table 5), we shall expect to find that the average length of each age group in Collection A (September–March) will be somewhat lower than the average length of the age group next above in Collection B (May) since, *e.g.*, the O. Group in winter = I. Group in spring, according to our nomenclature.

TABLE 5.—Average Lengths of the Age Groups in two collections of Plaice.

Collection A = Total samples collected during September–March (combined).*

Collection B = Leman-to-Texel Series, May, 1905.†

Index figures give the numbers of fish on which the averages are based.

Collection.	Age Group.	Age in Years.	Average Length (cm.).	
			Males.	Females.
B	I	$1\frac{1}{6}$	$9{\cdot}4^{20}$	$10{\cdot}3^{15}$
A	I	2 (nearly)	$(15{\cdot}5)^{126}$	$(15{\cdot}7)^{102}$
B	II	$2\frac{1}{6}$	$(16{\cdot}2)^{515}$	$(16{\cdot}8)^{432}$
A	II	3 (nearly)	$20{\cdot}4^{518}$	$21{\cdot}3^{526}$
B	III	$3\frac{1}{6}$	$22{\cdot}2^{442}$	$23{\cdot}6^{379}$
A	III	4 (nearly)	$26{\cdot}6^{431}$	$27{\cdot}4^{458}$
B	IV	$4\frac{1}{6}$	$27{\cdot}2^{282}$	$28{\cdot}3^{319}$
A	IV	5 (nearly)	$31{\cdot}5^{349}$	$33{\cdot}8^{388}$
B	V	$5\frac{1}{6}$	$31{\cdot}6^{56}$	$34{\cdot}3^{48}$
A	V	6 (nearly)	$36{\cdot}3^{103}$	$40{\cdot}7^{96}$
B	VI	$6\frac{1}{6}$	$34{\cdot}8^{6}$	$38{\cdot}5^{6}$
A	VI	7 (nearly)	$37{\cdot}2^{24}$	$43{\cdot}4^{47}$

Making a reasonable allowance for spring-growth (chiefly in April–May), it will be seen that the two series of averages and the curves derived therefrom do agree closely.

It is obvious, however, that the averages for the I. Group in Collection A are somewhat too high, partly because all the fishes of this group in the September–March period were captured (*see* Synoptic Table) in deeper water than seven fathoms, whereas the bulk of the I. group lives in shallower water than this (*see* p. 11).

In the curve for Collection A (Fig. 12), I have accordingly omitted the values for the average of the I. group as calculated from the actual data. The curve has been completed (dotted portion) by assigning the value of 7 cm. as the average length of one-year-old plaice. This value is based partly on observations made earlier in the year, according to which just over one-year-old plaice in May, at Lowestoft, averaged 7·5 cm., and partly on Redeke's observations in regard to the Dutch Coast, which agree.

* Reference Nos. 8, 12 to 21, and 26.

† Reference No. 2.

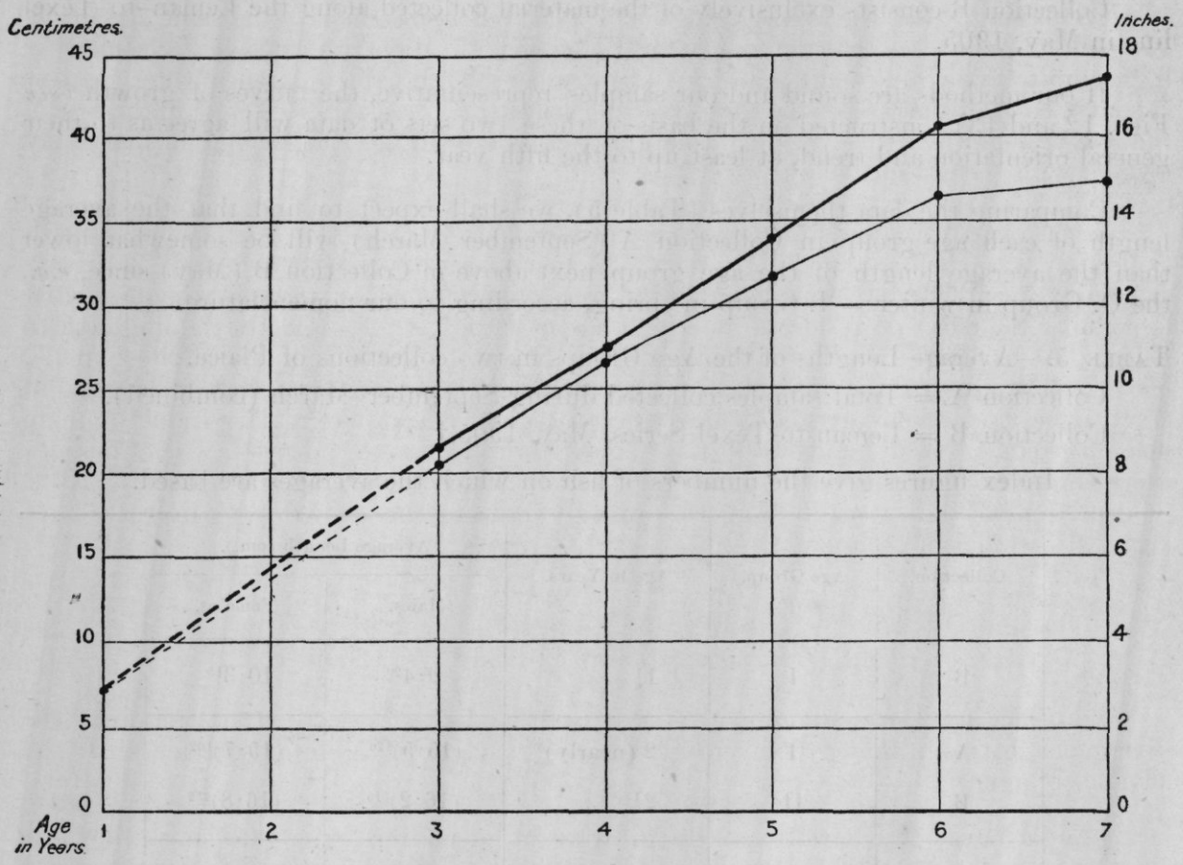


FIG. 12. COLLECTION A.

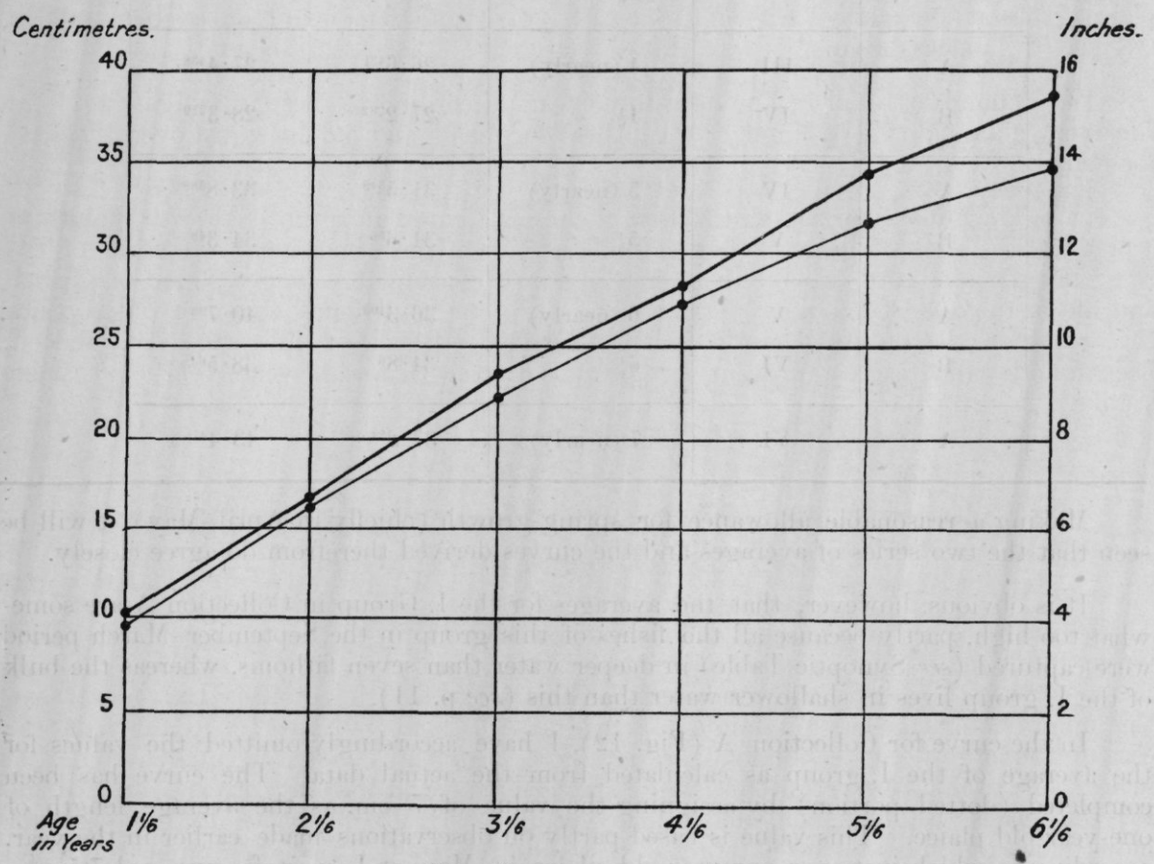


FIG. 13. COLLECTION B.

FIGS. 12 and 13. Curves showing Average Growth-Rate of Plaice, based on the otolith-analysis of Collections A and B (*see* Table 5).

——●—— Females. ——●—— Males.

Comparing, then, the average lengths of plaice of *approximately* the same age in the two collections, we see that the values for Collection B (May) are consistently somewhat higher up to five years of age than in A (September–March), the difference being greatest (about 2 cm.) in the case of the three-year-old fishes, and least (0·1–0·5 cm.) in the case of the five-year-old plaice, as we should naturally expect, owing to the decline in the yearly growth with the advance of age.

In the relatively large size of the six-year-old plaice in Collection A as compared with Collection B, as well as the slightly increased increment between fourth and fifth years as compared with the previous year (in the case of the females), we may recognise what is possibly the effect of residence on the Dogger Bank* as an episode in the life of these fishes. As explained above, the analysis of the Leman-to-Texel samples (Collection B), *alone* do not give us the information we require in regard to the average lengths of six-year-old and seven-year-old plaice, since these older fishes are mainly found on more distant grounds. The numbers of these ages in Collection A, however, which includes representatives from the northern central grounds, are, however, considerable, so that the final portions of the curves in Fig. 13 probably indicate the growth-rate in these later years with sufficient accuracy.

General Deductions (*see* Table 5 and Figs. 12 and 13).

(1.) The males grow more slowly than the females apparently from the first, the divergence between the growth curves for the two sexes becoming greater with the advance of age.

(2.) Whereas the females go on growing at much the same rate until they are six years old, the growth of the males shows a distinct decline after the fourth year.

(3.) During the first four years of their life, according to these observations, male plaice grow at an average rate of 6·6 cm. a year; and females at an average rate of 6·8 cm. (2·7 inches) a year.

(4.) The growth during the next three years, according to these investigations, is at the average annual rate of 3·5 cm. (1·4 inches) for males and 5·3 cm. (just over 2 inches) for females.

(5.) The almost horizontal direction of the male curve after the sixth year points to a practical cessation of growth after seven years. On the other hand, the form of the curve for females after the sixth year points to a considerably longer period of growth and life in the case of this sex. This agrees with our experience that the older plaice (according to the otoliths) are invariably females. Plaice of this sex have, indeed, been found which were apparently up to 16 or even 20 years old (*see* next section).

IV.—NOTE ON THE RELATIVE MORTALITY OF MALES AND FEMALES AT DIFFERENT AGES.

A reference to the Synoptic Table will show that there are no males in the IX.+ Group; this means that *no males showing more than eight rings in their otoliths have come under our notice*, whereas the number of females of which the otoliths had more than this number of rings was 47. Indeed as many as 16–20 rings have been counted in the case of the largest females, but so far not more than eight rings have been found in males. To avoid, however, a too definite statement in regard to the precise limit of life for the males, we may combine in one group (VIII.+) all plaice having eight or more than eight rings in their otoliths. If we do this we find that the number of males in the oldest group so formed is only six, whereas the number of females is 59 or 91 per cent.

* *See* Garstang, 1902–03, *op. cit.* Transplantation Experiments.

TABLE 6.—Showing Numbers and Proportions (Percentages) of the Sexes at different Ages.

Sex.	—	0.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.+	Total.
♂	No.	—	163	1,068	883	635	159	30	11	6	2,955
	%	—	56	52	51	47	53	37	24	9	49
♀	No.	—	127	998	863	710	140	51	35	59	2,983
	%	—	44	48	49	53	47	63	76	91	51

The above Table gives the result of adding up the number of males and females in each age group in all the samples so far examined in which the sexes were distinguished.

We learn from this Table that :—

(1.) The number of males and females up to five years of age is approximately the same, but shows a slight excess in favour of the males.

(2.) After the fifth year the number of females distinctly preponderates over the number of males, the relative scarcity of this sex gradually increasing with age.

(3.) Of plaice of eight and over eight years of age the total number of males found in our samples was six, whereas the number of females was 59 (*i.e.* 91 per cent.)

A result of considerable biological importance is clearly indicated by these statistics limited as they are, *i.e.*, the higher death rate of the males after the fifth year with the final result that after eight years relatively very few males remain.

An obvious objection to this generalisation is that the slower growth of the males (*see* Fig. 13, p. 32) would lead to a confusion of the white rings at the peripheries of their otoliths, and so lead to an under-estimation of their age.

In answer to this it may be pointed out that the *gradual* falling off in the relative numbers of males with increase of age after the fifth year, as is indicated in the table, precludes the possibility of this interpretation.

Fig. 8, Plate IV., shows the otoliths of a male plaice, 44 cm. long, the oldest and one of the largest of the sex found by us.

In these otoliths the number of white rings is very clear : they can be easily counted and their number is seen to be eight. There is no indication of the fusion of white rings at the margin.

Although a detailed discussion of the biological significance of this phenomenon would be premature or, at any rate, out of place in this Report, two collateral phenomena may be mentioned which possibly bear on the earlier death of the males. These are as follows :—

(1.) In males, according to our investigations, the advent of maturity is one year or (on an average) even two years earlier than in the case of the females.

(2.) The curve of the growth for the males (shown in Fig. 12) points to a practical cessation of growth after seven years.

KEY TO PLATES I. TO IV. FIGS. 1–9.

ILLUSTRATIONS FROM PHOTOGRAPHS BY R. A. TODD, B.Sc.

These figures give views of the concave (outer) surfaces of the otoliths. All are magnified 4·8 times.

Fig. 1.—Right otoliths of 36 plaice: length 16 centimetres. Mostly with 2 rings (II. Group). From Leman-to-Texel Collection, 9th–12th May, 1905.

Fig. 2.—Right otoliths of 25 plaice: length 21 centimetres. Mostly with 3 rings (III. Group). From Leman-to-Texel Collection, 9th–12th May, 1905.

Fig. 3.—Right otoliths of 20 plaice: length 27 centimetres. Mostly with 4 rings (IV. Group). From Leman-to-Texel Collection, 9th–12th May, 1905.

Fig. 4.—Right otoliths of 32 plaice: length 16 centimetres. Mostly with 2 rings (II. Group). Bridlington Bay, 7th July, 1905.

Fig. 5.—Right otoliths of 24 plaice: length 14 centimetres. Mostly with 1 ring (I. Group). Leman-to-Texel Collection, 5th–14th September, 1905.

Fig. 6.—Right otoliths of 25 plaice: length 20 centimetres. Mostly with 2 rings (II. Group). Leman-to-Texel Collection, 5th–14th September, 1905.

Fig. 7.—Right otoliths of 18 plaice: length 24 centimetres. Mostly with 3 rings (III. Group). Leman-to-Texel Collection, 5th–14th September, 1905.

Fig. 8.—Pair of otoliths of a male plaice: length 44 centimetres. 8 rings. Flamborough Head Ground, 13th January, 1905.

Fig. 9.—Right otoliths of 5 plaice, females: length 46 centimetres. 7–9 rings. Leman-to-Texel Collection, 9th–12th May, 1905.

PLATE V. Natural Average Size of Female Plaice in Southern North Sea.

SYNOPTIC TABLE summarising the RESULTS of OTOLITH INVESTIGATIONS in regard from various parts of the SOUTHERN NORTH SEA; and giving

Index figures give the numbers of observations

The two series of Averages in thick type are based on the analyses of plaice collected in one in May and the

Age Nomenclature.

Group O. = under one year old, *i.e.*, with no white ring in otoliths.

Group I. = fully one year old but less than two years old, *i.e.*, with one white ring in otoliths, &c., &c.

N.B.—A plaice's year is assumed to commence on April 1st.

Period of Year.	Date of Collection.	Locality.	Depth in Fathoms.	Gear and Reference Numbers of Hauls.	O.		I.		II.		Reference No.
					Males.	Females.	Males.	Females.	Males.	Females.	
May	1–4/v/05	Off Lowestoft... ...	3–5	Shrimp Trawl	...	...	$7{\cdot}6^{96}$		$12{\cdot}4^{272}$		1
,,	9–12/v/05	**Leman Ground to the Texel.**	7–16	O. 301–309; B.* 300.	...	...	**$9{\cdot}4^{20}$**	**$10{\cdot}3^{15}$**	**$16{\cdot}2^{515}$**	**$16{\cdot}8^{432}$**	2
July–August	7–11/vii/04	Bridlington Bay ...	9–5½	Shrimp Trawl	$2{\cdot}8^{93}$		$9{\cdot}2^{40}$		$13{\cdot}8^{61}$		3
,,	7/vii/05	Bridlington Bay ...	3½–5	B. 345	...	...	...	...	$16{\cdot}2^{94}$		4
,,	2–7/viii/05	The Wash	1½–7	Shrimp Trawl	$5{\cdot}0^{10}$		$9{\cdot}6^{183}$		$14{\cdot}6^{86}$		5
,,	23–24/viii/05	Off Mablethorpe ...	3½–9	,,	...	...	$12{\cdot}0^{68}$		$17{\cdot}1^{70}$		6
,,	16/vii/04	Thames Estuary ...	7–10	,,	...	...	$9{\cdot}6^{54}$		$13{\cdot}5^{58}$		7
September	27–29/ix/04	Leman Ground ...	14–17	B. 213, 214, 220.	...	$10{\cdot}5^{1}$	...	...	$14{\cdot}5^{1}$	$22{\cdot}3^{12}$	8
,,	5–6/ix/05	Leman Ground ...	15½–17	O. 343–346; B.* 374–375.	...	...	$16{\cdot}7^{14}$	$15{\cdot}9^{20}$	$23{\cdot}2^{34}$	$24{\cdot}5^{31}$	9
,,	6–14/ix/05	Brown Bank Ground...	14–16	O. 347, 351. 352.	...	...	$18{\cdot}1^{5}$	$19{\cdot}2^{4}$	$21{\cdot}6^{96}$	$22{\cdot}8^{112}$	10
,,	13/ix/05	The Texel	7–14	O. 348–350; B.* 377.	...	...	$14{\cdot}5^{92}$	$14{\cdot}6^{67}$	$19{\cdot}1^{326}$	$19{\cdot}8^{329}$	11
,,	5–14/ix/05	**Leman Ground to the Texel.**	7–17	O. 343–352; B.* 374, 375, 377.	...	...	**$14{\cdot}9^{111}$**	**$15{\cdot}2^{91}$**	**$19{\cdot}9^{456}$**	**$20{\cdot}9^{472}$**	12†
October–March	12/x/05	Clay Deep edge of Dogger.	20–24	O. 360, 361	...	...	...	...	...	...	13
,,	11/x/05	Dogger Bank—South part.	10½–14	O. 358, 359	...	..	...	...	$29{\cdot}5^{1}$	$28{\cdot}5^{3}$	14
,,	22/i/05	,, ,,	11½–17	O. 270–272	...	...	...	...	...	...	15
,,	11/iii/04	,, ,,	9–17	O. 160–164, 166.	...	...	...	...	...	$23{\cdot}0^{2}$	16
,,	19–20/x/05	Flamborough Off Ground.	25–30	O. 362–366; B. 397.	...	...	...	...	$21{\cdot}7^{8}$	$28{\cdot}5^{2}$	17
,,	20/i/05	,, ,,	25½–26	O. 268	...	...	$19{\cdot}5^{2}$	...	$22{\cdot}5^{1}$	...	18
,,	13–14/i/05	,, Head Ground.	31–31	O. 266, 267	...	...	$20{\cdot}5^{1}$	...	$25{\cdot}5^{2}$	...	19
,,	25/i/05	Botney Ground—South part.	17½–20	O. 276	...	...	...	$16{\cdot}5^{1}$	$26{\cdot}5^{2}$	$27{\cdot}0^{2}$	20
,,	24/x/05	Leman Ground ...	12–17	O. 368	...	...	$19{\cdot}4^{8}$	$20{\cdot}0^{10}$	$24{\cdot}9^{32}$	$25{\cdot}3^{33}$	21
,,	28/xi/03	Brown Ridges—North part.	14–17	B. 93	...	...	...	...	$25{\cdot}9^{15}$		22
,,	1/xii/03	Off Egmond	10–11	B. 95	...	...	$16{\cdot}0^{14}$		$20{\cdot}2^{81}$		23
,,	1/xii/03	Off Ymuiden	9–10	B. 96	..	...	$15{\cdot}0^{10}$		$19{\cdot}0^{62}$		24
,,	29/xi/03	Off Ymuiden	8–9	B. 94	...	...	$13{\cdot}8^{87}$		$16{\cdot}4^{101}$		25
,,	26/xi/04	Off Sandette Light Vessel.	19–21	B. 247, 248	...	...	$21{\cdot}5^{4}$	—	$25{\cdot}1^{15}$	...	26
,,	11/xi/04	Teignmouth Bay (Channel.)	4½–7	B. 242, 243	...	...	$22{\cdot}2^{3}$	$23{\cdot}0^{2}$	$27{\cdot}3^{18}$	$28{\cdot}0^{13}$	27
,,	27/ii/04	Great West Bay (Channel.)	17–23	G. 159	...	...	$19{\cdot}2^{14}$	$18{\cdot}5^{8}$	$25{\cdot}1^{17}$	$26{\cdot}7^{28}$	28

† No. 12 = 9, 10 and 11 combined.

to the AVERAGE LENGTH (in centimetres) of PLAICE of different AGES in SAMPLES

particulars of the TRAWL HAULS in which the SAMPLES were obtained.

on which the averages in each case are based.

two continuous lines of trawlings between the Leman Banks and the Dutch Coast, the other in September, 1905.

Symbols denoting Gear.

O. = Otter Trawl of ss. *Huxley*.
B. = Beam ,, ,,
B.* = ,, ,, ,, with small mesh covering net.
N.B.—The actual courses of the particular hauls specified are shown on the Charts in Reports on "Trawling Investigations."

Reference No.	III.		IV.		V.		VI.		VII.		VIII.		IX.+		Total in Sample.		Total Caught.	Number of Hours Fishing.
	Males.	Females.	Males.	Females.	Males.	Females.	Males.	Females.	Males.	Females.	Males.	Females.	Males.	Females.	Males.	Females.		
1	$15{\cdot}2^{75}$		$20{\cdot}8^{3}$		...	...	...	...	...	...	...	...	...	...	446		...	...
2	$\mathbf{22{\cdot}2^{142}}$	$\mathbf{23{\cdot}6^{379}}$	$\mathbf{27{\cdot}2^{282}}$	$\mathbf{28{\cdot}3^{319}}$	$\mathbf{31{\cdot}6^{56}}$	$\mathbf{34{\cdot}3^{48}}$	$\mathbf{34{\cdot}8^{6}}$	$\mathbf{38\ 5^{6}}$	$\mathbf{37{\cdot}5^{2}}$	$\mathbf{42\ 6^{13}}$	$\mathbf{38{\cdot}0^{2}}$	$\mathbf{48{\cdot}8^{3}}$	...	$\mathbf{51{\cdot}6^{21}}$	**1325**	**1236**	**11502**	**39½**
3	$19{\cdot}5^{68}$		$24{\cdot}0^{38}$		$24{\cdot}9^{25}$		$26{\cdot}2^{3}$		...	...	...	...	...	...	328		...	...
4	$18{\cdot}6^{74}$		$22{\cdot}3^{12}$		$20{\cdot}5^{1}$		$24{\cdot}5^{2}$		...	...	...	...	...	...	183		...	...
5	$16{\cdot}6^{6}$		...	...	...	...	...	...	...	...	...	...	...	...	285		...	...
6	$20{\cdot}3^{27}$		...	...	...	...	...	...	...	...	...	...	...	...	165		...	...
7	$20{\cdot}1^{12}$		...	...	...	...	...	...	...	...	...	...	...	...	124		...	...
8	$28{\cdot}8^{19}$	$30{\cdot}5^{17}$	$31{\cdot}7^{24}$	$35{\cdot}0^{27}$	$33{\cdot}8^{6}$	$38{\cdot}8^{6}$	$34{\cdot}0^{2}$	$39{\cdot}1^{6}$	...	$44{\cdot}5^{1}$	...	$45{\cdot}5^{1}$	...	$48{\cdot}5^{3}$	52‡	74‡	120	11½
9	$26{\cdot}8^{61}$	$26{\cdot}6^{38}$	$30{\cdot}9^{44}$	$32{\cdot}4^{38}$	$35{\cdot}2^{4}$	$39{\cdot}2^{7}$	$35{\cdot}5^{1}$	$40{\cdot}2^{3}$	$37{\cdot}5^{1}$	$43{\cdot}8^{3}$	$36{\cdot}1^{3}$	$47{\cdot}0^{2}$	...	$46{\cdot}7^{4}$	163	166	335	20
10	$26{\cdot}1^{115}$	$26{\cdot}5^{113}$	$29{\cdot}1^{50}$	$30{\cdot}6^{57}$	$32{\cdot}2^{4}$	$34{\cdot}1^{3}$	$33{\cdot}5^{1}$	$42{\cdot}5^{2}$	...	...	...	...	...	...	269	292	567	13½
11	$23{\cdot}7^{97}$	$24{\cdot}6^{111}$	$27{\cdot}3^{28}$	$29{\cdot}2^{18}$	...	...	...	...	...	...	...	...	...	...	543	525	1345	12
12†	$\mathbf{25{\cdot}4^{274}}$	$\mathbf{25{\cdot}8^{282}}$	$\mathbf{29{\cdot}3^{122}}$	$\mathbf{30{\cdot}9^{113}}$	$\mathbf{33{\cdot}7^{8}}$	$\mathbf{37{\cdot}7^{10}}$	$\mathbf{34{\cdot}5^{2}}$	$\mathbf{41{\cdot}3^{5}}$	$\mathbf{37{\cdot}5^{1}}$	$\mathbf{43{\cdot}8^{3}}$	$\mathbf{36{\cdot}1^{3}}$	$\mathbf{47\ 0^{2}}$	...	$\mathbf{46{\cdot}7^{4}}$	**977**	**983**	**2247**	**45½**
13	$27{\cdot}3^{7}$	$28{\cdot}9^{10}$	$31{\cdot}6^{32}$	$32{\cdot}7^{54}$	$35{\cdot}6^{8}$	$40{\cdot}1^{10}$	...	$48{\cdot}2^{4}$	...	$51{\cdot}8^{3}$	...	...	...	...	47	81	129	10
14	$33{\cdot}5^{1}$	$28{\cdot}0^{4}$	$32{\cdot}9^{9}$	$33{\cdot}9^{10}$	$39{\cdot}2^{4}$	$44{\cdot}3^{6}$	...	$46{\cdot}5^{2}$	...	...	...	...	...	...	15	21	40	9
15	$29{\cdot}5^{8}$	$29{\cdot}6^{14}$	$33{\cdot}2^{6}$	$35{\cdot}2^{24}$	$35{\cdot}5^{1}$	$45{\cdot}0^{2}$	...	...	...	...	...	...	...	...	15	40	58	20
16	$30{\cdot}1^{12}$	$30{\cdot}4^{30}$	$35{\cdot}3^{17}$	$36{\cdot}9^{33}$	$38{\cdot}0^{2}$	$41{\cdot}9^{24}$	...	$45{\cdot}9^{15}$	...	$48{\cdot}5^{5}$	...	...	...	$55{\cdot}0^{6}$	31	135	328	30
17	$28{\cdot}2^{19}$	$30{\cdot}2^{18}$	$33{\cdot}3^{25}$	$36{\cdot}6^{62}$	$36{\cdot}0^{19}$	$41{\cdot}2^{19}$	$38{\cdot}0^{10}$	$43{\cdot}6^{7}$	$38{\cdot}0^{2}$	$48{\cdot}7^{4}$	...	...	...	$56{\cdot}1^{8}$	83	120	203	27½
18	$29{\cdot}6^{9}$	$29{\cdot}7^{5}$	$32{\cdot}9^{29}$	$35{\cdot}5^{2}$	$35{\cdot}5^{7}$	$39{\cdot}5^{3}$	$38{\cdot}5^{2}$	$36{\cdot}5^{3}$	$39{\cdot}5^{1}$	...	...	...	...	...	41	13	55	4
19	$30{\cdot}2^{6}$	$36{\cdot}0^{2}$	$36{\cdot}3^{16}$	$36{\cdot}2^{4}$	$38{\cdot}4^{29}$	...	$37{\cdot}6^{7}$	$42{\cdot}0^{2}$	$39{\cdot}4^{4}$	...	$44{\cdot}5^{1}$	...	...	...	66	8	151	10
20	$27{\cdot}9^{12}$	$28{\cdot}7^{26}$	$33{\cdot}8^{3}$	$32{\cdot}7^{7}$	...	$43{\cdot}8^{3}$	...	...	...	$39{\cdot}5^{1}$	...	$47{\cdot}5^{2}$	...	$48{\cdot}5^{2}$	17	44	70	5
21	$28{\cdot}4^{23}$	$30{\cdot}3^{25}$	$31{\cdot}7^{21}$	$33{\cdot}9^{48}$	$36{\cdot}2^{7}$	$37{\cdot}8^{10}$	$35{\cdot}5^{1}$	$42{\cdot}8^{3}$	...	$45{\cdot}0^{4}$	...	$47{\cdot}5^{2}$	...	$50{\cdot}5^{2}$	94	132	226	4
22	$27{\cdot}9^{16}$		$31{\cdot}7^{5}$		...	...	...	...	...	...	...	...	...	...	36		38	3
23	$27{\cdot}1^{3}$		$32{\cdot}5^{1}$		...	...	...	...	...	...	...	...	...	...	99		514	3
24	25.5^{6}		...	...	...	...	...	...	...	...	...	...	...	...	78		478	3
25	...	...	...	...	...	...	...	...	...	...	...	...	...	...	181		879	4
26	$28{\cdot}5^{39}$	$32{\cdot}1^{5}$	$32{\cdot}0^{54}$	$36{\cdot}5^{9}$	$34{\cdot}3^{12}$	$36{\cdot}5^{1}$	...	...	$38{\cdot}5^{1}$	...	...	$42{\cdot}5^{1}$	...	...	125	16	182	2
27	$32{\cdot}0^{4}$	$33{\cdot}1^{14}$	$33{\cdot}0^{2}$	$33{\cdot}2^{3}$	...	...	...	41.5^{1}	...	...	...	...	...	$51{\cdot}0^{2}$	27	35	64	4
28	$30{\cdot}0^{6}$	$32{\cdot}0^{12}$	$34{\cdot}5^{2}$	...	...	...	...	...	...	...	...	...	...	...	39	48	96	2½

‡ Six plaice from another haul (probably B. 265) have evidently been included in this sample.

TABLE I.—Measurements of Plaice with One White Otolith Ring (I. Group).

No.	Period of Year.	Date.	Gear and Reference Number of Hauls.	Locality.	Sex.	Centimetres.																				
						5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	May	1-4/v/05	Shrimp Trawl ..	Off Lowestoft	M. + F.	4	31	32	15	11	3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
2	„	9-12/v/05	O. 301-309; B.* 300	**Leman Ground to the Texel** ..	M.	..	..	**1**	**6**	**8**	**4**	..	**1**	..	..	..	..	..	..	..	..	..	..	..	..	..
					F.	..	..	**1**	**1**	**4**	**3**	**5**	**1**	..	..	..	..	..	..	..	..	..	..	..	..	..
3	July-August ..	7-11/vii/04 ..	Shrimp Trawl ..	Bridlington Bay	M. + F.	..	4	2	10	13	9	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..
5	„ ..	2-7/viii/05 ..	Shrimp Trawl ..	The Wash	M. + F.	..	..	25	43	54	27	19	7	4	3	..	..	..	1	..	..	..	..	..	..	..
6	„ ..	23-24/viii/05 ..	Shrimp Trawl ..	Off Mablethorpe	M. + F.	..	..	1	1	9	11	13	13	9	6	3	..	2	..	..	..	..	..	..	..	..
7	„ ..	16/vii/04	Shrimp Trawl ..	Thames Estuary	M. + F.	..	3	12	14	9	3	2	5	3	..	..	2	1	..	..	..	..	..	..	..	..
9[1]	September ..	5/ix/05	O. 343, 344 ..	Leman Ground	M.	..	..	..	..	..	..	..	..	1	..	2	..	2	1	..	1	..	..	..	..	..
					F.	..	..	..	..	..	..	..	..	..	1	..	..	1	..	1	2	..	..	..	..	..	..
9[2]	„ ..	5/ix/05	O. 345	Leman Ground	M.	..	..	..	..	..	..	..	..	1	..	1	..	..	..	..	..	..	..	..	..	..
					F.	..	..	..	..	..	..	..	1	1	1	..	..	..	..	..	..	..	..	..	..	..	..
9[3]	„ ..	6/ix/05	O. 346	Leman Ground	M.	..	..	..	..	..	..	..	..	..	..	..	1	..	2	..	..	..	..	..	..	..
					F.	..	..	..	..	..	..	..	..	1	2	1	1	1	..	..	..	..	..	..	..	..	..
9[4]	„ ..	6/ix/05	B.* 374, 375 ..	Leman Ground	M.	..	..	..	..	..	..	..	..	..	..	1	1	..	..	..	..	..	..	..	..	..
					F.	..	..	..	..	..	..	..	..	..	1	4	1	..	..	..	..	..	..	..	..	..	..
10[1]	„ ..	6/ix/05	O. 347	North of Brown Ridges	M.	..	..	..	..	..	..	..	..	..	1	..	..	..	1	..	1	..	..	..	..	..
					F.	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	1	..	..	..	..	..
10[2]	„ ..	14/ix/05	O. 352	Brown Bank Ground	M.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..
					F.	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..
10[3]	„ ..	14/ix/05	O. 351	Brown Bank Ground	M.	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..
					F.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..
11[1]	„ ..	14/ix/05	O. 350	Between Brown Bank and Texel Ground.	M.	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..
					F.	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..
11[2]	„ ..	13/ix/05	O. 349	The Texel	M.	..	..	..	..	..	..	..	..	..	..	..	..	2	3	..	..	..	..	..	..	..
					F.	..	..	..	..	..	..	..	..	..	..	..	..	2	1	..	..	..	..	..	..	..	..
11[3]	„ ..	13/ix/05	O. 348	The Texel	M.	..	..	..	..	..	..	..	..	1	6	7	3	2	..	..	..	..	..	..	..	..
					F.	..	..	..	..	..	..	1	..	..	2	5	4	1	..	..	..	..	..	..	..	..
11[4]	„ ..	13/ix/05	B.* 377	The Texel	M.	..	..	..	..	..	..	1	18	21	13	11	2	..	1	..	..	..	..	..	..	..
					F.	..	..	..	..	..	..	2	10	11	17	3	7	..	..	..	..	..	..	..	..	..
12	„ ..	5-14/ix/05	O. 343-352; B.* 374, 375, 377.	**Leman Ground to the Texel** ..	M.	..	..	..	..	..	..	**1**	**18**	**24**	**20**	**22**	**8**	**6**	**9**	**0**	**3**	..	..	..	..	..
					F.	..	..	..	..	..	..	**3**	**11**	**13**	**23**	**13**	**13**	**7**	**3**	**2**	**2**	**1**	..	..	..	..
18	October-March ..	20/i/05	O. 268	Flamborough Off Ground	M.	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	1	..	..	..	..	..
19	„ ..	13-14/i/05	O. 266, 267 ..	Flamborough Head Ground	M.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..
20	„ ..	25/i/05	O. 276	Botney Ground—South Part	F.	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..
21	„ ..	24/x/05	O. 368	Leman Ground	M.	..	..	..	..	..	..	..	..	..	..	..	..	1	3	1	2	1	..	..	..	..
					F.	..	..	..	..	..	..	..	..	..	..	..	..	..	3	2	3	1	1	..	..	..	..
23	„ ..	1/xii/03	B. 95	Off Egmond (10-11 fms.)	M. + F.	..	..	..	..	..	..	..	..	..	..	6	2	2	2	1	1	..	..	..	..	..
24	„ ..	1/xii/03	B. 96	Off Ymuiden (9-10 fms.)	M. + F.	..	..	..	..	..	..	..	..	..	2	5	1	1	..	1	..	..	..	..	..	..

| | | |

TABLE II.—MEASUREMENTS OF PLAICE WITH TWO WHITE OTOLITH RINGS (II. GROUP)—*continued.*

No.	Period of Year.	Date.	Gear and Reference Numbers of Hauls.	Locality.	Sex.	Centimetres. 7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
11[a]	September ..	13/ix/05	B.* 377	The Texel	M. ..	..	..	..	..	..	..	1	7	9	11	10	8	4	1	1	..	1	..	..	..	..	..	..	..	..	..	..	..	..
					F. ..	..	..	..	..	..	..	..	7	7	13	7	8	5	4	5	3	3	2	..	..	..	..	..	..	..	..	..	..	..	..
12	„ ..	5-14/ix/05	O. 343-352; B.* 374, 375, 377.	**Leman Ground to the Texel**	M. ..	..	..	..	..	..	..	**1**	**11**	**18**	**27**	**36**	**64**	**74**	**77**	**46**	**38**	**31**	**16**	**11**	**5**	**1**	..	..	..	..	..	..	..	..	..
					F. ..	..	..	..	..	..	..	..	**9**	**15**	**29**	**27**	**46**	**64**	**59**	**60**	**48**	**42**	**28**	**22**	**10**	**8**	**2**	**3**	..	..	..	..	..	..	..	..
14	October-March ..	11/x/05	O. 358, 359 ..	Dogger Bank—South Part	M. ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..
					F. ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	1	1	..	..	..	..	..	..	..
17	„ ..	19-20/x/05	O 362-366; B. 397	Flamborough Off Ground	M. ..	..	..	..	..	..	..	..	..	..	..	..	1	3	..	..	2	1	..	..	..	..	1	..	..	..	..	..	..	..	..
					F. ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	1	..	..	..	..	..
18	„ ..	20/i/05	O. 263	Flamborough Off Ground	M. ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..
19	„ ..	13-14/i/05	O. 266, 267 ..	Flamborough Head Ground	M. ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1	..	..	..	..	..	..	..	..	..	..	..
20	„ ..	25/i/05	O. 276	Botney Ground—South Part	M. ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	1	..	..	..	..	..	..	..
					F. ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1	..	..	..	..	..	..	..	..	..	..	..
21	„ ..	24/x/05	O. 368	Leman Ground	M. ..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	2	4	7	4	5	1	4	1	2	1	..	..	..	..	..	..
					F. ..	..	..	..	..	..	..	..	..	..	..	..	..	2	1	..	2	3	8	5	4	4	1	..	2	1	..	..	..	..	..	..
22	„ ..	28/xi/03	B 93	Brown Ridges	M. + F.	..	..	..	..	..	..	..	..	..	..	..	..	1	..	2	3	1	3	1	4	..	..	..	..	..	..	..	..	..	..
23	„ ..	1/xii/03	B. 95	Off Egmond (10-11 fms.)	M. + F.	..	..	..	..	..	..	..	..	1	3	14	14	9	11	8	5	8	8	..	..	..	..	..	..	..	..	..	..	..	..
24	„ ..	1/xii/03	B. 96	Off Ymuiden (9-10 fms.)	M. + F,	..	..	..	..	..	..	..	3	5	15	9	6	3	1	4	5	5	5	1	..	..	..	..	..	..	..	..	..	..	..
25	„ ..	29/xi/03	B. 94	Off Ymuiden (8-9 fms.)	M. + F.	..	..	..	..	..	..	6	14	32	26	7	5	4	1	1	3	2	..	..	..	..	..	..	..	..	..	..	..	..	..
26	„ ..	26/xi/04	B. 247, 248 ..	Off Sandette Light Vessel	M. ..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	2	..	3	4	2	3	..	..	..	..	..	..	..	..	..	..
27	„ ..	11/xi/04	B. 343	Teignmouth Bay	M. ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	2	..	6	3	2	2	1	..	1	..	..	..	..
					F. ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1	4	4	3	..	..	..	..	..	..	..	..
28	„ ..	27/ii/04	O. 159	Great West Bay	M. ..	..	..	..	..	..	..	..	..	..	..	..	..	1	2	2	..	1	3	3	3	..	..	1	..	1	..	..	..	..	..
					F. ..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	2	1	2	3	2	4	3	3	3	3	1	1	1	1	..	..	..

TABLE III.—MEASUREMENTS OF PLAICE WITH THREE WHITE OTOLITH RINGS (III. GROUP).

No.	Period of Year.	Date.	Gear and Reference Numbers of Hauls.	Locality.	Sex.	Centimetres. 8	9	10	11	12	13	14	15	16	17*	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
1	May	1-4/v/05 ..	Shrimp Trawl	Off Lowestoft	M. + F.	..	2	4	3	4	7	16	11	10	6	8	..	3	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
2	„	9-12/v/05 ..	O. 301-309 and B.* 300.	**Leman Ground to the Texel.**	M. ..	..	..	..	..	**1**	**2**	**5**	**7**	**8**	**17**	**29**	**35**	**52**	**52**	**45**	**48**	**47**	**44**	**24**	**17**	**7**	**2**	..	..	..	..	..	..	..	..	..	..	..	..
					F. ..	..	..	..	..	..	..	..	**1**	**3**	**14**	**15**	**16**	**23**	**32**	**40**	**46**	**51**	**51**	**47**	**20**	**13**	**5**	**1**	..	**1**	..	..	..	..	..	..	..	..	..	..
3	July-August ..	7-11/vii/04 ..	Shrimp.. ..	Bridlington Bay	M. ..	..	..	..	..	1	..	..	1	2	7	8	3	7	5	2	1	2	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
					F. ..	..	..	..	..	..	..	..	2	2	3	5	7	1	5	..	1	1	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

| | | |

TABLE V.—MEASUREMENTS OF PLAICE WITH FIVE WHITE OTOLITH RINGS (V. GROUP).

No	Period of Year.	Date.	Gear and Reference Numbers of Hauls.	Locality.	Sex.	Centimetres.																														
						20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
2	May	9-12/v/05	O. 301-309; B.* 300	**Leman Ground to the Texel**	M.	..	..	..	..	**2**	**1**	**1**	**3**	**2**	**6**	**8**	**5**	**8**	**9**	**4**	**5**	**1**	**1**	..	..	..	..	..	..	..	..	..	..	..	..	..
					F.	..	..	..	..	..	..	**2**	**1**	..	2	**3**	**3**	**7**	**6**	**3**	**5**	**5**	**4**	**2**	**3**	**1**	**1**	..	..	..	..	..	..	..	..	..
3	July-August	7-11/vii/04	Shrimp Trawl	Bridlington Bay	M.	2	..	..	2	1	..	2	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
					F.	2	1	2	3	3	..	1	1	1	1	1	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..
8	September	17-19/ix/04	B. 213, 214; B. 220	Leman Ground	M.	..	..	..	..	..	..	..	..	..	..	..	1	1	1	1	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
					F.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	3	1	1	..	..	..	..	..	..	..	..	..	..
9[1]	„	5/ix/05	O. 343, 344	Leman Ground	M.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..
9[2]	„	5/ix/05	O. 345	Leman Ground	M.	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
					F.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1	1	..	2	..	..	..	..	..	..	..	..	..
9[3]	„	6/ix/05	O. 346	Leman Ground	F.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1	..	..	..	..	..	..	..	..	..	..	..	..
10[1]	„	6/ix/05	O. 347	North of Brown Ridges	M.	..	..	..	..	..	..	..	..	1	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
					F.	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
10[2]	„	14/ix/05	O. 351	Brown Bank Ground	M.	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..
					F.	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..
12	„	5-14/ix/05	O. 343-347, 351	**Leman Ground to the Texel**	M.	..	..	..	..	..	..	..	..	**1**	..	..	**1**	**1**	**1**	**1**	**1**	**1**	**1**	..	..	..	..	..	..	..	..	..	..	..	..	..
					F.	..	..	..	..	..	..	..	..	..	..	..	**2**	..	..	..	..	..	**2**	**2**	**2**	..	**2**	..	..	..	..	..	..	..	..	..
13	October-March	12/x/05	O. 360, 361	Clay Deep edge of Dogger	M.	..	..	..	..	..	..	..	..	..	..	..	1	1	..	2	1	1	..	..	1	1	..	..	..	..	..	..	..	..	..	..
					F.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1	..	2	1	1	..	1	..	..	1	1	..	1	..	..	..
14	„	11/x/05	O. 358-359	Dogger Bank—South part	M.	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	1	..	..	1	..	1	1	..	..	1	1	1	..	..
					F.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	1	1	..	..	1	1	1	..	..
15	„	22/i/05	O. 270-272	Dogger Bank—South part	M.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
					F.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	1	..	..	..	..
16	„	11/iii/04	O. 160-164, 166	Dogger Bank—South part	M.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..
					F.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1	2	..	2	1	2	3	3	2	2	1	1	1	2	..	..
17	„	19-20/x/05	O. 362-366; B. 397	Flamborough Off Ground	M.	..	..	..	..	..	..	..	..	..	..	1	1	1	1	..	4	5	2	3	..	..	1	..	..	..	..	..	..	..	..	..	..
					F.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1	2	..	..	..	4	4	..	1	1	2	..	1	1	..	..
18	„	20/i/05	O. 268	Flamborough Off Ground	M.	..	..	..	..	..	..	..	..	..	..	..	..	2	1	..	1	..	1	2	..	..	..	..	..	..	..	..	..	..	..	..	..
					F.	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1	..	..	..	..	..	..	..	..	..	..	..	..
19	„	13-14/i/05	O. 266, 267	Flamborough Head Ground	M.	..	..	..	..	..	..	..	..	1	..	..	..	1	..	1	1	6	4	3	1	2	6	2	1	..	..	..	..	..	..	..
20	„	25/i/05	O. 276	Botney Ground—South part	F.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	1	..	..	..	1	..	..	..
21	„	24/x/05	O. 368	Leman Ground	M.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	3	2	..	..	1	..	..	..	..	..	..	..	..	..	..	..
					F.	..	..	..	..	..	..	..	..	..	..	..	..	..	2	..	..	1	1	1	4	1	..	..	..	..	..	..	..	..	..	..
26	„	26/xi/04	B. 247, 248	Off Sandette Light Vessel	M.	..	..	..	..	..	..	..	..	..	..	1	..	3	2	3	..	2	..	..	..	1	..	..	..	..	..	..	..	..	..	..
					F.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..

Table VI.—Measurements of Plaice with Six White Otolith Rings (VI. Group).

No.	Period of Year.	Date.	Gear and Reference Numbers of Hauls.	Locality.	Sex.	Centimetres.																											
						24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
2	May	9-12/v/05	O. 301-309, B.* 300	**Leman Ground to the Texel**	M.	..	..	..	..	..	..	..	**2**	..	..	..	**2**	**1**	..	**1**	..	..	..	..	..	..	..	..	..	..	..	..
					F.	..	..	..	..	..	..	..	..	..	**1**	..	..	..	**1**	**2**	..	..	**2**	..	..	..	..	..	..	..	..	..	..
3	July-August	7-11/vii/04	Shrimp Trawl	Bridlington Bay	M.	..	1	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
					F.	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
4	„	7/vii/05	Shrimp Trawl	Bridlington Bay	M. + F.	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
8	September	17-19/ix/04	B. 213, 214, 220	Leman Ground	M.	..	..	..	..	..	..	..	..	..	1	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
					F.	..	..	..	..	..	..	..	..	..	..	..	1	..	2	1	..	..	1	..	..	1	..	..	..	..	..	..	..
9^1	„	5/ix/05	O. 343, 344	Leman Ground	M.	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
9^2	„	5/ix/05	O. 345	Leman Ground	F.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..
9^3	„	6/ix/05	O. 346	Leman Ground	F.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..
9^4	„	6/ix/05	B. 374, 375	Leman Ground	F.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..
10^1	„	6/ix/05	O. 347	North of Brown Ridges	F.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	1	..	..	..	..	..	..
10^2	„	14/ix/05	O. 352	Brown Bank Ground	M.	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
12	„	5-14/ix/05	O. 343-347, 352; B. 374, 375.	**Leman Ground to the Texel**	M.	..	..	..	..	..	..	..	..	..	**1**	..	**1**	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
					F.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	**2**	**1**	..	**1**	..	**1**	..	..	..	..	..	..	..
13	October-March	12/x/05	O. 360, 361	Clay Deep edge of Dogger	F.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1	..	..	..	2
14	„	11/x/05	O. 358, 359	Dogger Bank—South part	F.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	1	..	..
16	„	11/iii/04	Q. 160-164, 166	Dogger Bank—South part	F.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	4	..	1	..	2	2	4	..	1
17	„	19-20/x/05	O. 362-366; B. 397	Flamborough Off Ground	M.	..	..	..	..	..	..	..	1	..	..	..	1	..	2	2	1	1	2	..	..	..	..	..	..	..	..	..
					F.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	1	1	..	..	..	..	..	1	2	..	..
18	„	20/i/05	O. 268	Flamborough Off Ground	M.	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..
					F.	..	..	..	..	..	..	..	..	..	..	1	..	..	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..
19	„	13-14/i/05	O. 266, 267	Flamborough Head Ground	M.	..	..	..	..	..	..	..	..	..	1	1	..	1	..	..	3	1	..	..	..	..	..	..	..	..	..	..
					F.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	1	..	..	..	..	..	..	..	..

Table VII.—Measurements of Plaice with Seven White Otolith Rings (VII. Group).

No.	Period of Year.	Date.	Gear and Reference Numbers of Hauls.	Locality.	Sex.	Centimetres.																								
						31½	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55
2	May	9-12/v/05	O. 301-309; B.*300	**Leman Ground to the Texel**	M.	..	..	..	..	..	1	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
					F.	..	..	..	..	..	..	2	1	..	..	1	2	1	2	1	3	..	..	..	..	..	..	..	..	..	..
8	September	17-19/ix/04	B. 213, 214, 220	Leman Ground	F.	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..
9[1]	„	5/ix/05	O. 343, 344	Leman Ground	F.	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..
9[2]	„	5/ix/05	O. 345	Leman Ground	M.	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
9[3]	„	6/ix/05	O. 346	Leman Ground	F.	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..
12	„	5-6/ix/05	O. 343-346	**Leman Ground to the Texel**	M.	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
					F.	..	..	..	..	..	..	..	..	..	..	..	1	..	2	..	..	..	..	..	..	..	..	..	..	..
13	October–March	12/x/05	O. 360, 361	Clay Deep Edge of the Dogger	F.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	1	1	..	..
16	„	11/iii/04	O. 160-164, 166	Dogger Bank—South part	F.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	2	..	1	..	..	..	..	..
17	„	19-20/x/05	O. 362-366, B. 397	Flamborough Off Ground	M.	1	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
					F.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	1	1	..	..	..	..	1	..	..
18	„	20/i/05	O. 268	Flamborough Off Ground	M.	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
19	„	13-14/i/05	O. 266, 267	Flamborough Head Ground	M.	..	..	..	..	..	1	..	..	1	..	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..
20	„	25/i/05	O. 276	Botney Ground—South part	F.	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
21	„	24/x/05	O. 368	Leman Ground	F.	..	..	..	..	..	..	..	..	..	1	..	..	..	..	2	..	..	1	..	..	..	..	..	..	..
26	„	26/xi/04	B. 247, 248	Off Sandette Light Vessel	M.	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

Table VIII.—Measurements of Plaice with Eight White Otolith Rings (VIII. Group).

No.	Period of Year.	Date.	Gear and Reference Numbers of Hauls.	Locality.	Sex.	Centimetres.														
						35.	36.	37.	38.	39.	40.	41.	42.	43.	44.	45.	46.	47.	48.	49.	50.
2	May	9-12/v/05	O. 301-309; B.*300	**Leman Ground to the Texel**	M.	..	1	..	..	1	..	..	..	..	..	..	..	..	..	..	..
					F.	..	..	..	..	..	..	..	..	..	..	..	1	..	..	1	1
9[1]-9[4]	September	5-6/ix/05	O. 343-346; B.*374	**Leman Ground to the Texel**	M.	2	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..
					F.	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	1
8	„	17-19/ix/04	B. 213, 214, 220	Leman Ground, &c.	F.	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..
19	October–January	13-14/i/05	O. 266-267	Flamborough Off Ground	M.	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..
20	„	25/i/05	O. 276	Botney Ground—South part	F.	..	..	..	..	..	..	..	..	..	..	1	..	..	..	1	..
21	„	24/x/05	O. 368	Leman Ground	F.	..	..	..	..	..	..	..	..	..	..	..	..	2	..	..	..
26	„	26/xi/05	B. 247, 248	Off Sandette Light Vessel	F.	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..

TABLE IX.—MEASUREMENTS OF PLAICE WITH MORE THAN EIGHT WHITE OTOLITH RINGS.

No.	Period of Year.	Date.	Gear and Reference Numbers of Hauls.	Locality.	Sex.	Centimetres.															
						43.	44.	45.	46.	47.	48.	49.	50.	51.	52.	53.	54.	55.	56.	57.	58.	64.
8	September ..	27-29/ix/04 ..	B. 213, 214, 220 ..	Leman Ground	F. ..	..	..	..	..	1	1	1	..	..	..	..	..	..	..	..	..	..
9	„ ..	5-6/ix/05	O. 343-345.. ..	Leman Ground	F. ..	..	1	1	..	..	2	..	..	..	..	..	..	..	..	..	..	..
16	October-March	11/iii/04	O. 160-164, 166 ..	Dogger Bank - South part ..	F. ..	..	..	..	..	..	..	..	2	..	1	..	1	..	..	1	..	1
17	„ ..	19-20/x/05 ..	O. 362-366; B. 397	Flamborough Off Ground ..	F. ..	..	..	..	..	1	..	..	1	1	..	2	..	..	1	1	1	..
20	„ ..	25/i/05	O. 276	Botney Ground - South part ..	F. ..	1	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..
21	„ ..	24/x/05	O. 368	Leman Ground	F. ..	..	..	..	..	..	1	..	..	..	..	1	..	..	..	..	..	..
27	„ ..	11/xi/04	B. 242, 243.. ..	Teignmouth Bay	F. ..	..	..	..	..	..	..	..	1	1	..	..	..	..	..	..	..	..

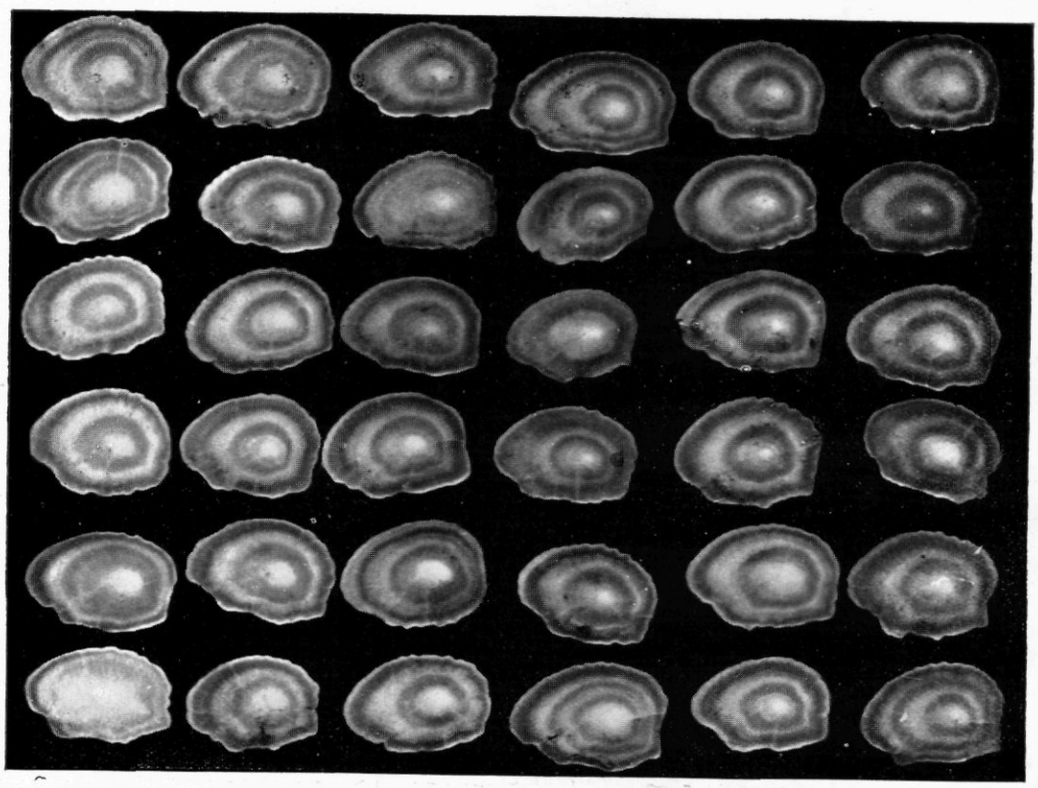


FIG. 1.

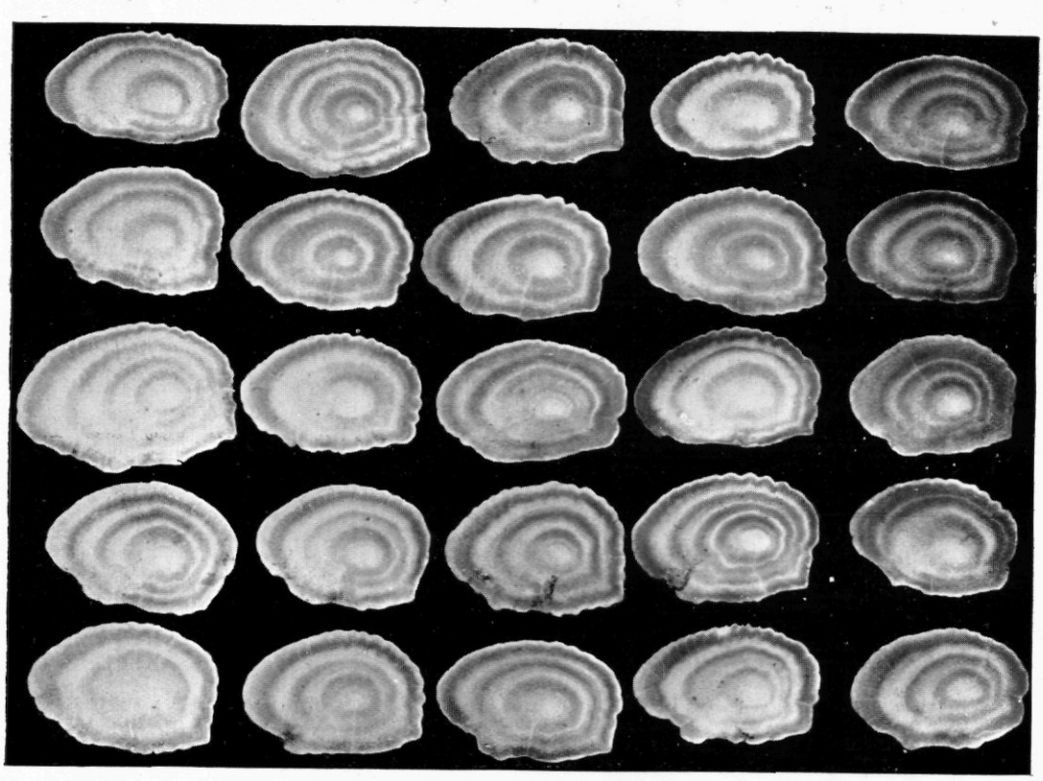
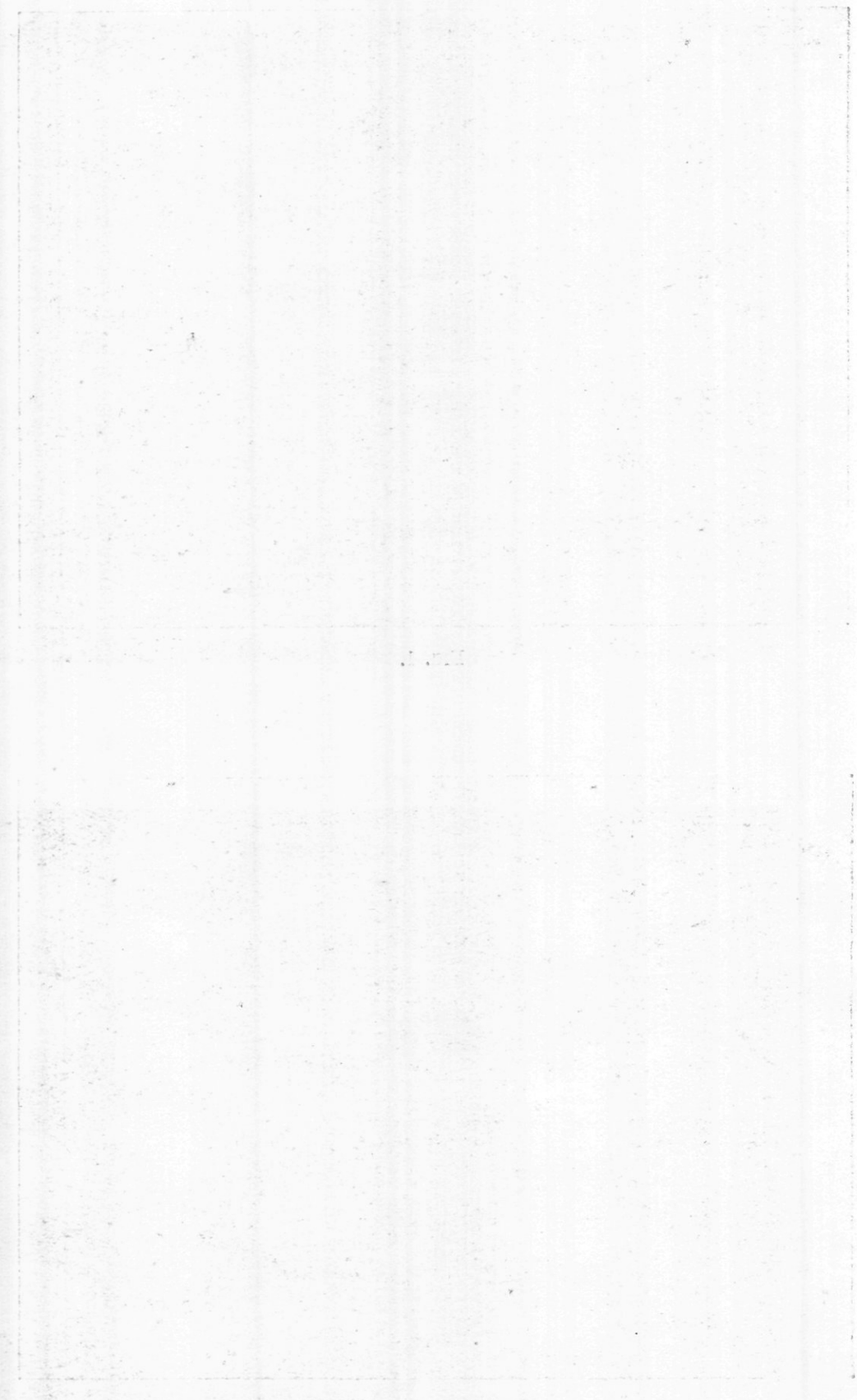


FIG. 2.

Wallace : Age and Growth Rate of Plaice. Photo. by R. A. Todd.



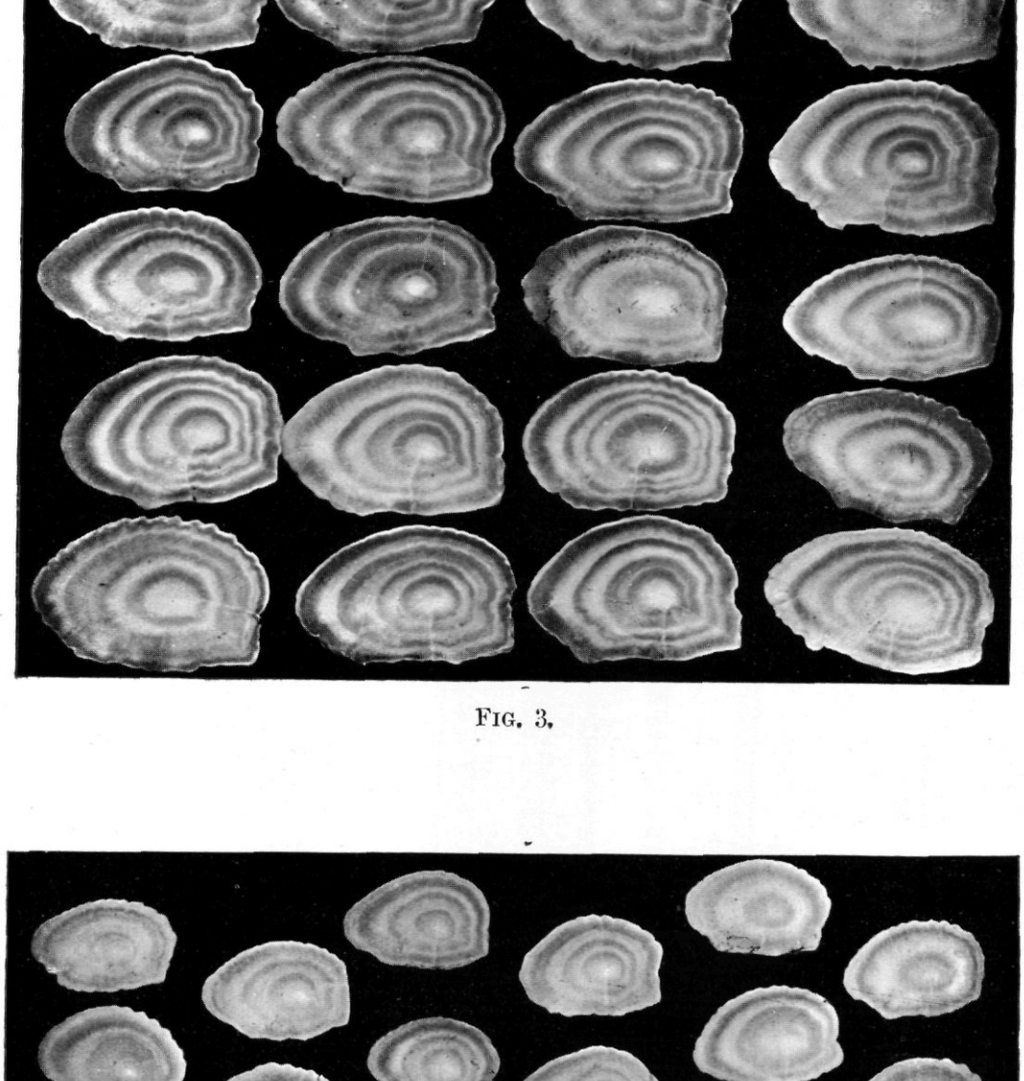


FIG. 3.

FIG. 4.

Wallace : Age and Growth Rate of Plaice. Photo. by R. A. Todd.

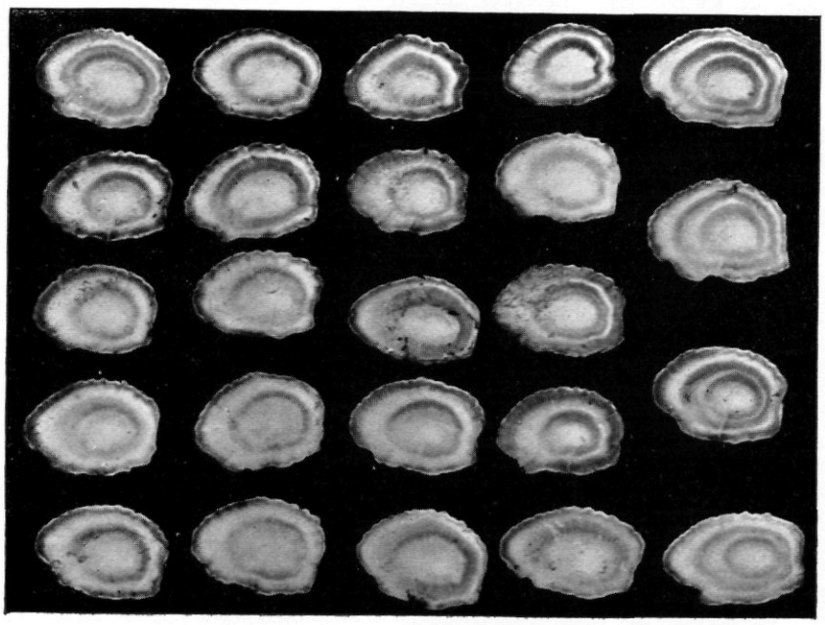


FIG. 5.

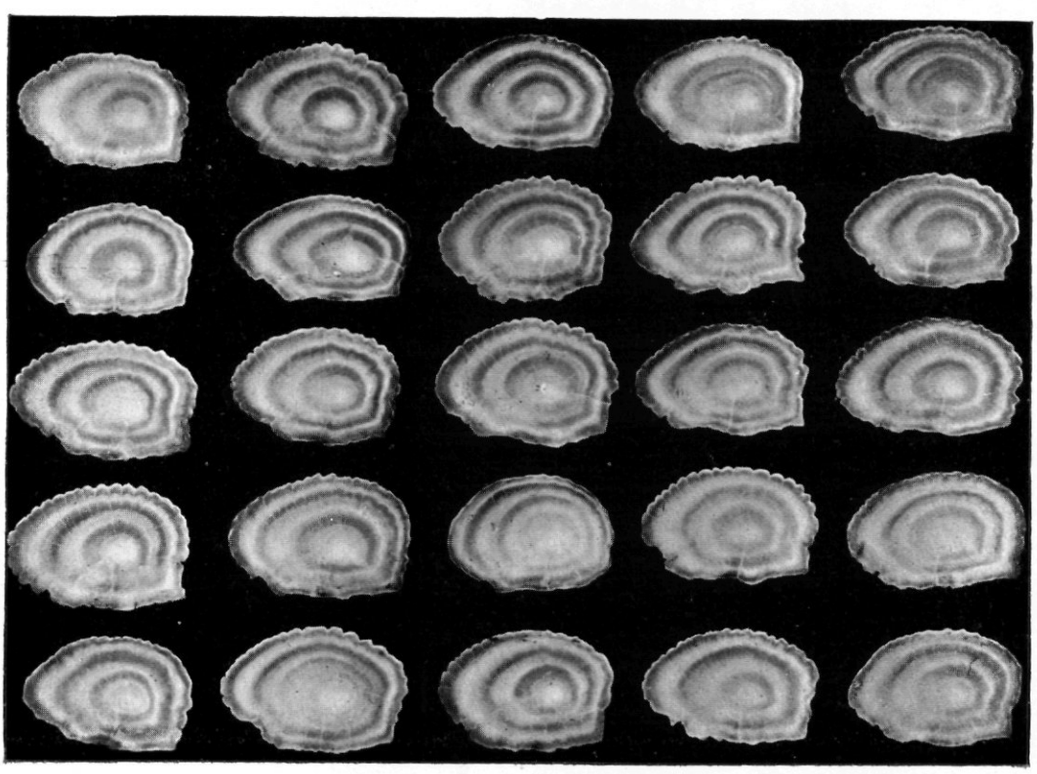


FIG. 6.

 Photo. by R. A. Todd.

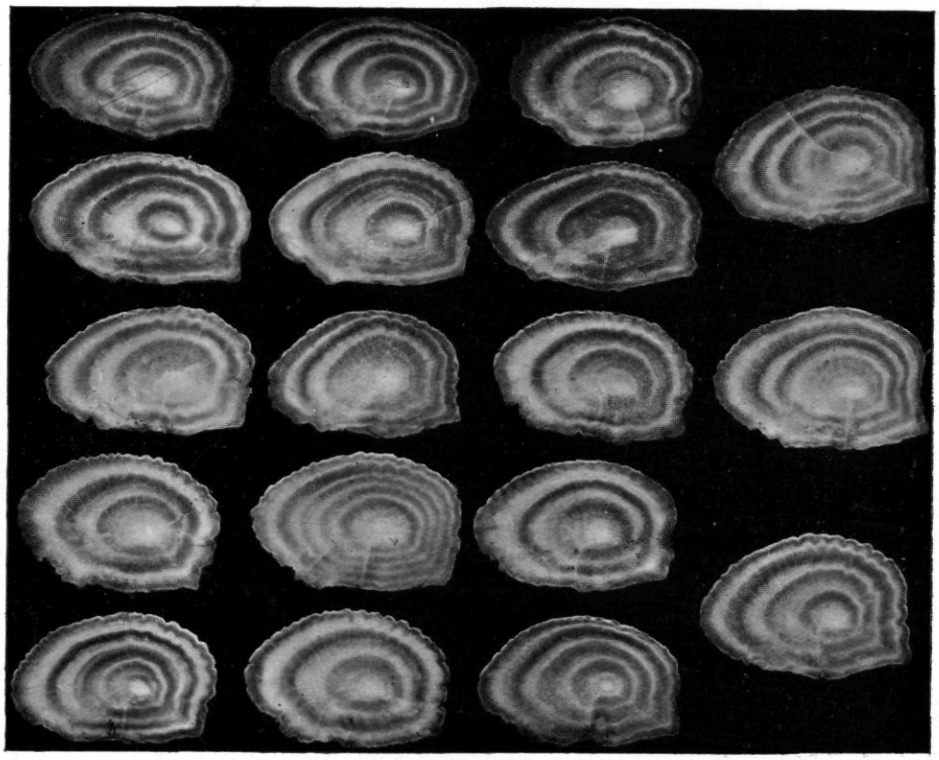


FIG. 7.

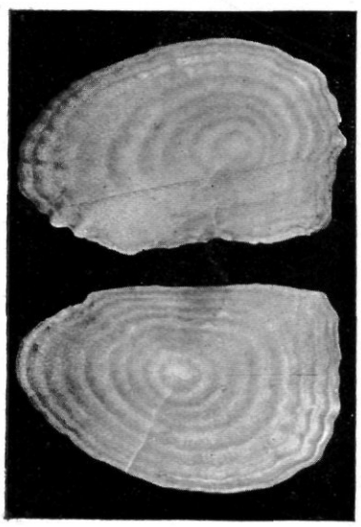


FIG. 8.

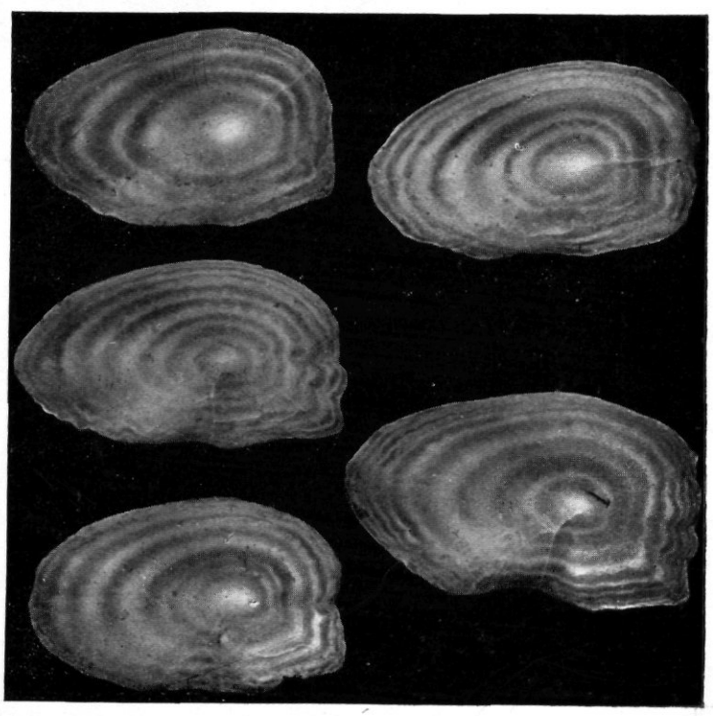
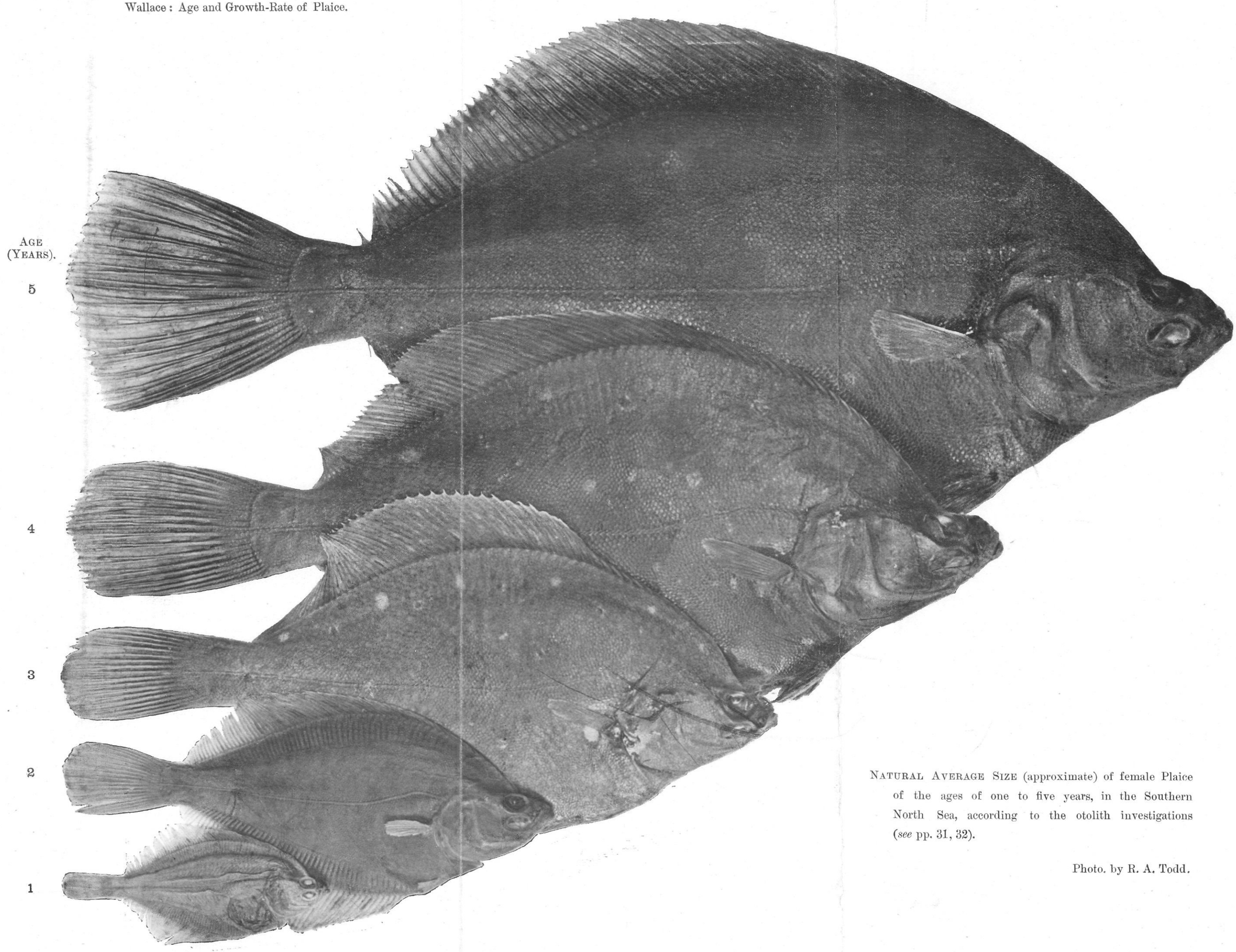


FIG. 9.







NATURAL AVERAGE SIZE (approximate) of female Plaice of the ages of one to five years, in the Southern North Sea, according to the otolith investigations (*see* pp. 31, 32).

Photo. by R. A. Todd.