PROCEEDINGS

AND

TRANSACTIONS

OF THE

LIVERPOOL BIOLOGICAL SOCIETY.

VOL. XXXVI.

SESSION 1921-1922.

LIVERPOOL:
C. TINLING & CO., LTD., PRINTERS, 53, VICTORIA STREET.

1922.

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PROCEEDINGS

OF THE

LIVERPOOL BIOLOGICAL SOCIETY.

OFFICE-BEARERS AND COUNCIL

Ex-Presidents:

1886—1887 Prof. W. MITCHELL BANKS, M.D., F.R.C.S.
1887—1888 J. J. DRYSDALE, M.D.
1888—1889 Prof. W. A. HERDMAN, D.Sc., F.R.S.E.
1889—1890 Prof. W. A. HERDMAN, D.Sc., F.R.S.E.
1890—1891 T. J. MOORE, C.M.Z.S.
1891—1892 T. J. MOORE, C.M.Z.S.
1892—1893 ALFRED O. WALKER, J.P., F.L.S.
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1896—1897 HENRY O. FORBES, LL.D., F.Z.S.
1897—1898 ISAAC C. THOMPSON, F.L.S., F.R.M.S.
1898—1899 Prof. C. S. SHERRINGTON, M.D., F.R.S.
1899—1900 J. WIGLESWORTH, M.D., F.R.C.P.
1900—1901 Prof. PATERSON, M.D., M.R.C.S.
1901—1902 HENRY C. BEASLEY.
1902—1903 R. CATON, M.D., F.R.C.P.
1903—1904 Rev. T. S. LEA, M.A.
1904—1905 ALFRED LEICESTER.
1905—1906 JOSEPH LOMAS, F.G.S.
1906—1907 Prof. W. A. HERDMAN, D.Sc., F.R.S.
1907—1908 W. T. HAYDON, F.L.S.
1908—1909 Prof. B. MOORE, M.A., D.Sc.
1909—1910 R. NEWSTEAD, M.Sc., F.E.S.
1910—1911 Prof. R. NEWSTEAD, M.Sc., F.R.S.
1911—1912 J. H. O'CONNELL, L.R.C.P.
1912—1913 JAMES JOHNSTONE, D.Sc.
1913—1914 C. J. MACALISTER, M.D., F.R.C.P.
1914—1915 Prof. J. W. W. STEPHENS, M.D., D.P.H.
1915—1916 Prof. ERNEST GLYNN, M.A., M.D.
1916—1917 Prof. J. S. MACDONALD, L.R.C.P., F.R.S.
1917—1918 JOSEPH A. CLUBB, D.Sc.
1918—1919 Prof. W. RAMSDEN, M.A., D.M.
1919—1920 HUGH R. RATHBONE, M.A., J.P.
1920—1921 Prof. P. G. H. BOSWELL, O.B.E., D.Sc

SESSION XXXV, 1921-1922.

President:

HERBERT R. RATHBONE, B.A., C.C.

Vice-Presidents:

Prof. P. G. H. BOSWELL, D.Sc.
Prof. W. J. DAKIN, D.Sc.

Hon. Treasurer:

W. J. HALLS.

Hon. Librarian:

MAY ALLEN, B.A.

Hon. Secretary:

W. RIMMER TEARE, A.C.P.

Council:

BISBEE, M.Sc. (Mrs.)
S. T. BURFIELD, B.A.,
J. A. CLUBB, D.Sc.
J. W. CUTMORE.
G. ELLISON.
ALWEN M. EVANS, M.Sc. (Miss)
Prof. Sir W. A. HERDMAN, D.Sc., F.R.S.
Prof. J. JOHNSTONE, D.Sc.
W. S. LAVEROCK, M.A., B.Sc.
Prof. R. NEWSTEAD, M.Sc., F.R.S.
HUGH R. RATHBONE, M.A., J.P.
T. SOUTHWELL, M.Sc.

Representative of Students' Section:
Miss E. ANGEL, B.Sc.

REPORT of the COUNCIL.

During the Session 1921-22 there have been seven ordinary evening meetings. The annual excursion was held on June 10th, when a number of members and students, under the leadership of Prof. Dakin, paid a visit to Hilbre Island, and a very enjoyable afternoon was spent.

The communications made to the Society at the ordinary meetings have been representative of many branches of Biology, and the various exhibitions and demonstrations thereon have been of the utmost interest and value.

The Council has appointed a Sub-Committee to consider the question of evening in place of afternoon meetings, and other possible means of extending the Society's work. The Sub-Committee will report to the annual meeting.

The Library continues to make satisfactory progress, and additional important exchanges have been arranged.

The Treasurer's statement and balance sheet are appended.

The members at present on the roll are as follows :—

Ordinary members	51
Associate members	11
Student members, including Students' Section, about	30
Total	92

SUMMARY of PROCEEDINGS at the MEETINGS.

The first meeting of the thirty-sixth session was held at the University, on Friday, October 14th, 1921.

1. The Report of the Council on the Session 1920-1921 (see "Proceedings," Vol. XXXV, p. viii) was submitted and adopted.
2. The Treasurer's Balance Sheet for the Session 1920-1921 (see "Proceedings," Vol. XXXV, p. xvi) was submitted and approved.
3. The following Office-bearers and Council for the ensuing Session were elected :—Vice-Presidents, Prof. P. G. H. Boswell, O.B.E., D.Sc., Prof. W. J. Dakin, D.Sc., F.L.S. ; Hon. Treasurer, W. J. Halls ; Hon. Librarian, May Allen, B.A. ; Hon. Secretary, W. Rimmer Teare, A.C.P. ; Council, Bisbee, M.Sc. (Mrs.), S. T. Burfield, B.A., M.Sc., J. A. Clubb, D.Sc., J. W. Cutmore, G. Ellison, Alwen M. Evans, M.Sc. (Miss), Prof. Sir Wm. Herdman, F.R.S., D.Sc., Prof. J. Johnstone, D.Sc., W. S. Laverock, M.A., B.Sc., Prof. R. Newstead, M.Sc., F.R.S., Hugh R. Rathbone, M.A., J.P., T. Southwell, M.Sc.
4. Herbert R. Rathbone, B.A., delivered the Presidential Address on "Functions of a Public Museum" (see "Transactions," p. 3). A vote of thanks proposed by Prof. Dakin, seconded by Mr. H. A. Cole, C.C., was passed.

The second meeting of the thirty-sixth session was held at the University, on Friday, November 11th, 1921, the President in the Chair.

1. Mr. Cutmore exhibited a cream-coloured rat, and dealt with the question of unusual colouration.
2. Prof. Johnstone submitted the report which he had prepared on "The Marine Biological Station at Port Erin" (See "Transactions," p. 31) and gave an address on "Marine Biological Crises"—dealing with the food supplies of young fish.

The third meeting of the thirty-sixth session was held at the University, on Friday, December 9th, 1921. Prof. Dakin in the Chair.

1. A paper was read by Sir William Herdman, F.R.S., on "Charles Kingsley," touching especially on his association with Chester naturalists.

The fourth meeting of the thirty-sixth session was held at the University, on Friday, January 20th, 1922. The President in the Chair.

1. Prof. Dakin, D.Sc. read a paper on "Rhythm in Nature," showing how recurrence of event or condition occurs in multitudes of cases and is responsible for many phenomena in the natural world.

The fifth meeting of the thirty-sixth session was held at the University, on Friday, February 10th, 1922. The President in the Chair.

1. Prof. Johnstone, D.Sc., presented the Report for 1921 on the Lancashire Sea-Fisheries Laboratory at the University and the Hatchery at Piel (see "Transactions," p. 65).
2. Prof. Johnstone then discussed the frequency of high tides and the effect of this periodicity on fish life in the ocean.

The sixth meeting of the thirty-sixth session was held at the University, on Friday, March 10th, 1922. Prof. Dakin in the Chair.

1. Mrs. Bisbee, M.Sc., read a paper on "Sex Determination—A Suggestion," after dealing with the theory of chromosomes as factors in determining sex, the lecturer proceeded to suggest as a possible solution a metabolic rhythm—an alternation between two types of metabolism giving maleness and femaleness respectively (see "Transactions," p. 5).

The seventh meeting of the thirty-sixth session was held at the University, on Friday, May 26th, 1922. The President in the Chair.

1. Miss Herdman read—
   (*a*) A paper on "Fertilisation and Migration of Echinocardium," by Miss Margaret Lillie ;
   (*b*) Her own paper on "Notes on Dinoflagellates and other Organisms causing Discolouration of the Sand at Port Erin. II (1921)" (see "Transactions," p. 15).
2. Prof. Dakin explained the structure and use of the epidiascope.

The eighth meeting of the thirty-sixth session was held on Saturday, June 10th. A considerable party of members and students, with Prof. Dakin as leader, visited Hilbre Island and spent a profitable afternoon. The most interesting finds were various worms, but a remarkable feature was the absence of the masses of *Sabellaria alveolata* that formerly covered the rocks by the life-boat slipway. The place is now occupied by large quantities of mussels.

At an adjourned meeting held in the University, it was unanimously resolved, on the motion of Sir Wm. Herdman, that Prof. W. J. Dakin, D.Sc., F.L.S., be elected President for the ensuing session, and also act as delegate of the Society to the British Association Meeting at Hull.

LIST of MEMBERS of the LIVERPOOL BIOLOGICAL SOCIETY.

SESSION 1921-1922.

A. Ordinary Members.

(Life Members are marked with an asterisk.)

ELECTED.

1908 Abram, Prof. J. Hill, M.D., F.R.C.P., 74, Rodney Street, Liverpool.

1919 Adami, Dr. J. G., F.R.S., Vice-Chancellor, The University, Liverpool.

1909 *Allen, Miss May, B.A., Hon. Librarian, University, Liverpool.

1918 Baldwin, Mrs., M.Sc., Zoology Dept., University, Liverpool.

1913 Beattie, Prof. J. M., M.A., M.D., The University, Liverpool.

1903 Booth, Chas., Cunard Building, Liverpool.

1919 Boswell, Prof. P. G. H., O.B.E., D.Sc., Vice-President, The University, Liverpool.

1912 Burfield, S. T., B.A., M.Sc., Zoology Department, University, Liverpool.

1886 Caton, R., M.D., F.R.C.P., 7, Sunnyside, Prince's Park, Liverpool.

1886 Clubb, J. A., D.Sc., Free Public Museums, Liverpool.

1920 Dakin, Prof. W. J., D.Sc., F.L.S., Vice-President, The University, Liverpool.

1917 Duvall, Miss H. M., M.Sc., Zoology Department, University, Liverpool.

1910 Ellison, George, 52, Serpentine Road, Wallasey.

1921 Fletcher, Miss Isabel, 42, Ullet Road, Liverpool.

1902 Glynn, Prof. Ernest, M.D., F.R.C.P., 67, Rodney Street.

1886 Halls, W. J., Hon. Treasurer, 2, Townfield Road, West Kirby.

1896 Haydon, W. T., F.L.S., 55, Grey Road, Walton.

1886 Herdman, Prof. Sir William, D.Sc., F.R.S., University, Liverpool.

1893 Herdman, Lady, Croxteth Lodge, Ullet Road, Liverpool.
1921 Herdman, Miss E. C., Croxteth Lodge, Ullet Road, Liverpool.
1912 Hobhouse, J. R., 19, Ullet Road, Liverpool.
1902 Holt, Dr. A., Rocklands, Thornton Hough, Cheshire.
1903 Holt, Richard D., India Buildings, Liverpool.
1920 Johnstone, Angus, 63, Church Road, St. Michael's, Liverpool.
1898 Johnstone, Prof. James, D.Sc., University, Liverpool.
1918 Jones, Philip, Brantwood, St. Domingo Grove, Liverpool.
1896 Laverock, W. S., M.A., B.Sc., Free Public Museums, Liverpool.
1915 Macdonald, Prof. J. S., B.A., F.R.S., The University, Liverpool.
1922 McDonald, Dr. Archie W., L.R.C.P., L.R.C.S. (Edin.), Glencoe, Huyton.
1917 Milton, J. H., F.G.S., Merchant Taylors' School, Great Crosby.
1904 Newstead, Prof. R., M.Sc., F.R.S., University, Liverpool.
1913 Pallis, Mark, Tätoi, Aigburth Drive, Liverpool.
1915 Prof. W. Ramsden, M.A., D.M., University, Liverpool.
1921 Rathbone, Herbert R., C.C., PRESIDENT, 35, Ullet Road, Liverpool.
1903 Rathbone, Hugh R., M.A., J.P., VICE-PRESIDENT, Greenbank, Liverpool.
1890 *Rathbone, Miss May, High House, Leaves Green, Keston, Kent.
1894 Scott, Andrew, A.L.S., Piel, Barrow-in-Furness.
1908 Share-Jones, J., D.Sc., F.R.C.V.S., University, Liverpool.
1886 Smith, Andrew T., Solna, Croxteth Drive, Liverpool.
1920 Southwell, T., M.Sc., School of Tropical Medicine, University, Liverpool.
1903 Stapledon, W. C., Annery, Caldy, West Kirby.
1913 Stephens, Prof. J. W. W., M.D., University, Liverpool.
1915 Teare, W. Rimmer, A.C.P., HON. SECRETARY, 12, Bentley Road, Birkenhead.

1903 Thomas, Dr. Thelwall, 84, Rodney Street, Liverpool.

1905 Thompson, Edwin, Woodlands, 13, Fulwood Park, Liverpool.

1921 Thompson, Prof. McLean, D.Sc., The University, Liverpool.

1889 Thornely, Miss L. R., Hawkshead, Ambleside.

1888 Toll, J. M., 49, Newsham Drive, Liverpool.

1920 Walker, Prof. C., D.Sc., M.R.C.S., The University, Liverpool.

1918 Whitley, Edward, Bio-Chemical Laboratory, University.

1920 Yorke, Prof. Warrington, M.D., School of Tropical Medicine, University, Liverpool.

B. Associate Members.

1916 Atkin, Miss D., High School for Girls, Aigburth Vale, Liverpool.

1915 Bisbee, Mrs., M.Sc., Zoology Department, The University, Liverpool.

1914 Cutmore, J. W., Free Public Museums, Liverpool.

1918 Evans, Miss Alwen M., M.Sc., School of Tropical Medicine, University, Liverpool.

1916 Gleave, Miss E. L., M.Sc., Oulton Secondary School, Clarence Street, Liverpool.

1905 Harrison, Oulton, 3, Montpellier Crescent, New Brighton.

1920 Kewley, Miss Helen C., 10, Park Road N., Birkenhead.

1919 Mayne, Miss C., B.Sc., 17, Laburnum Road, Fairfield.

1915 Stafford, Miss C. M. P., B.Sc., 312, Hawthorne Road, Bootle.

1917 Swift, Miss F., B.Sc., Queen Mary High School, Anfield.

1912 Wilson, Mrs. Gordon, High Schools for Girls, Aigburth Vale, Liverpool.

C. University Students' Section.

President: Miss E. Angel, B.Sc.

Secretary: Miss B. M. Illingworth, B.Sc.

(Contains about 30 members.)

D. Honorary Members.

S.A.S., Albert I., Prince de Monaco, 10, Avenue du Trocadéro, Paris.

Bornet, Dr. Edouard, Quai de la Tournelle 27, Paris.

Fritsch, Prof. Anton, Museum, Prague, Bohemia.

Hanitsch, R., Ph.D., Oxford.

THE LIVERPOOL BIOLOGICAL SOCIETY.

Cr. IN ACCOUNT WITH W. J. HALLS, HON. TREASURER. **Dr.**

1921, Oct. 1st to Sept. 30th, 1922.	£	s.	d.
By Balance from last Session	33	12	6
,, Subscriptions	23	2	0
,, ,, (Arrears)	4	4	0
,, ,, Associates Members	1	11	6
,, ,, ,, ,, (Arrears)	0	10	6
,, ,, Paid into Bank	3	3	0
,, Sale of Volumes	44	16	11
,, Interest on Investment	5	13	6
,, ,, from Bank	1	1	10
	£117	15	9

1921, Oct. 1st to Sept. 30th, 1922.	£	s.	d.
To Messrs. Woolman (Stationery)	1	1	9
,, Library Insurance	2	4	0
,, Associated Soirée Donation	1	0	0
,, Teas	3	17	1
,, Postages of Volumes	4	3	7
,, Messrs. Tinling & Co.	95	10	10
,, Hon. Secretary's Expenses	1	18	4
,, H n. Treasurer's Expenses	0	2	6
,, Cheque Book	0	1	8
,, Balance in Bank	6	19	2
,, Cash in hand	0	16	10
	£117	15	9

INVESTMENT—

£113 11s. 1d. War Loan 5% 1927-49 Registered

Audited and found correct,

JAS. JOHNSTONE.

LIVERPOOL, *October* 11*th*, 1922.

TRANSACTIONS

OF THE

LIVERPOOL BIOLOGICAL SOCIETY

PRESIDENTIAL ADDRESS.

By HERBERT R. RATHBONE, J.P., C.C.

Chairman of the Museums Committee of the City of Liverpool.

(Delivered October 14th, 1922)

[Abstract]

The President, in his Inaugural Address, dealt with the functions of a Public Museum, especially in relation to the education of the community served by the museum. Starting with quotations showing the views of Dr. J. E. Gray and Sir William Flower, of the British Museum, he traced the evolution of the "new museum idea," laying stress upon "the diffusion of instruction among the mass of the people," and expressing the hope that means might be found by which "this and other scientific societies in Liverpool could co-operate in developing the work of the Museums, and the Museums Committee could make the museums of greater use to the members of the societies." He quoted, with special approval, Sir William Flower's statement that it is the duty of the Curator in a local museum "to develop the side of the museum which is educational and attractive to the general visitor, and to all who wish to obtain that knowledge which is the ambition of many cultivated persons to acquire without becoming specialists or experts."

After referring to the wide range of subject-matter covered by the collections in the Liverpool Municipal Museums and the inadequacy in number of the assistant staff provided, he said: "We must consider if there is not some way in which the work done by the staff can be supplemented and assisted by others not directly connected with the museum, who have the necessary knowledge, enthusiasm and belief in the educational function of the museum."

The President referred to the help in special sections of the museum that had been given by some of the Professors at the University in the past. "All this valuable help has been gratefully accepted by the Curator and the Committee."

He then proceeded to give an interesting account, illustrated by a series of beautiful lantern slides, of some of the educational activities of other great museums, and especially of the American Museum of Natural History in New York. In describing some examples from the large number of "Habitat Groups" in that museum—cases that display in a wonderfully realistic manner various animals and different types of savage and semi-civilized races amid their natural surroundings—he referred to the beautiful series of "Bird-habitat groups" in the Liverpool museum, which are justly regarded as admirable examples of the taxidermist's art. Another case in which the Liverpool and New York museums have developed a like educational effort is in providing nature-study portable cases which circulate to the elementary schools of the City. "Moreover, in our local museum we have a large number of lantern slides of natural history subjects which the staff are willing to lend either to schools or societies, but, so far, this branch of work has not been systematized, and I venture to think it is one to which more attention should be given in the future."

Much can be done to interest and instruct the public by supplying special guide-books and leaflets, and in the preparation of these it might be possible for the members of learned societies such as this to assist the Museum Committee. "Mr. P. M. C. Kermode, of the Isle of Man, has already prepared a popular pamphlet explaining the remarkable exhibit of early Manx carved stones. Why should not some of our enthusiastic specialists prepare leaflets drawing attention to and explaining the principal historic exhibits in the 'Liverpool Room,' the collection of Arms and Armour, the Palaeolithic and Neolithic Implements, the African Ethnology collection, etc."

"The provision of Guide-Demonstrators offers another field for valuable co-operation. On Saturdays, and on Sundays especially, the attendance at our Museum is very large, and with little or no preliminary arrangement an interested audience would collect to listen to any well-informed person who might be willing to talk to them at the cases, pointing out and explaining the principal exhibits. . . . I cannot help thinking that some of those in our local societies who are interested in Archaeology and other branches of science might be willing to do voluntarily some pioneer work of this kind which might lead to important developments in the future."

SEX DETERMINATION—A SUGGESTION.

By Ruth C. Bamber, M.Sc. (Mrs. Bisbee).
Zoology Department, University of Liverpool.

(Read March 10th, 1922.)

No hypothesis so far put forward to account for sex-determination is entirely satisfactory. The most widely accepted view is that the X chromosome is the sex determiner, and this is very strongly supported by cytological evidence. There are, however, several serious difficulties to be faced. In the first place many cases are known where the sex ratio of the offspring is upset by that parent which, according to cytological evidence, is not responsible for the determination of sex at all. For example, in man, where haemophilia is sex-linked in the male, transmitting women have on an average more sons than daughters; and in cats where the yellow colour is sex-linked in the male, the transmitting females have more male than female progeny.[1] Then, in cattle[2] there is considerable evidence that the length of time allowed to elapse between ovulation and fertilization affects the sex ratio, early fertilization giving a preponderance of females. It seems as though in these cases the female parent in some way influences the sex of the offspring in spite of the fact that it is the male which possesses the odd X chromosome. Another and greater difficulty arises in connection with the production of unisexual families under circumstances which do not allow of an explanation on the hypothesis of selective maturation or selective death rate. Riddle,[3] by crossing different genera of pigeons and causing them to "over-work at egg production" obtained nearly all males in Spring, and nearly all females in the Autumn of the same year. Harrison[4] and Goldschmidt[5] by crossing different races of moths have separately obtained intersexes, and in extreme cases, unisexual families. Here selective maturation seems to be out of the question. Also, in a paper now in the press, Doncaster[6] shows that in a certain strain of *Abraxas* which has an odd number of chromosomes in the female, and which shows a tendency to produce all-female families, those unisexual families are not due to a selective death rate, and the most careful cytological work has shown that there is definitely not selective maturation. In all these cases it seems certain that zygotes with the chromosome content usually associated with one sex have developed into adults of the opposite sex. Such results have forced many workers to conclude that the X chromosome is, to say the least, not wholly responsible for the determination of the sex of the embryo.

Goldschmidt,[7] still looking upon the X chromosome as the carrier of a sex factor, has put forward a theory which brings into line a remarkable number of facts. He suggests that the sex factor has different strengths in different individuals particularly in different varieties and species, and so does not always give the expected result at fertilization. In order to work out this hypothesis it is necessary to suppose that in part of the animal world, *e.g.*, Mammalia and Diptera, the X chromosome carries a factor for femaleness, whereas in Aves and Lepidoptera it carries the factor for maleness ; and that in the former groups the factor for maleness is carried by the Y chromosome or possibly by the cytoplasm, while in the latter groups it is the factor for femaleness which has this location. This, of course, splits the animal world into two parts in an arbitrary way. It is true that the split does exist cytologically, the Mammalia and Diptera having the odd X chromosome in the male, whereas in Aves and Lepidoptera it is found in the female : but to suppose that in the former it carries femaleness and in the latter maleness, seems to make the gulf even wider, and suggests a state of affairs not easy to reconcile with any idea of evolution.

Not only are there difficulties in the way of accepting the X chromosome unreservedly as the sex determiner, but many facts seem to point to the general metabolism as the basis of sex determination. In Rotifers[8], for example, recent work has shown that a change of sex in the offspring can be brought about by controlling the food supply and oxygen supply of the parents. In Daphnids[9], food and temperature have been shown to affect the sex of the offspring : the same is true also in canaries.[10] Then in pigeons, Riddle[11] found that normally a male-producing egg has a smaller yolk and a higher water content than a female-producing egg, and that under conditions of overwork the eggs produced have successively larger yolks, while at the same time the percentage of females is steadily increasing. Hertwig[12] has shown that by delaying fertilization of the eggs in Frogs, a large percentage of males results, and it is probable that this is correlated with the absorption of water by the unfertilized eggs. King[13] has shown that by desiccating frogs' eggs a majority of females is obtained. In all these cases a changed metabolism in the parents or their germ cells influences the sex of the offspring ; but of course, in all, there is the possibility that the changed metabolism brings about selective maturation and so only affects the sex of the offspring through its chromosome content. Riddle's evidence against this is, however, very strong. Again, Geoffrey Smith's[14] work on parasitism in crabs points even more clearly to the type of metabolism as the basis of sex-determination ; a change in sex being effected during the lifetime of certain individuals, seemingly due to the change in their metabolism brought about by the parasites which infect them. Baltzer[15] has shown, that in *Bonellia*, larvæ which develop attached to the proboscis of the female develop quickly into males, whereas those which remain in the mud or sand grow slowly, and eventually become females. This also seems a clear case where the general metabolism determines the sex, and not any given chromosome content.

Such facts have led many workers to look to the metabolism and not to the chromosomes as the basis of sex determination; but the cytological facts brought to light during the last few years have been so overwhelmingly in favour of the X chromosome theory, that suggestions which centre round the metabolism alone, have not carried any real conviction.

It seems possible, however, that sex may be a result of the type of metabolism and still be in harmony with the observed distribution of chromosomes.

I wish to suggest tentatively, that sex may be the expression of a fundamental rhythmical reaction of protoplasm itself, giving an alternation between two types of metabolism characteristic of maleness and femaleness respectively.* A great number of natural phenomena have been found to be oscillatory,[20] particularly bio-chemical reactions, and I suggest that sex may be due to another of the many rhythms found in living matter, and that, left to run its course apart from any mixing at fertilization, protoplasm would tend to give an alternation between maleness and femaleness. When mixing does occur, as at fertilization, the " strongest " germ-cell would be expected to determine the type of metabolism of the zygote, the " strong " egg giving a male, the " strong " sperm a female.

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* This idea, of course, involves the supposition that the metabolism of the two sexes is fundamentally different, and this, as a fact universally applicable, is by no means proven ; unless the production of anabolic germ cells by the female and katabolic germ cells by the male be accepted as proof. There are, however, other indications that in the higher animals at least, the sexes are characterised by different types of metabolism. In man,[16] for example, the blood has a higher specific gravity, more red blood corpuscles, and a higher percentage of haemoglobin than in women : men retain much more calcium than women : the basal metabolism[17] of men is about 6 per cent. higher than that of women. Amongst insects, too, some[18] caterpillars have green blood in the females, and yellow or colourless blood in the males. All these differences may, of course, be secondary, but in the hermit crab, Geoffrey Smith[19] has shown that a change in metabolism, caused by the parasite *Sacculina*, brings about a change in the sex of the individual even to the extent of a change from sperm production to egg production. This strongly suggests that it is the type of metabolism which determines the sex, and not the sex which determines the type of metabolism.

Any egg then, which has completed its female phase, if able to proceed with development without external interference such as fertilization, natural or artificial, should give rise to a male. It is significant that wherever eggs undergo a perfectly normal maturation and are then capable of development with or without fertilization, as in Hymenoptera and Rotifera, those eggs which develop without fertilization do always give rise to males. The fact that these eggs have matured normally is emphasised, because, in the light of recent research, it seems possible that the readjustment between nucleus and cytoplasm during the maturation of germ-cells may not be necessarily a preparation for fertilization, but may really mark the completion of successive phases of metabolic activity. A foreshadowing of this process has been demonstrated recently by Woodruff[21] and Erdmann in *Paramoecium*, and has been shown to be a phenomenon which occurs periodically quite apart from conjugation. A well-marked rhythm occurs during the life history of *Paramoecium*, a period of maximum activity in division alternating with a period of minimum activity. When the minimum is reached a readjustment takes place between cytoplasm and nucleus; division then proceeds with increasing rapidity to a maximum, then gradually slows down to a minimum when readjustment again takes place: and this without any conjugation whatever. In *Paramoecium* we have no evidence that the phases differ from each other in any way; such evidence has never to my knowledge been sought: but in Hymenoptera and Rotifera it is an established fact that after the *complete* nuclear readjustment which ends the female phase of the egg, the following period of activity invariably gives a male. In most other groups where parthenogenesis occurs, the eggs do not mature normally, and they then give rise to females. The abnormal maturation is usually looked upon as a device which, by causing the retention of the chromosome content usually associated with the female, determines the development of females in the next generation. It seems as reasonable to look upon the abnormal maturation as an abortive attempt at normal maturation, its abnormality simply indicating that the egg has not arrived at that stage when complete nuclear adjustment can take place; has not, in fact, come to the end of its own particular type of metabolic activity. In that case the same phase would be expected to continue and a female to develop in the next generation, as is the case.

If the tendency for male and female types of metabolism to alternate really exists in protoplasm, and at fertilization the "stronger" germ cell has the casting vote as regards the type of metabolism of the zygote, then it is conceivable that the observed chromosome distribution may run parallel with sex without the chromosomes carrying a "sex factor" at all. It is, of course, highly improbable that any living part of a cell is without its influence on the general metabolism of the cell—the total cell chemistry—and undoubtedly, the chromosomes play their part. Clearly, too, they are very closely connected with the inheritance of Mendelian characters, but whatever may be their total functions, they need not carry "factors" for either maleness or femaleness, and still could have their observed distribution in the two sexes. It is an established fact that sometimes at cell division a chromosome is lost from one of the daughter cells. Probably in some cases this occurs gradually; certainly in other cases it occurs suddenly. Seiler[22] and Doncaster[23] have separately reported the loss of chromatin on the equatorial plate during division of germ cells in Lepidoptera, and Doncaster suggests as a possibility, that in *Abraxas*, the loss of a large amount of chromatin from the X chromosome may cause it to become functionless, and so account for the production of unisexual families. A clear case of sudden elimination is provided by *Rhabdonema nigrovenosum*.[24] Here, during the maturation of the spermatozoa of the hermaphrodite generation, one chromosome lags behind at reduction division and fails to reach the pole of the spindle, remaining on or near the plane of division. In this way two kinds of spermatozoa are formed, one with and one without the X chromosome. This is believed to be a normal and regular occurrence. In other cases however, a chromosome is lost quite irregularly, as in non-disjunction described by Bridges[25] in *Drosophila*. Here, during the reduction division, two chromosomes sometimes fail to separate, both going to one daughter cell. This apparently happens most often in the case of the X chromosomes, but may occur with any pair of autosomes. If then, at any time during the evolution of a species, one member of any pair of chromosomes be lost during division of the germ cells, at meiosis the chromosome without a partner will pass to one daughter cell only. Now, whether the movement of the chromosomes at anaphase be due to activity at the poles of the spindle, or in the chromosomes themselves, or in both, it seems probable that the daughter cell which obtains the odd chromosome is in way some " stronger " than its sister cell. If then there is an odd number of chromosomes in the male germ mother cells the " strongest " sperms will probably be the ones which have obtained the full complement of chromosomes, *i.e.*, the ones with the X chromosome: also these " strongest " sperms will be more likely than their weaker fellows to have the power to determine the type of metabolism of the zygote at fertilization, and will give female embryos, as is the case in the Mammalia and Diptera. If, on the other hand, the female has the odd number, the " stronger " eggs will be those which have obtained the odd chromosome, and these will also have a greater chance of determining the type of metabolism at fertilization than their weaker sisters, and so will give males, as is the case in Aves and Lepidoptera.

This idea, of course, involves the supposition that the

X chromosome is simply an odd chromosome : that if one member of *any* pair of chromosomes be lost, or degenerate, during the history of a species, the remaining one would be the X chromosome, with all its known relations to sex : that, in fact, the X chromosome has no more vital connection with sex than any odd chromosome might have. The X chromosomes are not sharply distinguished from the autosomes by size or shape : they are often larger than the rest, but by no means always so. Usually they are most clearly distinguishable during cell division, and then their whole behaviour suggests lack of activity rather than special function. They seem to have fallen out of line as it were, remaining inactive while the rest go through the complicated changes prior to syndesis, and lagging behind on the spindle during anaphase, sometimes even being left out of the daughter nuclei altogether as in *Rhabdonema.* The fact that in many species one member of the abnormal pair is altogether lost, while in others, although present, it behaves in regard to Mendelian inheritance as though it carries no factors, all seem to point to a condition of degeneracy. Also Morgan and Bridges[26] have recently shown that non-disjunction appears to take place more often in the X chromosomes than in the autosomes ; and if this be true it again points to lack of normal activity In fact, if *any* pair of chromosomes began to take a less active part in the total metabolism, they could give the complete cytological phenomena associated with the X chromosome. They might also have the observed distribution in regard to the two sexes, as outlined above. The facts of sex-linked inheritance would then follow whichever chromosomes happened to become the X chromosomes. Morgan has recently reported an interesting fact. In *Nature*, February 23rd, 1922, he writes : " Complete triploid individuals having three of each kind of chromosome, have recently been found by Bridges. . . . Their eggs, as shown by genetic tests, contain all possible combinations of chromosomes, behaving as though non-disjunction takes place independently in each set of three. Amongst the offspring of a triploid female (mated to a normal male) there is one class that has three II's, three III's, and three IV's, but with two X chromosomes. This individual is an inter-sex, more like a male than a female. There is another class that has three II's, three III's, but only two IV's. It also is an inter-sex, but more like a female." Here is an abnormality of sex associated with an abnormal distribution of autosomes. Morgan concludes, "Thus sex itself, in this animal, is shown to be an expression of a balance between the X chromosomes and the rest of the chromosomes. The results show that the differentials which determine sex are not confined to the sex-chromosomes alone. Some appear to be in the II- and III-chromosomes, and others in the IV-chromosome."

I would suggest that there are no sex determinants at all in any chromosomes, but that sex is the expression of the total metabolism of a cell and is as fundamental a property of protoplasm as life itself; and that being an alternating phenomenon it carries with it the chromosome distribution in some such way as is outlined above.

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NOTES ON DINOFLAGELLATES AND OTHER ORGANISMS CAUSING DISCOLOURATION OF THE SAND AT PORT ERIN. II. (1921).

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(Read 26 May, 1922)

During the spring and summer of 1921, further work* was carried out on the dinoflagellates and other micro-organisms found on Port Erin beach. Observations were taken on a total of 94 days—March 19th to April 19th (inclusive), July 6th to July 26th (inclusive), August 4th to August 30th (inclusive) and September 17th to September 30th (inclusive). The whole of the summer was an exceptionally hot and dry one, and this probably had a profound influence on the relative abundance of the various organisms under consideration. The general impression received was that, as the summer advanced, the dinoflagellates—most markedly *Amphidinium herdmani*, Kofoid, and to a lesser degree *A. asymmetricum*, Kofoid—became much less abundant than in former years, while the diatoms flourished under the abnormal conditions.

A comparison of the daily records with the meteorological and tidal conditions leads to general conclusions, which are in harmony with those expressed by R. D. Laurie in a paper read to Section D of the British Association in 1913. There is a daily rhythm depending on a combination of the stimuli of light and tide, the optimum in the case of the former stimulus being a dim light, such as occurs in the morning and evening or when the sky is overcast, while, in the case of the latter stimulus, some species are at the surface only at the time of low water. These movements are evidently dependent on the

* See *Trans. L.B.S.* 1912, 1913 and 1921

continued application of the stimuli and are not " habits," as in the case of Convoluta ; for when a bucketful of sand, containing the organisms, is brought into the laboratory, they remain at the surface, whatever the state of the tide may be, unless covered by water. There is also a lunar rhythm, as pointed out by Laurie, periods of great abundance and activity at spring tides, alternating with periods of scarcity at neaps. Laurie accounts for this on the grounds that, at Hoylake, where most of his observations were made, high water at neaps does not cover the region occupied by *Amphidinium*. From my observations at Port Erin, I am inclined to attribute this rhythm rather to the same causes as the diurnal rhythm, viz., light and tide. Low water of springs on this part of the coast occurs in the morning and evening, and hence the rhythm caused by the stimulus of light will coincide with that caused by the stimulus of tide, giving rise to a greater amplitude of variation than is possible at neaps. Both explanations are probably true to some extent. The third rhythm noted by Laurie is a seasonal one. He records a maximum from February to April, after which the discolouration of the sand decreases in intensity and extent, and is barely distinguishable in the late summer. This discolouration was produced by the " short form " of *A. operculatum* since placed by Kofoid in a new species, *A. herdmani*. Laurie also records a small patch of the " long form," *A. asymmetricum*, which was first noticed on July 6th, and which persisted through the late summer. Recent observations at Port Erin confirm these results. *A. herdmani* is the principal cause of the discolouration in spring, while later, especially during the hot summer of 1921, it is almost absent and is replaced to a large extent by *A. asymmetricum* and other forms not observed by Laurie.

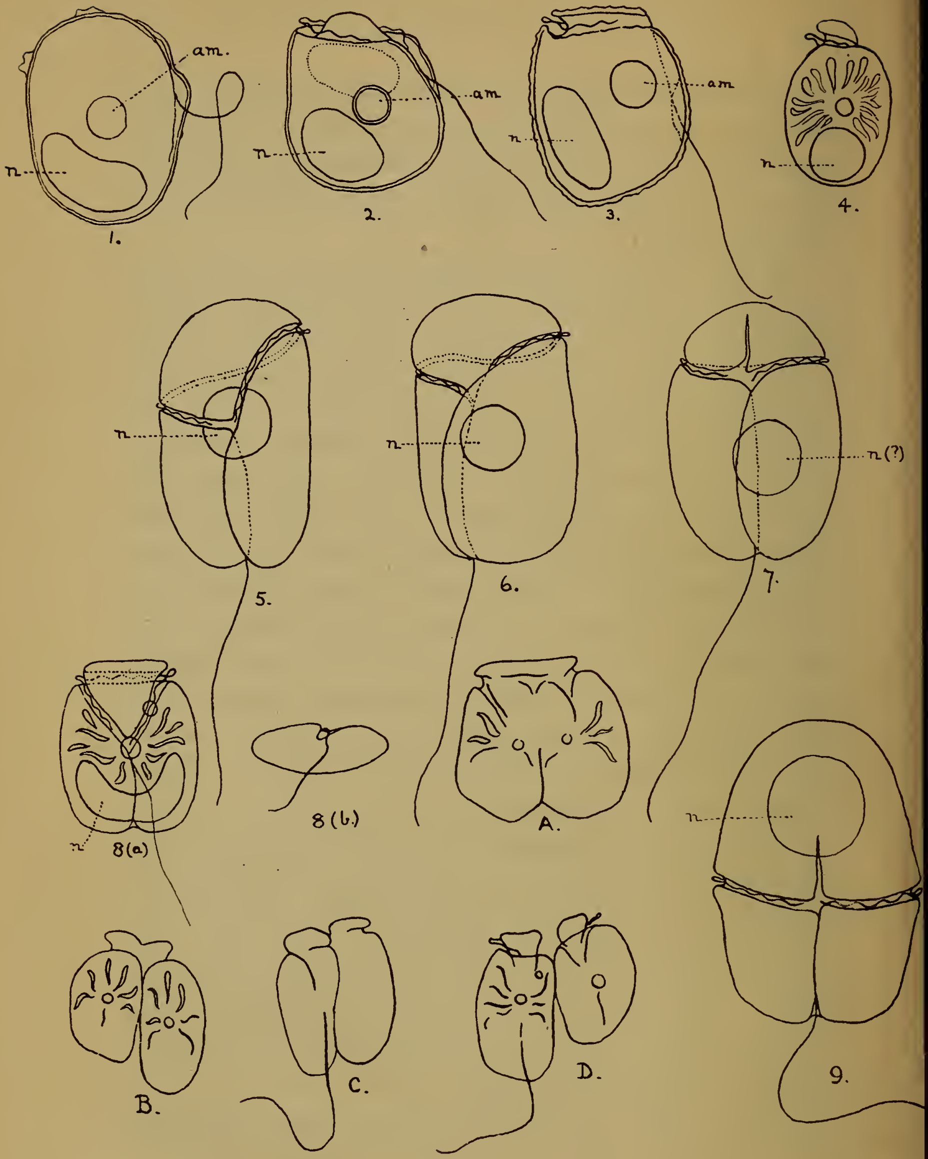
During the summer of 1920, efforts were made, but without success, to observe the division stages of Amphidinium. Although, both on the shore and in the laboratory, these organisms multiply rapidly, no division stages were found, even when the organisms were kept under frequent observation from 5.30 a.m. to 8 p.m. Difficulties in obtaining satisfactory light for microscopic work limited this observation to the hours of daylight.

In April, 1921, however, observations were made from 8 p.m. onwards, the species used being *A. herdmani.* It was found that division began soon after dark, but was arrested, at whatever stage it had reached, as soon as the organisms were exposed to light. Attempts were made, by the use of "Ratten" colour filters, to observe, without arresting, division; but, although red, yellow, blue, orange, green and purple lights were tried, the effect was always the same. The organisms, at whatever stage of division they might be when the light was turned on, continued swimming actively for an hour or so, after which they became more and more quiescent and, after about another hour, broke up. Thus, by keeping a reserve of material in the dark and taking new samples from it every half-hour or so, most stages of the division were observed (Figs. A to D), but the whole process of division was not watched in any one individual.

Division in *A. herdmani* is oblique, and thus typical of the Dinoflagellata, but owing to the small size of the epicone, it appears to be almost longitudinal (Figs. A to D). The schizonts remain together swimming actively for some time after division, this stage being presumably homologous with the "chain," which is best developed in the Peridinioidae. By 3 a.m., most of the schizonts had separated, and no division stages were found after that hour.

Division has not yet been observed in the other forms described below.

The curiously constant distribution of the various forms suggested transplantation experiments, but, so far, these have yielded only negative results.



1. Amphidinium eludens, right side. 2. A. kofoidi, right side 3. A. kofoidi, var petasatum, right side. 4. A. klebsi, dorsal side. 5. A. asymmetricum, var britannicum, ventral side. 6. A. asymmetricum, var. compactum, ventral side. 7. A. pellucidum, ventral side. 8(a). A. herdmani, ventral side. 8(b) Same, posterior view. A, B, C, D. Division stages of same. 9. Gymnodinium placidum, ventral side. am. = amyloid body. n = nucleus.

In two of the experiments *A. herdmani* was the species used. In each case a bucketful of sand, with its contained organisms, was transferred from the flourishing patch just south of the stream to a position only a few yards away on the north side of the stream (see Map), where the conditions were apparently similar. A healthy culture of the same species, which had been kept in the laboratory for ten days, was also transplanted to the north bank of the stream. In each case the transplanted patch had either disappeared completely by the next day or was present in a reduced and unhealthy state, and dwindled to nothing in three or four days.

A. kofoidi was also transplanted to the nearest point on the north side of the stream, but, although the discolouration due to this species was intense on the south side for the next few days, no further sign of the transplanted patch could be found.

Observations made during the spring of 1922 (March 22nd to April 23rd inclusive) revealed nothing new except the unusual scarcity of all kinds of shore-living dinoflagellates. The discolouration of the shore was slight and due almost entirely to small diatoms. While the dinoflagellate population was poor in numbers, it was, however, very rich, for the time of the year, in species. All the Diniferidea mentioned below, except *Amphidinium eludens*, *Polykrikos schwarzi*, and *Noctiluca scintillans*, were represented by a few individuals.

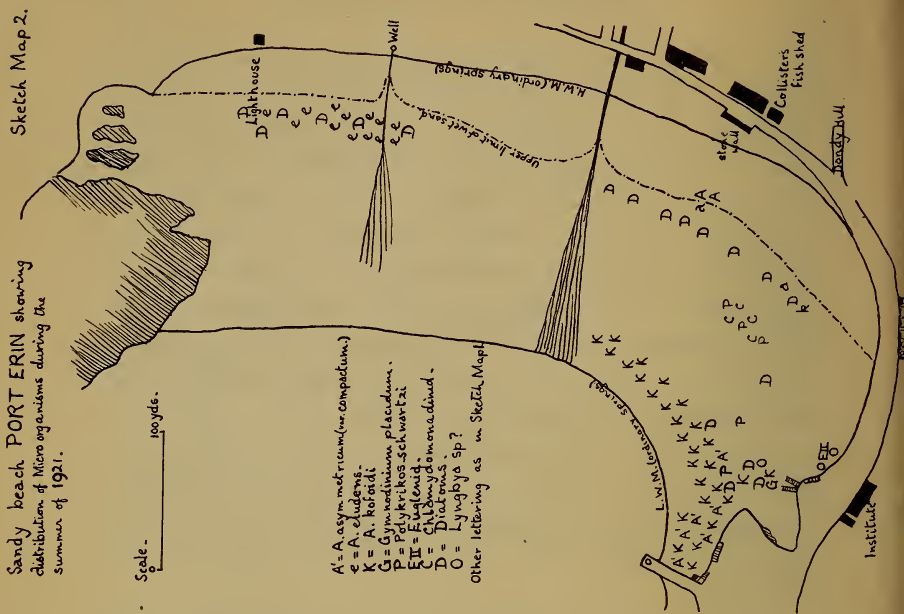
The following dinoflagellates were observed at Port Erin during 1921 and the spring of 1922.

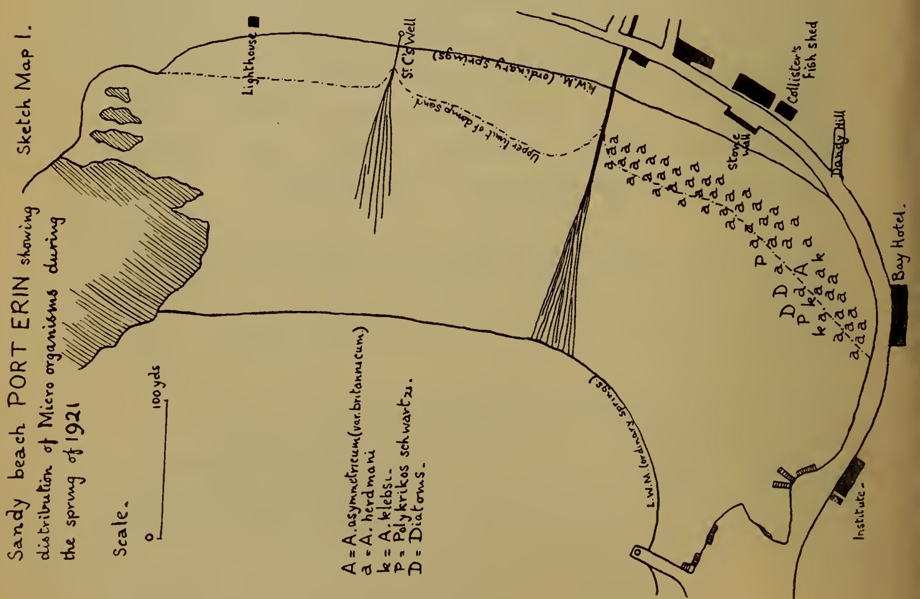
ADINIFERIDEA.

Exuviella lima (Ehrbg.) Bütschli. *Prorocentrum micans*, Ehrbg.

DINIFERIDEA.

Amphidinium asymmetricum, Kofoid, var. *britannicum*, var. nov.
A. asymmetricum, Kofoid, var. *compactum*, var. nov.
A. eludens, sp. nov.
A. herdmani, Kofoid.
A. klebsi, Kofoid.
A. kofoidi, sp. nov.
A. kofoidi, sp. nov., var. *petasatum* var. nov.
A. scissum, Kofoid.
Gymnodinium agile, Kofoid.
G. placidum, sp. nov.
Polykrikos schwarzi, Bütschli.
Noctiluca scintillans, Macartney.


Sketch Map 2.
Sandy beach PORT ERIN showing distribution of Micro organisms during the summer of 1921.
Scale. 0 100yds.
A' = A. asymmetricum (var. compactum.)
e = A. eludens.
K = A. kofoidi
G = Gymnodinium placidum.
P = Polykrikos schwartzi
E II = Euglenid.
C = Chlamydomonadind.
D = Diatoms.
O = Lyngbya sp?
Other lettering as in Sketch Map 1.
Lighthouse
Well
H.W.M. (ordinary springs)
Upper limit of wet sand
L.W.M. (ordinary springs)
stone wall
Collister's Fish shed
Dandy Hill
Bay Hotel
Institute


Sketch Map 1.
Sandy beach PORT ERIN showing distribution of Micro organisms during the spring of 1921
Scale. 0 100yds
A = A. asymmetricum (var. britannicum.)
a = A. herdmani
k = A. klebsi.
P = Polykrikos schwartzi.
D = Diatoms.
Lighthouse
St. C's Well
H.W.M. (ordinary springs)
Upper limit of damp sand
L.W.M. (ordinary springs)
stone wall
Collister's Fish shed
Dandy Hill
Bay Hotel.
Institute.

[The descriptions have been made chiefly from the living organisms, but specimens of most species have also been preserved in the two following fixatives, for the particulars of which I am indebted to Prof. D'Arcy W. Thompson.,

1.	Cupric acetate ...	2 gms.	2.	Cupric acetate...	0·3 gm.
	Distilled water ...	600 c.c.		Cuprous chloride	0·3 gm.
	Glacial acetic acid	3 c.c.		Glacial acetic acid	1·0 gm.
	Glycerine ...	150 c.c.		Distilled water ...	75 c.c.
	Mercuric chloride	1 gm.		Camphor water ...	75 c.c.

The results obtained with these two fixatives were almost identical, but, on the whole, the first caused rather less shrinkage than the second. The specimens were subsequently stained

(1) With Iron Alum Haematoxylin.

(2) With Thionin and Eosin.

(3) With Tolluidin Blue and Eosin.

(4) With Mann's Methyl Blue and Eosin.

In this way further information as regards the internal structure was obtained than was possible in the living organism.]

Descriptions of the Species and Varieties.

Exuviella lima (Ehrbg.) Butschli.

Prorocentrum micans, Ehrbg.

Never very abundant. Odd individuals appear from time to time in scrapings taken from the inner harbour. Usually found together with diatoms.

Amphidinium asymmetricum, Kofoid, var. *britannicum*, var. nov. Very constantly present throughout the spring and summer, especially from July onwards. Maximum range from below the north end of the stone wall to below Dandy Hill in a band about 20 yards wide at the upper limit of the damp sand. (See Sketch Maps). In spring of 1921 occurred as a small isolated patch below Dandy Hill, in summer as one or more patches below the stone wall. No discolouration when the sand is covered by water.

D e s c r i p t i o n . Body asymmetrically ellipsoidal, the length being 1·7 transdiameters. Epicone very asymmetrical, its length at the left side being about 0·15, and at the right ventral region being about 0·5 -of the total body length. Hypocone sack-shaped, more symmetrical than the epicone, but sometimes slightly elongated posteriorly at the left side. Antapex broadly rounded and often slightly notched by the sulcus. Girdle ascending from the flagellar pore to its most anterior point on the left side of the body and thence descending in a uniform spiral to its distal most posterior part. Transverse flagellum completely encircling the body. Sulcus extending from the girdle to the posterior end of the hypocone, its left border forming a flap which overlaps slightly its right margin. Longitudinal flagellum extending posteriorly beyond the antapex for a distance equal to the whole length of the body. Nucleus situated about the centre of the body in an area of clear protoplasm and surrounded by a granular radiating chromatophore of a uniform yellow ochre colour. Length 150μ.

This description differs from Kofoid's description of *A. asymmetricum* as occurring in California in the following points : his specimens are only 50μ in length, the dorsoventral and transdiameters are subequal, the course of the girdle is less markedly asymmetrical than in the British form, and the surface is covered with longitudinal striations. It has, therefore, been thought best to place the form occurring at Port Erin in a new variety of the old species.

Amphidinium asymmetricum, Kofoid, var. *compactum*, var. nov. Differs from the above in being more compact, slightly darker in colour and usually smaller. Girdle and sulcus less evident, girdle not such a steep spiral and sulcus situated to the right of the mid-ventral line. Maximum range of this variety roughly coincides with that of *A. kofoidi* (see Sketch Map 2), but it is less abundant and rarely found except in the outer harbour. Remains on the surface at all states of the tide.

Amphidinium eludens, sp. nov. The only dinoflagellate causing discolouration on the north end of the beach. Occurred in great numbers, together with naviculoid diatoms, in late summer of 1921. Also present, but less abundant, in late summer of 1920 and early summer of 1922. Discolouration is yellower than that caused by other dinoflagellates. Maximum range from below lighthouse to a little south of St. Catherine's Well in a band about 20 yards wide at the upper limit of wet sand. (See Sketch Map 2). Most abundant at south end of range.

D e s c r i p t i o n . Body nearly symmetrical, flattened laterally, the greatest dorsoventral axis being about 1·7 of the transverse axis and 0·75 of the total length. Epicone very small and imperfectly divided from the hypocone. Girdle asymmetrical, passing in an anterior direction slightly to the left of the middle line. At the extreme apex the girdle crosses the middle line and continues dorsally and now slightly to the right. It gradually fades out, but the transverse flagellum passes on round the body to the left side at a distance, from the apex, of rather more than a quarter of the total body length. Sulcus extending to within one trans-diameter (measured from side to side) of the antapex and partly overhung by the projecting left border. Longitudinal flagellum hardly any longer than the body and often lying free from the anterior end of the sulcus. Body enclosed in a distinct homogeneous and colourless pellicle, from which, under adverse conditions, the cytoplasm may be retracted. Two highly refractile bodies, having the appearance of the amyloid bodies of the Adiniferidea, occur one on each side. Protoplasm of a uniform yellow ochre colour. Nucleus posterior and slightly dorsal, elongated and often gently curved to fit the contour of the body. Length about 70μ.

Amphidinium herdmani, Kofoid. Principal cause of discolouration during spring. In bulk causes greenish brown patches, which always disappear before the in-coming tide and do not reappear until that region of the beach is again exposed.

Maximum range from south bank of stream to below Bay Hotel in a band about 20 yards wide at upper limit of damp sand. (See Sketch Map 1).

Description. Body broadly ellipsoidal in ventral view, dorsoventrally flattened, rounded posteriorly and truncate anteriorly, its length about 1·2 transdiameters at the widest part. Epicone small and triangular with a length on the dorsal side of 0·06, and on the ventral side of 0·36 of the total body length and a greatest breadth of 0·53 transdiameter. The borders of the ventral portion converge posteriorly at an angle of about 70 °. Apex truncate. Hypocone broad with rounded sides, and a broad, rounded, slightly notched antapex. Girdle separating epicone from hypocone, both ends meeting ventrally without displacement. Furrow deeply impressed with overhanging borders. Sulcus extending from girdle to antapex, wide at its beginning, contracted below, owing chiefly to a slight projection of the left border and expanding as it nears the antapex, where it sometimes forms a deep notch. Transverse and longitudinal flagella arising near each other at the junction of the girdle and sulcus, probably from the same pore. Transverse flagellum reaching almost completely round the body; posterior flagellum extending beyond the antapex for a distance as great as the whole length of the body.

Nucleus elongated and curved so as to form a crescent or horse-shoe shape—placed posteriorly across the body with the horns of the crescent directed anteriorly. Central part of the cytoplasm occupied by a small spherical body containing a central granule, from which radiate out towards the periphery long slender chromatophores, pale yellow ochre in colour. A second small spherical body is present in most individuals, anterior and slightly to the left of the central one. In ventral view it shows through the girdle about half-way between its origin and the point where it passes over to the left dorsal side of the body. Length, 40 to 50μ.

The above description agrees closely with that given by Kofoid in his monograph, "The Free-living Unarmored Dinoflagellata" (1921). As that description was taken from one of the figures in the L.M.B.C. Report for 1911 (this species has not yet been found on the Californian coast), some of his measurements are omitted as being hard to verify and liable to great variation, and the shape and position of the nucleus, which were then unknown, have been added here.

Amphidinium klebsi, Kofoid. A few specimens have been seen from time to time, usually associated with *A. herdmani*.

D e s c r i p t i o n. Body elliptical, dorsoventrally compressed. Length about 1·7 transdiameters. Epicone small and tongue-shaped, and deflected to the left. Hypocone broadly ellipsoidal, subtruncate anteriorly, rounded posteriorly, its sides sub-parallel for the middle third of their extent. Girdle broad, its ends meeting without displacement. Sulcus extending from the girdle nearly to the antapex. The transverse flagellum, arising on the left ventral side, and extending completely round the neck-like girdle to the right ventral side, and often projecting well beyond its borders, so as to be visible throughout its length from the ventral side. Posterior flagellum extending beyond the antapex for a distance probably about equal to the total body length.

Nucleus large and spherical, situated in the posterior half of the hypocone. Small spherical body similar to that which occurs in *A. herdmani* occupying the centre of the hypocone. From it slender radiating chromatophores of a pale yellow ochre colour extend towards the periphery. Length 40 to 50μ.

This description differs from that given by Kofoid, from Klebs's figure, in the arrangement of the chromatophore and the course of the transverse flagellum. If, however, Klebs's figure be taken as a *dorsal* view, then the description given differs from his specimens not in the course of the transverse flagellum but in the side to which the tongue-like epicone is deflected.

Amphidinium kofoidi, sp. nov.—Usually present during 1921 from August 11th onwards—often forming very large and intense cocoa-coloured patches, which are strongly marked at all times of tide. Maximum range from inner harbour northward to just south of stream at about level of low water mark of neap tides. (See Sketch Map 2).

D e s c r i p t i o n. Body slightly asymmetrical and broadly ellipsoidal, the dorsoventral axis being about 0·8 of the total length—flattened laterally and more convex on the ventral than on the dorsal side. Epicone small and sometimes retracted so as to be hidden in lateral view between the projecting edges of the hypocone. Hypocone sack-shaped, with its greatest width (dorsoventrally) at about 0·4 of the total length from the posterior end. Left border of the sulcus projecting beyond the right in the anterior ventral region. Girdle deep, its two ends meeting without displacement. Sulcus not extending as far as the antapex nor continued upon the epicone. Transverse flagellum completely encircling the body and usually easily visible projecting beyond the margins of the girdle. Posterior flagellum extending beyond the antapex and lying with its proximal part in the sulcus. Body enclosed in a colourless homogeneous pellicle.

Two amyloid bodies (?), situated one at about the middle of each side. Numerous small refractile granules usually present throughout the cytoplasm, which is a uniform light brown colour. Nucleus posterior and slightly dorsal, very slightly elongated and with the side next the surface of the body more convex than the inner side. Anterior part of the hypocone usually occupied by a large, rather clear region, which does not take stains. Length about 50 to 80μ.

Amphidinium kofoidi, sp. nov., var. *petasatum*, var. nov. This variety occurred abundantly during the summer of 1920, but was not again recorded until June, 1922, when it appeared in considerable numbers. Maximum range coincides with that of *A. kofoidi*. In Part I of this report it was described as *A. sulcatum*, Kofoid, but comparison with the description and figures in his monograph, which has appeared since, show that this identification was incorrect.

This variety differs from *A. kofoidi* (see above) in the larger and more flattened epicone, the deeply impressed and undercut girdle and the thicker and rougher pellicle—also in its paler and more greyish yellow colouration.

[Both varieties of this species, together with *A. eludens* (see above), are of especial interest in connection with the phylogenetic position of the genus Amphidinium in the sub-class Dinoflagellata. In the poor development of the epicone in two of them, and in the presence of a pellicle covering the body in all, they resemble the more primitive Adiniferidea, while in other points they fall in more nearly with the generic characters of Amphidinium. Possibly, then, the genus Amphidinium may have branched off from the stem of the Diniferidea at a very early stage, close to the point of origin of the Adiniferidea.]

Amphidinium pellucidum, sp. nov. Occurring from time to time in scrapings of sand containing coloured dinoflagellates—especially from south end of beach.

D e s c r i p t i o n. Body almost symmetrical, broadly elliptical and flattened dorsoventrally. Transverse axis 0·7 of total length.

Epicone much smaller than hypocone, almost equal in width to greatest transdiameter, its length on the ventral side being 0·26 of total length. Apex rounded and sometimes slightly notched by a forward extension of the sulcus. Hypocone broadly sack-shaped, rounded and notched posteriorly. Girdle deep, rising very little on dorsal side, broad at its proximal and distal ends, which meet almost without displacement. Transverse flagellum completely encircling the body. Sulcus extending from apex to antapex, very broad just posterior to the girdle, but overhung by projections from either side. Longitudinal flagellum usually lying within the sulcus and extending beyond the antapex for a distance nearly as great as the whole length of the body.

Body colourless and of a glassy transparency. Nucleus probably situated near the centre of the body slightly to the left of the middle line. Coloured (usually red) bodies, which probably consist of food matter, often present in the region of the sulcus. Length about 150μ.

This species seems to be on the border line between the genera Amphidinium and Gymnodinium, and it is doubtful to which of them it should be referred.

Amphidinium scissum, Kofoid. This species occurs frequently, though never in large numbers, on the south end of the beach, especially round the inner harbour and off the end of the little pier.

Description. Body ovate, dorsoventrally compressed. Length about 1·8 to 2 transdiameters. Apex flattened and sloping to the right, traversed by the sulcus, which crosses the apex and swings round to the left, encircling a small terminal button. Hemispherical outline of the antapex broken by the deep semicircular notch at the posterior end of the sulcus; this notch lies a little to the right of the main axis and the left margin is the longer one. Girdle forms a descending left spiral, the proximal and distal ends of which are deflected posteriorly at angles of about 30° and 45° respectively with the horizontal. Distal displacement posteriorly about twice the width of the girdle. Sulcus runs the whole length of the body, terminating anteriorly in a sinistral loop around an apical button and flaring posteriorly in the antapical notch. Longitudinal flagellum extends posteriorly beyond the antapex for a distance equal to the length of the body. Nucleus ellipsoidal and posterior. Red and brown food masses frequently present in region of sulcus. Body colourless or very faint greenish grey. Length about 100μ.

This description differs from that given by Kofoid in the following points : Fewer details as to cell contents, accurate dimensions, surface striations, etc., have been observed in the British specimens, which are considerably larger and less deeply coloured than those occurring on the Californian coast.

Gymnodinium agile, Kofoid. Individuals of this species have occurred from time to time in scrapings from the south end of the beach, though they are never abundant.

Description. Body rounded in ventral view, flattened dorsoventrally. Epicone and hypocone subequal. Epicone hemispherical with the apex displaced to the left as a minute, pointed, finger-like projection bending downwards towards the surface of the body. Hypocone symmetrically hemispherical in ventral view. Girdle equatorial and without displacement. Sulcus extending from girdle to antapex.

Position of nucleus uncertain. Cytoplasm clear and colourless. Minute refractile bodies numerous in epicone and absent in hypocone where a single large amyloid body (?) is present. No chromatophores. Length about 30μ.

So far as this description goes it agrees with that of Kofoid for *G. agile* taken from beach sand at La Jolla. In the Californian form, however, there are coral-red pusules and orange green chromatophores.

Gymnodinium placidum, sp. nov. This species occurred frequently, though never abundantly, in the inner harbour during 1920-1922, especially in the trickle of water draining down from under the harbour steps. Movements slow and deliberate.

Description. Body ellipsoidal and dorsoventrally flattened, its length 1·5 transdiameters and its dorsoventral diameter about half its transdiameter. Ventral surface more flattened than dorsal. Epicone slightly longer than hypocone, tapering anteriorly and expanding slightly posteriorly so as to form a thickened anterior rim to the girdle. Hypocone hemispherical. Girdle and transverse flagellum completely encircling the body, the distal end very slightly displaced posteriorly. Sulcus extending from about half way between the apex and the girdle to the antapex, the left border overlapping the right. Longitudinal flagellum projecting about the length of the body beyond the antapex.

Nucleus placed centrally within the epicone. Cytoplasm filled with small refractive granules and with a longitudinally streaked appearance. Colour yellowish brown. Length about 150μ.

Polykrikos schwartzi, Bütschli. Of frequent occurrence on almost all parts of the beach, but especially at the south end. During the late summer of 1921 it was very constantly present off the end of the little pier, feeding on *Amphidinium kofoidi*, and again at a higher level opposite Dandy Hill feeding on a small but very abundant Chlamydomonadinid. (See Sketch Map 2).

Noctiluca scintillans, Macartney = *N. miliaris*, Suriray.

On July 23rd, 1921, over a considerable area of the beach off the end of the little pier, the ripple marks were filled with pink gelatinous masses of *N. scintillans*. These were in a very healthy and active state, showing all stages in division. For some time previously this species had been plentiful though not unusually abundant in the plankton from Port Erin bay.

THE

MARINE BIOLOGICAL STATION AT PORT ERIN

BEING THE

THIRTY-FIFTH ANNUAL REPORT

DRAWN UP BY

Professor JAMES JOHNSTONE, D.Sc.
(Department of Oceanography, University of Liverpool).

Introduction

During the past year the transition from the management of the Station by the old "L.M.B.C." to that now exercised by the Department of Oceanography of the University of Liverpool has been very successfully effected. The former Curator, Mr. H. C. Chadwick, retired from the active control of the establishment in July and has been succeeded by Mr. J. Ronald Bruce, who is now "Naturalist-in-Charge." The services of Mr. Chadwick are, however, still retained by the Department, and he is now resident at the Station as "Research Assistant," and is fully occupied with various investigations. An additional Assistant, or "Fisherman-collector," Mr. W. Christian, has been employed, as from July last, to help Mr. T. N. Cregeen in the mechanical work of the establishment and in collecting for the Aquarium and for the students and investigators working in the laboratories.

These changes, and many others which will be recorded in this and future Reports, have been made possible by a grant of £1,000 made, for the year April 1st, 1921 to March 31st, 1922, by the Development Commissioners. It is expected that this grant-in-aid will be renewed for the next four years at least, and such assistance is of very great value in the maintenance and further expansion of the work of the Station. Some assured increase in the income had become very necessary: The general upkeep of the buildings, machinery and scientific apparatus had to be neglected during the war years, so that these expenses became rather formidable considering the very meagre resources of the Station apart from Government grants ; a contemplated development of the scientific researches has made the purchase of new apparatus and stores quite essential and, for the same reason, it has been found necessary to make certain structural alterations in the work-rooms and stores. All this has, fortunately, become possible by the grant-in-aid made by the Development Commissioners. Given the continuance of this, and the grant also made by the Tynwald Court, the continued equipment of the laboratory and Aquarium as an up-to-date Marine Biological Station need give us no further anxiety. Certain other additions to our resources are, however, very desirable and I venture to give some emphasis to the following " needs " :—

(1) *A strong and sea-worthy vessel of the Admiralty " steam picket boat," or " harbour launch " type ;*

(2) *A capital expenditure on the steam-heating and electric-lighting of the Station ;*

(3) *An endowment, yielding an annual income of* £100 *a year, for printing reports on scientific investigations.*

The above, with a continuance of the present income, would enable us to develop the work of the Station to about its maximal degree. In short, the Port Erin Marine Biological Station *requires a capital expenditure of about* £6,000 *and a further endowment bringing in* £100 *a year to make the contemplated scheme of work possible.*

This Report follows the former lines and presents only a short summary of the activities of the year 1921. The educational work was, as in the previous year, very encouraging, students and investigators worked at the Station mainly during the months March to September. The visitors to the Aquarium and Museum were very numerous, about 27,900 being recorded. In this side of the business there are quite remarkable opportunities for public instruction and propaganda. Exhibits and synopses illustrating the local sea-fishing industry and natural history might be further developed while short evening lantern lectures during the holiday season might deal with such matters as the " Fish as Food " campaigns of the pre-war period, health subjects, etc. It is hoped that, after the present period of material development, something may be done in this direction. Here I must notice the course of public lectures at the George Herdman Institute which Mr. Bruce is arranging at the beginning of 1922.

A detailed list of the workers at the Station is given in the " Curator's Report."

The Research work carried on during the last year includes :—

That by Miss Maisie Hobbins, B Sc. (the Edward Forbes Exhibitioner for 1921) on Protozoan parasites ;

Continued work by Miss Margery Knight, M.Sc. on the life history of local Algæ ;

Various investigations by Professor Dakin,[1] Mr. S. T. Burfield, M.Sc.,[2] and Mrs. R. C. Bisbee, M.Sc. ;[3]

An investigation of the morphology of local species of *Amphidinium*, etc., by Miss E. C. Herdman ;

A description of the food of larval and post larval plaice, spawned and reared in the hatchery ponds, by Mr. A. Scott ;

A survey of the distribution of young stages of the plaice and other flat fishes, in the Bays of the Island, by Mr. W. Birtwistle ;

Observations made in the neighbourhood of Port Erin on board local steam trawlers, by Mr. W. C. Smith ;

1. Behaviour of *Pecten*.
2. Experiments on fixation of plaice ova.
3. Circulation of water in *Echinu*

Odds and ends of investigation carried out by Mr. J. R. Bruce, M.Sc., during the few intervals of time that were available for scientific work as apart from that of seeing to the control and further equipment of the Station ;

Plankton collections made by Professor Herdman and the description of these by Mr. A. Scott ;

A study of the "colossal" accumulation of data representing the results of the plankton collections made by Professor Herdman, and identified and enumerated by Mr. A. Scott during the last fifteen years : Dr. Johnstone is doing this.

Wherever noteworthy scientific results have been obtained the above researches are mentioned, in rather more detail, further on in this Report.

The work done by Messrs. Birtwistle and Smith is part of a larger scheme adumbrated by the Ministry of Agriculture and Fisheries.

The condition of the Station is, I think, thoroughly healthy. A great deal of research work is in progress and its completion or expansion awaits additional resources for collecting and study at Port Erin itself, or the opportunity for publication in this Report or elsewhere. Undoubtedly, much still remains to be done in the way of collecting material for investigation and particularly in providing for experimental work in the Station. Various reproaches made by the staff of the Zoological Departments at Liverpool and elsewhere are stimulating us to the further improvement of the aquarium and laboratories in the ways indicated, and I hope that, in the course of time, no investigator visiting Port Erin will have any reasonable cause for dissatisfaction.

Curator's Report.

Sixty-six workers—a considerably smaller number than that of last year—occupied our laboratories. The great majority came from the departments of Zoology, Botany and

Oceanography of the University of Liverpool, but the Universities of Cambridge, Manchester, Birmingham, and Wales (Aberystwyth) were again represented by students and researchers. The University of Chicago, U.S.A. was represented by Miss M. Lillie.

As in former years, the students coming from the Zoological Department of the University of Liverpool were accompanied by the staff and systematic instruction was given to them by Professor Dakin, Mr. Burfield, and Mrs. Bisbee.

Miss Knight spent six weeks during the summer in prosecuting her researches into the life histories of certain marine algæ. Miss Catherine Herdman, during both the Easter and Summer vacations, continued her investigation of the Amphidiniums and Peridiniales of Port Erin beach. In May, June and August, Mr. W. Birtwistle, making the Biological Station his headquarters, conducted some enquiries into the occurrence and distribution of young food fishes in the bays of the Island.

Much faunistic work was done during the Easter and Summer vacations, both on the Port Erin and neighbouring beaches by the undergraduate students and in the deeper waters of the coast by Professor Herdman from his motor-boat, "Redwing," some very productive hauls of the dredge being taken. Professor Herdman also carried on his special plankton investigations, and the official tow-nettings were taken with regularity throughout the year.

The Fish Hatchery.

The stock of plaice assembled for the spawning season of 1921 consisted of 230 survivors of the previous year's stock and 78 excellent fish purchased from local fishermen during October, 1920. On November 1st, after thorough cleansing of the ponds, 130 of the fish were placed in the West pond and 178 in the East pond. Of the former number there were 97 survivors when the pond was again drained early in May. Eighteen are known to have died in the East pond before and during the earlier half of the hatching season, and the mortality in the West pond was very considerable.

It is worthy of note that an exceptionally luxuriant growth of the green alga *Enteromorpha* on the lower portion of the Port Erin lifeboat slip had its counterpart in the ponds during the hatching season, the bottoms and lower half of the sides being thickly covered with the weed.

The first batch of eggs, numbering 6,300, were placed in the hatching boxes on February 14th. The daily numbers of eggs collected were comparatively small until March 9th, when 105,000 were obtained. The largest daily number of the season—243,600—was reached three days later. Over 200,000 were collected on March 24th and 26th and April 1st, 11th and 20th. After the last named date the numbers decreased very rapidly, and the season ended on the 30th with 31,500. The total number of eggs spawned was 4,445,800 and of larvæ set free 3,594,650.

The Hatchery Record, giving the number of eggs collected and of larvæ set free on the various days, is as follows :—

Eggs collected.		Date.		Larvae set free.		Date.	
126,000	...	Feb.	14 to 28	81,900	...	March	17
216,300	...	March	3 to 7	186,900	...	„	22
231,000	...	„	9 and 10	203,700	...	„	26
764,400	...	„	12 to 19	680,400	...	April	2
262,500	...	„	21 and 22	221,500	...	„	5
231,000	...	„	24	199,500	...	„	7
220,500	...	„	26	196,350	...	„	9
237,300	...	„	28 and 29	207,900	...	„	12
155,400	...	„	30	131,250	...	„	13
336,000	...	„	31 and April 1	275,100	...	„	16
178,500	...	April	2	154,350	...	„	18
373,800	...	„	4 to 8	342,300	...	„	23
367,500	...	„	11 to 15	262,500	...	„	29
634,200	...	„	18 to 22	386,400	...	May	5
113,400	...	„	25 to 30	64,600	...	„	7
4,445,800				3,594,650			

Lobster Culture.

Twenty berried lobsters—five more than last year—were purchased from the local fishermen. The yield of larvæ per lobster was, however, considerably smaller than last year, being only 867·5 as compared with 1,914. Of the 17,350 larvæ hatched, 15,800 were set free in the first and second stages, while the remaining 1,550 were placed in the rearing jars in the hatchery and fed exclusively on plankton. Two hundred and seventy-six of the latter number were successfully reared to the lobsterling stage and set free. The exceptionally high temperature of the summer was found to have a prejudicial effect upon the larvæ in the rearing jars.

The Aquarium.

The great falling off in the number of visitors to the Isle of Man during the prolonged Coal Strike is reflected in the number admitted to the Aquarium, and the total for the year—27,900—compares unfavourably with that of last year. Still, the attendance in July and August was very satisfactory, and compares well with any previous year. The display of local fishes was well maintained, and Professor Herdman's dredging excursions provided many interesting Invertebrates for exhibition. One thousand two hundred and thirty copies of the 'Guide to the Aquarium' were sold.

List of Workers, 1921.

March 19*th to April* 22*nd*	Professor Herdman.
	Miss E. C. Herdman.
March 21*st to April* 1*st*	Mr. F. J. Brown.
March 19*th to April* 20*th*	Miss Knight.
March 19*th to April* 20*th*	Miss Hanson.
March 19*th to April* 1*st*	Miss C. E. Mayne.
March 19*th to April* 15*th*	Miss M. Hobbins.
March 21*st to* 28*th*	Professor Johnstone.
March 25*th to April* 18*th*	Miss L. Thorpe.
March 25*th to April* 2*nd*	Miss M. E. Oliver.
March 25*th to April* 15*th*	Dr. W. Ritchie.
March 25*th to April* 4*th*	Mr. D. O. Morgan.
March 25*th to April* 4*th*	Mr. W. M. Speight.
March 25*th to April* 2*nd*	Mr. P. A. Little.
March 30*th to April* 8*th*	Mr. C. J. Ford.

April 1*st to* 11*th* ... ... Miss K. Murray.
April 1*st to* 8*th* ... ... Mr. R. W. Eldridge.
April 2*nd to* 22*nd* ... ... Miss D. M. R. Allan.
April 2*nd to* 22*nd* ... ... Miss W. Kehoe.
April 2*nd to* 22*nd* ... ... Miss E. Staidler.
April 2*nd to* 20*th* ... ... Miss E. M. Roper.
April 2*nd to* 20*th* ... ... Miss C. L. Hall.
April 2*nd to* 22*nd* ... ... Mrs. Bisbee.
April 5*th to* 20*th* ... ... Mr. R. A. Fleming.
April 5*th to* 13*th* ... ... Mr. J. R. Bruce.
April 6*th to* 20*th* ... ... Miss G. Lishman.
April 6*th to* 20*th* ... ... Miss M. Ryder.
April 6*th to* 20*th* ... ... Miss D. A. S. Hughes.
April 7*th to* 20*th* ... ... Miss J. McInnes.
April 7*th to* 15*th* ... ... Miss Jackson.
April 7*th to* 20*th* ... ... Miss M. Scott.
April 8*th to* 12*th* ... ... Mr. G. F. Sleggs.
April 8*th to* 22*nd* ... ... Miss A. E. Chesters.
April 8*th to* 22*nd* ... ... Miss M. A. Wilson.
April 8*th to* 22*nd* ... ... Miss E. M. E. Gardner
April 9*th to* 20*th* ... ... Professor W. J. Dakin.
April 9*th to* 20*th* ... ... Mr. S. T. Burfield.
April 9*th to* 22*nd* ... ... Miss H. V. Davies.
April 9*th to* 22*nd* ... ... Mr. S. K. Montgomery.
April 9*th to* 22*nd* ... ... Miss R. Hilton.
April 9*th to* 22*nd* ... ... Miss O. R. Bangham.
April 9*th to* 22*nd* ... ... Miss A. Butterfield.
April 9*th to* 22*nd* ... ... Miss F. Hey.
April 9*th to* 22*nd* ... ... Miss E. Owen.
April 9*th to* 22*nd* ... ... Miss B. Illingworth.
April 9*th to* 22*nd* ... ... Miss E. Angel.
April 9*th to* 22*nd* ... ... Miss J. Anderton.
April 9*th to* 22*nd* ... ... Miss K. Stoddart.
April 11*th to* 20*th* ... ... Miss H. M. Clayton.
April 11*th to* 22*nd* ... ... Miss M. Knowles.
April 11*th to* 22*nd* ... ... Miss N. Dawson.
April 11*th to* 22*nd* ... ... Miss D. F. Bell.
April 11*th to* 22*nd* ... ... Miss E. Fox.
April 11*th to* 22*nd* ... ... Miss E. L. Gleave.
April 13*th to* 22*nd* ... ... Miss E. M. Lind.
April 13*th to* 22*nd* ... ... Miss V. L. Beszant.
April 13*th to* 22*nd* ... ... Miss E. Phillips.
April 13*th to* 20*th* ... ... Miss Clague.
May 24*th to June* 9*th* ... ... Mr. W. Birtwistle.
June 27*th and* 28*th* ... ... Professor Johnstone.
June 27*th and* 28*th* ... ... Dr. E. S. Russell.
July 2*nd to August* 15*th* ... ... Miss Knight.
July 2*nd to August* 15*th* ... ... Miss D. Hanson.
July 6*th to September* 3*rd* ... ... Professor Herdman.
July 6*th to September* 3*rd* ... ... Miss E. C. Herdman.
July 6*th to August* 20*th* ... ... Miss M. Lillie.
August 1*st to* 6*th* ... ... Mr. W. Birtwistle.
August 8*th to* 17*th* ... ... Miss H. M. Wright.
August 9*th to* 15*th* ... ... Mr. C. W. Smith.
August 9*th to September* 17*th* ... ... Mr. C. W. D. Kermode.
August 10*th to* 16*th* ... ... Mrs. Bisbee.
September 17*th to October* 1*st* ... ... Professor Herdman.
September 17*th to October* 1*st* ... ... Miss E. C. Herdman.
September 17*th to October* 1*st* ... ... Miss Gibbs.

H. C. Chadwick.

THE PLAICE HATCHING.

The hatching operations carried on by Mr. T. N. Cregeen afford what I regard as quite remarkable opportunities for biological investigation. In the first place the morphology itself of these embryonic and larval plaice still awaits satisfactory investigation—in spite of the fact that various members of the staffs of the Liverpool and other Zoological laboratories have made collections with that intention. Secondly, large numbers of plaice have been reared in the spawning pond and in the Aquarium tanks without any obvious difficulty. At the present time some of these fish are four years old and an F_2 generation has been spawned and might, with care, be reared if so desired.

Larger questions than those of morphology may, however, be studied in connection with the habits of these baby plaice.

The War and the North Sea Plaice Fisheries.

The general opinion among fishery zoologists, both in this country and in Germany, is that one effect of the war was a marked improvement in the catch of plaice made by North Sea trawlers. This catch, whether expressed as the total quantity of fish landed, or as the catch per day's fishing, decreased from year to year on the whole, during the period 1908-1914. After the outbreak of war there were military restrictions in the form of areas of sea closed to fishing vessels and there was, therefore, a considerable falling off in the quantities of plaice caught and landed. What fractions of the plaice grounds in the North Sea, English Channel and Irish Sea were so protected from exploitation by fishing vessels appears to be a military secret, and so these data have not been discussed though they have obvious importance in the question at issue. There were restrictions in the Channel and Irish Sea as well as in the North Sea, and so one would expect to find that the same increase in the stock of plaice occurred in the South and West as on the East. Looking critically at the data for the two former coasts I can see no evidence that the increase (which *did* occur in 1919) was due to the saving-up of plaice uncaught because of restrictions on fishing during the war years.

It seems " reasonable " to assume that, because a large quantity of plaice were not caught in 1915-18, the fishery had improved in 1919 and there is no doubt that the reduction of fishing during the war did have *some* effect. But how much ? Since the catch made by the North Sea trawlers was less in 1920 than in 1919 it does not appear that the effect *was* a notable one. Now, one has to accept the general conclusion arrived at by the English and German fishery zoologists—that the effect of the war restrictions was a recovery of the plaice fishery from the process of depletion that was in progress from 1908 to 1914—but, all the same, one does so without much conviction ! In *that* attitude of mind, then, it is up to the doubter to seek for some other explanation of the facts.

Is the egg-production per plaice of mean size always the same from year to year ? This is unlikely (though I know of no satisfactory observations on this matter). In some years, for instance, in 1914, and the years before and after, there may have been an egg-production well above the average. In that case the numbers of plaice of four to six years old ought to have been greater in 1919 (or in the years before and after) than it would have been if the egg-production had been an average one in 1913-15—provided that the proportion of post-larval fish resulting from the development of the eggs *had been, at least, as good as the average.*

That leads to the suggestion that the proportion of eggs that successfully develop and become young plaice may be greater or smaller in some years than it is, on the average. This is the idea underlying much fine work by Dr. Johann Hjort. Obviously either it, or the idea that egg-production rules the abundance of plaice in a fishing region some three to five years later, or both, may be used to explain such variations in the productivity of the North Sea plaice fisheries as those that are attributed to the effects of the war. Unless we can rule out these two former possible explanations the latter one—that the variations depend on "intensity of fishing"—must remain doubtful. Can one be sure that the falling-off in the quantity of plaice landed from the North Sea in 1908-1914 would have continued, or become less, or become greater had there been no war? Fluctuations of much the same range have occurred in the Irish Sea *before* the war, so that there are undoubtedly factors that lead to fat years and lean years apart altogether from legislative restrictions.

What conditions rule the egg-production?

It ought to be possible to make an enumeration of the mature female plaice in the pond and to calculate their mean length. The total number of eggs spawned is known. A certain number remain in the pond and develop in spite of the care taken by Mr. Cregeen to skim the surface. This fraction unenumerated may be taken to be the same from year to year. What then are the *physical* conditions that may be correlated with variations in the egg-production?

What conditions rule the successful development?

A female plaice can be "stripped" of her eggs. The numbers of those that die after fertilisation can be estimated. Upon what conditions will the variation in this fraction of eggs failing to develop depend?

The duration of development: How does this depend on temperature?

There are no data for the Port Erin or Piel plaice (though an investigation might easily be made). But take the following* data:—

Temperature ...	31, 32, 33, 34, 35, 36, 37, 38, 39
Incubation period	50, 40, 35, 31, 28, 25, 23, 21, 19
Temperature ...	40, 41, 42, 43, 44, 45, 46, 47 : °F.
Incubation period	17, 16, 15, 14, 13, 12, 11, 10·5: days.

*This is the best series of observations I know. It is from *Manual of Fish Culture, U.S.A. Fish Commission*, p. 206.

The transformation and growth of the larva.

What conditions determine these processes? Doubtless, the relative abundance of food in the sea in a form suitable for the nutritive organs of the baby plaice. Doubtless, also the temperature of the sea, which will govern the rate of assimilation.

The food.

The nature of the food is restricted since the organisms eaten must be below a certain limit of size. There are many pelagic organisms (animals and plants) that are small enough so that there is usually a choice. Individual plaice exhibit preferences.

An account of the food of larval and post-larval plaice has been prepared by Mr. A. Scott from collections made in the Port Erin spawning pond. This is being published elsewhere.

The variations in the abundance of the food.

What are the ranges in the variations in abundance of Diatoms, Peridinians and Copepods throughout a series of years? I hope to deal with this question soon, after the very laborious task of collating the plankton estimates made by Mr. Scott for the last fifteen years has been completed. The conclusions may be applied to the data indicated above provided that we can be sure that the planktonic fauna and flora of the spawning pond is similar to that of Port Erin Bay. There are indications that it is similar and obviously it will be an easy matter to apply tests.

This discussion suggests that those fluctuations in the productivity of the fishing grounds that are to be deduced from the official statistics are due to the variations in the physical conditions that rule the abundance of food in the sea. If in any one year an unusually large number of eggs are spawned, or an unusually large number of eggs develop and metamorphose successfully, there will be a rise in the productivity of the plaice fisheries several years afterwards. If (as is very likely) these favourable conditions are repeated for several years the effect (as regards the fisheries) will be still greater. This is, of course, Dr. Johan Hjort's well-known hypothesis.

The Edward Forbes Exhibition.*

The Exhibitioner for the year 1921 was Miss Maisie Hobbins, B.Sc., who spent a month at Port Erin (21st March to 16th April) working on the life history of the Sporozoan *Merocystis kathae*. This organism is parasitic in the renal organ of the common whelk (*Buccinum undatum*). A large number of whelks from Port Erin, Piel and Millport have now been examined and, so far, very few have been found to be uninfected with *Merocystis*. It has been supposed that the parasite passes through a sporogenous stage in the renal organ of the whelk and so the main object of Miss Hobbin's research was to discover a second host. Two series of experiments were therefore made. (1) The infected renal organs of the whelks were dissected out and offered as food to various crabs (*Eupagurus*, *Portunus* and *Carcinus*). The latter animals were kept in separate tanks. Several died and the alimentary canals were removed, preserved in Bouin's Fluid and taken back to Liverpool; (2) Pieces of the infected renal organ of the whelk were enclosed in the mantle cavities of the boiled mussels used for feeding the fish in the Aquarium. These were offered to various cod in one of the tanks and were readily eaten. During the fourth week of the experiment one of the cod died. Its alimentary canal was dissected out, fixed in Bouin's fluid, and taken back to Liverpool. The object of these experiments was to find whether or not *Merocystis* passes through a schizogenous phase in the tissues of a second host. The latter has to be discovered by various "feeding experi-

* For the Regulations with regard to the Exhibition, see pp. 57-58.

ments," and those mentioned above were all that it was practicable to try in the time at Miss Hobbin's disposal. The results are still uncertain and, no doubt, other experiments will have to be made.

Another series of experiments made by Miss Hobbins was to note what changes take place in the parasite itself, and for this purpose hanging drops of fluid from the kidney, containing a small number of the parasites, were suspended from a cover-slip. Cells of vaseline were made on the slides, and the cover-slip with its hanging drop was placed on the cell.

The preparations were examined at intervals of a few minutes, and notes and drawings were made daily, the position of the parasite being denoted in each drawing so that any change could be easily detected. To the naked eye the parasite had the appearance of a rounded milky white dot. Under the microscope these dots were found to show several stages. Some of them appeared opaque and occasionally granular. These were the trophozoites which were in preparation for becoming microgametocytes. After the expiration of about twenty-four hours the outlines of a large number (generally about twenty) of smaller rounded masses could be seen inside the microgametocyte; they possessed a dark centre and a lighter ring round the periphery, and at a still later stage they were set free into the surrounding fluid. These masses were afterwards discovered to be groups of microgametes. Round the edge of each mass was a single layer of nuclei, which in the next stage separated one from another—each taking with it a small portion of the cytoplasm. Previously it had been thought that the bodies, described above as microgametocytes, were zygotes undergoing division preparatory to the formation of spores. Other of the parasites were found to contain large numbers of tiny spores with two sporozoites in each. These were set free by the bursting of the sporocyst.

A large amount of material was fixed in Bouin's fixative for examination by means of sections in Liverpool.

FAUNISTIC NOTES.

Various notes on the natural history of marine animals inhabiting the old " L.M.B.C." district are given below. Some of the observations referred to may receive more detailed attention when the opportunity occurs.

(1) A stranded Cephalopod, *Illex coindeti.*

In March attention was called to a large Cephalopod which had been stranded on the beach during the previous night. When first seen it had been mutilated by gulls, which had not only picked out the eyes but had attacked the viscera. The long tentacular arms had been cut off close to their bases, probably by the original captors of the specimen. The presence of six conical teeth on the distal semi-circumference of the suckers borne by the sessile arms enabled the observer to identify the specimen as *Illex coindeti.* Its dimensions were as follows :—Total length from base of sessile arms to posterior extremity—95 cm. ; circumference at mantle collar 56 cm. ; extreme width of posterior fin, 59 cm. ; average length of sessile arms, 40 cm. ; length of " pen," 71 cm.

H. C. Chadwick.

(2) Rare Polychaete larvae.

In a paper on " Recent Additions to the British Marine Polychæta," (*Ann. and Mag. of Nat. Hist.*, Series 9, Vol. VIII, p. 290, Sept. 1921) Professor W. C. McIntosh describes two interesting Polychætes from the plankton of Port Erin Bay. One of these is a post-larval stage of *Euphrosyne*, probably *E. foliosa*, which was first observed to occur sparingly in the plankton in December, 1905, and has been noted about the same time in several subsequent years. The other, of which several specimens representing post-larval stages were submitted to Professor McIntosh, is *Pelagobia longicirrata*, which has been observed in the mid-winter plankton on several occasions.

H. C. Chadwick.

(3) The Vestlet Anemone, *Cerianthus lloydii*, Gosse.

A fairly extensive colony of this somewhat rare tube-building anemone was found between tide marks on the shore of Piel Island, Barrow-in-Furness, in the spring of 1921. It extends in a vertical direction from rather above low water neap tides to beyond low water of the highest spring tides. It spreads laterally from a short distance south of the ferry pier, right round into that part of the Channel on the south side of Piel Castle known as "Basspool." The shore is mostly boulder clay with a surface of gravel which makes the extraction of specimens usually a matter of some difficulty. An ordinary garden spade has to be employed to get them out. The presence of the anemone is recognised by the spreading tentacles floating in the water just clear of the clay and gravel. A square block about the width and depth of the spade and having the anemone in the centre is dug out, carefully broken up, and the felted tube with the anemone inside extracted. The tube is seldom quite vertical in the clay. Its length varies from six to nine inches, according to the size of the anemone. The animal does not make any attempt to escape from its tube when disturbed. It simply contracts, by expelling water, to a fraction of its original size. The colony was examined frequently till October and continues in a flourishing state. Specimens were dug out from time to time and various experiments made to keep them alive in the aquaria. They were removed from their felty tubes and placed in upright glass-tubes about half-an-inch bore and six to eight inches long. In the first experiment the tubes were closely cemented to square glass plates with sealing wax. This was unsuccessful. Decomposition set in at the aboral extremity and gradually extended to the disk and tentacles. In the next experiment one end of the glass tube was softened in the flame of a blowpipe and a rounded opening made at the side. The tube was again cemented to the plate with sealing wax, taking care that the hole remained open. This form of tube proved quite successful, but in course of time it became detached from the plate. Finally, the tubes were fixed into thin circular blocks of concrete, made from an equal mixture of fine sand and cement. The communication between the base of the tube and the exterior was made by laying a rod across the mould before the mixture was poured into it. The communication at the base appears to be important, at any rate all our specimens died when no opening was left. Specimens have lived now for many months in these tubes, feeding freely on small pieces of mussel or crab liver. The vestlets when violently disturbed retire into their tubes with a rapid series of corkscrew-like movements and a slight shrinking of the column. The colours of the Piel Island colony vary much more than is described by Gosse. The column is always pale buff or whitish. The disk and tentacles vary in colour from chocolate to pellucid white. In some, the tentacles and disk are wholly chocolate colour. In others, the disk is white, and the tentacles chocolate. Occasionally both the disk and tentacles are pellucid white, or the tentacles only may have faint ladder-like chocolate bands.

The only previous record for the adult in the Irish Sea area is that given by Gosse in "The British Anemones and Corals," page 270. He had specimens sent from the Menai Strait collected by Mr. Alfred Lloyd in 1856, and after whom the species is named. The discovery of *Cerianthus* on Piel Island was purely accidental and it is little use speculating on the age of the colony, but it would be interesting to know if the colony in Menai Strait still exists after the lapse of sixty-five years. When the preliminary investigations were made, before the laboratory was established at Roa Island, some twenty-five years ago, I noted a considerable colony of white and orange plumose anemones (*Metridium dianthus*, Ellis) on the underside of the platform of Roa Island ferry pier, near the seaward end. Extensive repairs have been made at various times in the interval and practically the whole of the platform has been renewed. The colony has persisted through all the changes and is as extensive now as it was twenty-five years ago. There is a distinct indication of segregration of the orange and white members composing the colony. There is only slight intermingling.

There are indications that other colonies of the vestlet exist in the Irish Sea area. Its pelagic larva, known as "*Arachnactis*," is not rare at times in the surface plankton of Port Erin Bay. It is quite easy to fail to find the adults, even after the colony has been located. If the tide has finished ebbing when one arrives at the spot, the chances are that no vestlets will be seen. That has been my experience on more than one occasion. Even then, however, it is possible to detect the exposed end of the felted tube.

The south-east shore of Piel Island has long been known to be rich in some marine forms. It carries an extensive growth of algae such as *Halidrys*, *Laminaria*, etc. It was this particular area that supplied Drs. Gamble and Keeble with practically all the *Hippolyte varians* used in their lengthy experiments in colour change 1898-1900. *Hippolyte* is still abundant. Other crustacea and various echinoderms are to be found amongst the algae and under the stones. *Pholas candida* lives in the boulder clay.

A. Scott.

(4) The occurrence of *Priapulus caudatus*, Lamarck, in Luce Bay.

Priapulus caudatus, Lam. This Gephyrean was noticed for the first time in the autumn of 1919 and is recorded in Appendix B., Thirty-third Annual Report of the Liverpool Marine Biology Committee. It may be useful to explain where and how it was obtained. Early in October, 1919, the Lancashire Fisheries steamer collected a number of adult plaice in Luce Bay, which were eventually transferred to the tanks at Piel. After a day or two a quantity of regurgitated empty shells of *Scrobicularia* began to appear at the bottom of the tanks. When the debris was removed one nearly complete and two partially digested specimens of *Priapulus* were found. The best specimen was preserved and sent to Liverpool. No further specimens resulted from the visit to Luce Bay in 1920, although a careful lookout was kept. Adult plaice from Luce Bay were landed at the end of September, 1921. Almost at once after they were put in the tanks, a very fine specimen of *Priapulus* was regurgitated by one of the fish. There were slight indications that the Gephyrean was not quite dead, but it did not recover. It was preserved as a museum specimen. One can safely conclude that *Priapulus caudatus* is an inhabitant of the sandy bottom of Luce Bay.

A. Scott.

(5) Various Nudibranchs.

Archidoris tuberculata, Cuv., *Polycera quadrilineata*, O.F.M., *Dendronotus arborescens*, O.F.M., *Facelina drummondi*, Thomp., and *Fiona marina*, Forbes. These five species of Nudibranchiata are occasionally found in the spring on the shore at low water on the west side of Roa Island ferry pier. The *Archidoris* and the *Facelina* are moderately common, but the others appear to be rare. Four specimens of *Fiona* were found in the crevices of the wood of the ferry pier in May, 1921. The *Archidoris*, *Polycera* and *Facelina* live amongst the algæ and under the stones. Although *Polycera* was rare on the Roa Island shore at the same time, it was occurring in immense numbers on the *Halidrys* and *Laminaria* on Piel Island shore, near the colony of *Cerianthus*. The ebbtide left the swarm of *Polycera* stranded, and as it rose again they floated off adhering to the surface film of the water. Twenty to forty specimens at a time could be scooped up by hand. These five species of Nudibranchiata apparently only came into the shallow water to spawn. They were never seen in the summer and autumn. Specimens of the whole five species were kept alive in the aquaria for some weeks. They all spawned at frequent intervals, gradually getting smaller each time, and finally disappeared.

A. Scott.

Nudibranchs from Port Erin.

Crab pots set off Bradda Head and brought ashore at the end of the season, October 1st and 2nd, yielded a rich harvest of invertebrates, including a large number of Nudibranchs belonging to at least a dozen species, the more notable of which were:—*Triopa clavigera*, *Polycera quadrilineata*, *Ancula cristata*, *Doto coronata*, *Coryphella landsburgii*, *Galvina picta*, *Galvina farrani*, *Tergipes despectus*, *Facelina drummondi*, and the rare *Hero formosa.*

E. C. Herdman.

(6) The Oyster Parasite, *Bucephalus haimeanus.*

While examining the morphology of cockles, during a vacation class for school teachers, held at Piel, Barrow-in-Furness, in August, 1920, several molluscs were noticed in which the tissues in the dorsal region of the visceral mass were stained yellow. On further examination it was seen that this colouration was due to a tangled mass of very long, filamentous sporocysts of a trematode parasite. These contained very numerous cercaria larvæ. The most prominent character of the latter was the extremely long, highly mobile, bifurcated tail. A further collection of cockles was made and examined. It was very easy to distinguish the infected molluscs by the faint yellow staining of the tissues round the liver and gonads. About half-a-dozen individuals in fifty were thus found to harbour the parasites which are provisionally identified as above.

Jas. Johnstone.

"L.M.B.C. MEMOIRS."

Although the Liverpool Marine Biology Committee has now been dissolved, it is thought well to retain the former title for this series of publications. They have become well-known in laboratories and are referred to in literature as the "L.M.B.C. Memoirs," and it would only lead to confusion to change the title, although they are no longer published by a Committee but by the Oceanography department of the University.

Since the last report was published, the Memoir on APLYSIA has been issued to the public. HIMANTHALIA, by Miss L. G. Nash, M.Sc., is ready to print; Miss E. L. Gleave, M.Sc., has nearly completed her Memoir on DORIS, the Sea-lemon; Mr. Burfield, is writing the Memoir on SAGITTA; Mrs. Bisbee has made further progress with TUBULARIA, and still other Memoirs are in preparation.

The following shows a list of the Memoirs already published or arranged for:

I. ASCIDIA, W. A. Herdman, 60 pp., 5 Pls.
II. CARDIUM, J. Johnstone, 92 pp., 7 Pls.
III. ECHINUS, H. C. Chadwick, 36 pp., 5 Pls.
IV. CODIUM, R. J. H. Gibson and H. Auld, 3 Pls.
V. ALCYONIUM, S. J. Hickson, 30 pp., 3 Pls.
VI. LEPEOPHTHEIRUS AND LERNÆA, A. Scott, 5 Pls.
VII. LINEUS, R. C. Punnett, 40 pp., 4 Pls.
VIII. PLAICE, F. J. Cole and J. Johnstone, 11 Pls.
IX. CHONDRUS, O. V. Darbishire, 50 pp., 7 Pls.
X. PATELLA, J. R. A. Davis and H. J. Fleure, 4 Pls.
XI. ARENICOLA, J. H. Ashworth, 126 pp., 8 Pls.
XII. GAMMARUS, M. Cussans, 55 pp., 4 Pls.
XIII. ANURIDA, A. D. Imms, 107 pp., 8 Pls.
XIV. LIGIA, C. G. Hewitt, 45 pp., 4 Pls.
XV. ANTEDON, H. C. Chadwick, 55 pp., 7 Pls.
XVI. CANCER, J. Pearson, 217 pp., 13 Pls.
XVII. PECTEN, W. J. Dakin, 144 pp., 9 Pls.
XVIII. ELEDONE, A. Isgrove, 113 pp., 10 Pls.
XIX. POLYCHAET LARVÆ, F. H. Gravely, 87 pp., 4 Pls.
XX. BUCCINUM, W. J. Dakin, 123 pp., 8 Pls.

XXI. Eupagurus, H. G. Jackson, 88 pp., 6 Pls.
XXII. Echinoderm Larvæ, H. C. Chadwick, 40 pp., 9 Pls
XXIII. Tubifex, G. C. Dixon, 100 pp., 7 Pls.
XXIV. Aplysia, Nellie Eales, 84 pp., 7 Pls.
Himanthalia, L. G. Nash.
Doris, E. L. Gleave.
Tubularia, R. C. Bisbee.
Sagitta, S. T. Burfield.
Ostracod (Cythere), A. Scott.
Asterias, H. C. Chadwick.
Botryllus, E. C. Herdman.
Nematode, T. Southwell.

As the result of a slight fire in the Zoology Department of the University, a portion of the stock of L.M.B.C. Memoirs has been partially destroyed. There are a certain number of damaged copies of some of the Memoirs which are stained or singed externally, but are still quite usable, and are suitable for laboratory work. It has been decided to offer these at prices ranging according to the condition from one-half to one-fourth of the published prices, as follows:—Memoir I., Ascidia, 6d. to 9d.; VI., Lepeophtheirus and Lernæa, 6d. to 1s.; VII., Lineus, 6d. to 1s.; XIII., Anurida, 1s. to 2s.; XIV., Ligia, 6d. to 1s.; XV., Antedon, 6d. to 1s. 3d.

Memoirs should be ordered from the University Press, Ashton Street, Liverpool.

Appended to this Report are:—

(A) The Laboratory Regulations—with Memoranda for the use of students, and the Regulations in regard to the "Edward Forbes Exhibition" at the University of Liverpool;

(B) The Financial Statement, List of Subscribers, and Balance Sheet for the year.

Appendix A

LIVERPOOL MARINE BIOLOGICAL STATION AT PORT ERIN.

General Regulations.

I.—This Biological Station is under the control of the Oceanography department of the University of Liverpool, and the Director of the Laboratory is the Professor of Oceanography.

II.—In the absence of the Director, the Station is under the temporary control of the Naturalist-in-Charge (Mr. J. R. Bruce, M.Sc.), who will keep the keys, and will decide, in the event of any difficulty, which places are to be occupied by workers, and how the tanks, boats, collecting apparatus, etc., are to be employed.

III.—The Naturalist-in-Charge will be ready at all reasonable hours and within reasonable limits to give assistance to workers at the Station, and to do his best to supply them with material for their investigations.

IV.—Visitors will be admitted, on payment of a small specified charge, at fixed hours, to see the Aquarium and Museum adjoining the Station. Occasional public lectures are given in the Institution by members of the staff.

V.—Those who are entitled to work in the Station, when there is room, and after formal application to the Director, are :—(1) Annual Subscribers of one guinea or upwards to the funds (each guinea subscribed entitling to the use of a work place for three weeks), and (2) others who are not annual subscribers, but who pay the University 10s. per week for the accommodation and privileges. Institutions, such as Universities and Museums, may become subscribers in order that a work place may be at the disposal of their students or staff for a certain period annually ; a subscription of two guineas will secure a work place for six weeks in the year, a subscription of five guineas for four months, and a subscription of £10 for the whole year.

VI.—Each worker is entitled to a work place opposite a window in the Laboratory, and may make use of the microscopes and other apparatus, and of the boats, dredges, tow-nets, &c., so far as is compatible with the claims of other workers, and with the routine work of the Station.

VII.—Each worker will be allowed to use one pint of methylated spirit per week free. Any further amount required must be paid for. All dishes, jars, bottles, tubes, and other glass may be used freely, but must not be taken away from the Laboratory. Workers desirous of making, preserving, or taking away collections of marine animals and plants, can make special arrangements with the Director in regard to bottles and preservatives. Although workers in the Station are free to make their own collections at Port Erin, it must be clearly understood that (as in other Biological Stations) no specimens must be taken for such purposes from the Laboratory stock, nor from the Aquarium tanks, nor from the steam-boat dredging expeditions, as these specimens are the property of the Institution. The specimens in the Laboratory stock are preserved for sale, the animals in the tanks are for the instruction of visitors to the Aquarium, and as all the expenses of steam-boat dredging expeditions are defrayed from the funds, the specimens obtained on these occasions must be retained (*a*) for the use of the specialists working at the Fauna of Liverpool Bay, (*b*) to replenish the tanks, and (*c*) to add to the stock of duplicate animals for sale from the Laboratory.

VIII.—Each worker at the Station is expected to prepare a short report upon his work—not necessarily for publication—to be forwarded to the Director before the end of the year for notice, if desirable, in the Annual Report.

IX.—All subscriptions, payments, and other communications relating to finance, should be sent to the Accountant, the University of Liverpool. Applications for permission to work at the Station, or for specimens, or any communications in regard to the scientific work should be made to the Director, Department of Oceanography, University, Liverpool.

Memoranda for Students and Others working at the Port Erin Biological Station.

Post-graduate students and others carrying on research will be accommodated in the small work-rooms of the ground floor laboratory and in those on the upper floor of the new research wing. Some of these little rooms have space for two persons who are working together, but researchers who require more space for apparatus or experiments will, so far as the accommodation allows, be given rooms to themselves.

Undergraduate students working as members of a class will occupy the large laboratory on the upper floor or the front museum gallery, and it is very desirable that these students should keep to regular hours of work. As a rule, it is not expected that they should devote the whole of each day to work in the laboratory, but should rather, when tides are suitable, spend a portion at least of either forenoon or afternoon on the sea-shore collecting and observing.

Occasional collecting expeditions are arranged under guidance either on the sea-shore or out at sea, and all undergraduate workers should make a point of taking part in these.

It is desirable that students should also occasionally take plankton gatherings in the bay for examination in the living state, and boats are provided for this purpose at the expense of the Biological Station to a reasonable extent. Students desiring to obtain a boat for such a purpose must apply to the Curator at the Laboratory for a boat voucher. Boats for pleasure trips are not supplied by the Biological Station, but must be provided by those who desire them at their own expense.

Students requiring any apparatus, glass-ware or chemicals from the store-room must apply to the Curator. Although a few microscopes are kept at the Biological Station, these are mainly required for the use of the staff or for general demonstration purposes. Students are therefore strongly advised, especially during University vacations, not to rely upon being able to obtain a suitable microscope, but ought if possible to bring their own instruments.

Students are advised to provide themselves upon arrival with the "Guide to the Aquarium" (price 6d.), and should each also buy a copy of the set of Local Maps (price 2d.) upon which to insert their faunistic records and other notes.

Occasional evening meetings in the Biological Station for lecture and demonstration purposes will be arranged from time to time. Apart from these, it is generally not advisable that students should come back to work in the laboratory in the evening; and in all cases all lights will be put out and doors locked at 10 p.m. When the institution is closed, the key can be obtained, by those who have a valid reason for entering the building, only on personal application to the Naturalist-in-Charge.

REGULATIONS OF THE EDWARD FORBES EXHIBITION.

[Extracted from the *Calendar* of the University of Liverpool for the Session 1920-21, p. 427.]

"EDWARD FORBES EXHIBITION.

"Founded in the year 1915 by Professor W. A. Herdman, D.Sc., F.R.S., to commemorate the late Edward Forbes, the eminent Manx Naturalist (1815-1854), Professor of Natural History in the University of Edinburgh, and a pioneer in Oceanographical research.

The Regulations are as follows :—

(1) The interest of the capital, £100, shall be applied to establish an Exhibition which shall be awarded annually.

(2) The Exhibitioner shall be a post-graduate student of the University of Liverpool, or, in default of such, a post graduate student of another University, qualified and willing to carry on researches in the Manx seas at the Liverpool Marine Biological Station at Port Erin, in continuation of the Marine Biological work in which Edward Forbes was a pioneer.

(3) Candidates must apply in writing to the Registrar, on or before 1st February.

(4) Nomination to the Exhibition shall be made by the Faculty of Science on the recommendation of the Professor of Zoology.

(5) The plan of work proposed by the Exhibitioner shall be subject to the approval of the Professor of Zoology.

(6) Should no award be made in any year, the income shall be either added to the capital of the fund, or shall be applied in such a way as the Council, on the recommendation of the Faculty of Science, may determine.

(7) The Council shall have power to amend the foregoing Regulations, with the consent of the donor, during his life-time, and afterwards absolutely; provided, however, that the name of Edward Forbes shall always be associated with the Exhibition, and that the capital and interest of the fund shall always be used to promote the study of Marine Biology."

Edward Forbes Exhibitioners.

1915	Ruth C. Bamber, M.Sc.
1916	E. L. Gleave, M.Sc.
1917	C. M. P. Stafford, B.Sc.
1918	Catherine Mayne, B.Sc.
1919	George Frederick Sleggs, B.Sc.
1920	Laura Thorpe, B.Sc.
1921	Maisie Hobbins, B.Sc.

Appendix B.

FINANCIAL STATEMENT.

On December 31st, 1919, the Honorary Treasurer of the Liverpool Marine Biology Committee handed over the accounts of the Port Erin Biological Station to the Accountant of the University of Liverpool, with the following assets :—

	£	s.	d.
Balance in Treasurer's hands	2	10	7
Memoir Fund (for printing)	229	4	4
Extension Fund (for buildings)	37	4	9
Ministry of Agriculture and Fisheries Fund (for Fisheries research)	91	3	6

Capital Account.

1. British Workman Public House Co., 99 shares £1 each, fully paid.
2. The Trustees of the British Association (1896) Fund also transferred to the University their fund of about £1,000 to be held for the benefit of the researches carried out at Port Erin in continuation of the work of the Liverpool Marine Biology Committee. This has since been invested in £1,135 16s. 7d. Funding Loan, 4 %, 1960-1990.

Interest on Investments.

The investments mentioned above have yielded an income, during the year, 31st July, 1920 to 31st July, 1921, of £76 13s. 3d.

Government Grants.

The Isle of Man Government, by the terms of their agreement with the University of Liverpool, makes an annual grant of £200 in aid of the Fish Hatching work done at the Station. This sum is expended in part payment of the cost of fuel, lighting, and general supplies and apparatus—such a fraction of the cost of maintaining the Station, apart from salaries, as may reasonably be debited to the cost of this work.

The Development Commission have recommended to H.M. Treasury that an annual grant of £1,000 be made to the Station in respect of the general maintenance thereof, as apart from the fish hatching work (the cost of which is provided as stated above). This grant is expended in the salaries of the Naturalist-in-charge, Assistant Curator and Assistant; in the provision of apparatus, chemicals, books, various structural alterations, printing, and part of boat hires. A scheme of allocation for these purposes has been approved by H.M. Treasury and a separate account of the expenditure is kept for submission to the Development Commissioners.

This grant was made in respect of the Government financial year, April 1st, 1921 to March 31st, 1922, but it is expected that it will be renewed for, at least, the succeeding four years. A first instalment of £500 became available in May, 1921, and expenditure really began in June, 1921. Up to the end of the University financial year (31st July,1921) £60 6s. 8d. had been expended, and this appears in the general account as the "Transfer from Development Fund Account."

"Memoir" and "Extension" Funds.

These funds originated as special donations—(1) for the publications of the "L.M.B.C. Memoirs," and (2) for the extension of the Buildings of the Station. The "Memoir" Fund is expended in the printing of new Memoirs. The latter are now sold by the Liverpool University Press, and the net proceeds of such sales appear on the "Receipts" side of the general account. For the last year a sum of £10 12s. 9d. was so obtained. The future policy of the Oceanography Department is to expend the balance of the "Memoir" Fund

(£158 7s. 6d.) in the publication of "Memoirs," as suitable manuscripts become available and then to endeavour to raise a publication Fund, the interest on which will be devoted to printing Reports and Memoirs.

The "Extension" Fund is being merged into the general one.

Other Sources of Income.

These are :—(1) Donations to special funds and subscriptions from supporters of the former "L.M.B.C." movement: in the year ended 31st July, 1921, the subscriptions and donations amounted to £116 16s. (2) Hire of Work Tables by Universities and private students: this amounted to £30. (3) Admissions to the public part of the Aquarium and Museum at the rate of 3d. per person: this brought in an income of £302 14s. 1d. (4) Proceeds of the Sale of "Guides to the Aquarium," picture post-cards showing the work of the Institution, and sales of specimens to students, &c.: in this way £38 4s. 5d. was obtained. (4) Finally, £12 12s. 6d. came from Bank Interest.

THE UNIVERSITY OF LIVERPOOL
OCEANOGRAPHY: PORT ERIN ACCOUNT.

LIST OF SUBSCRIPTIONS TO 31st JULY, 1921.

	£	s.	d.
Brunner, Mond & Co., Northwich...	1	1	0
Brunner, J. F. L., 43, Harrington Gardens, London, S.W.	2	2	0
Brunner, Roscoe, Belmont Hall, Northwich ...	1	1	0
Brunner, Sir John	2	2	0
Herdman, Professor W. A.	4	4	0
Hickson, S. J.	2	2	0
Holt, Miss	4	4	0
Holt, Alfred	1	0	0
Halls, W. J.	1	1	0
Hutton, J. A., Woodlands, Alderley Edge ...	2	0	0
Isle of Man Natural History Society	2	2	0
Jarmay, Sir John, Hartford, Cheshire	1	1	0
Manchester Microscopical Society...	1	1	0
Mond, R., Sevenoaks, Kent...	5	0	0
Mond, E. L.	5	0	0
Muspratt, Dr. E. K.	10	0	0
Nuttall, F. R. Dixon	2	2	0
Rathbone, Miss M.	1	1	0
Roberts, Mrs. Isaac, Thomery, S. et M., France ...	1	1	0
Robinson, Miss M. E., Holmfield, Aigburth, L'pool	1	0	0
Smith, A. T., 43, Castle-street, Liverpool... ...	1	1	0
Tate, Sir W. H.	4	4	0
Thompson, Edwin	1	1	0
Thornely, Miss, Field Head, Out Gate, Ambleside	2	2	0
Toll, J. M., 49, Newsham-drive, Liverpool ...	1	1	0
Walker, A. O., Ulcombe-place, Maidstone ...	1	1	0
Watson, A. T., Tapton Crescent-road, Sheffield ...	1	1	0
Whitley, E., 13, Linton-road, Oxford	5	0	0
	£66	16	0
Herdman, Professor (Special donation)	50	0	0
	£116	16	0

PORT ERIN BIOLOGICAL STATION.

Account of Receipts and Payments for the Year 1 August, 1920, to 31 July, 1921.

General Account

Payments		£ s. d.	Receipts		£ s. d.
To Salaries (including Insurance)—			By Balance—31 July, 1920		144 4 5
Naturalist-in-charge	31 13 4		,, ,, —Board of Agriculture and Fisheries		88 3 6
Curator	303 0 0		,, Interest on Investments		76 13 3
Assistants	227 9 9		,, Subscriptions and Donations		116 16 0
		562 3 1	,, Hire of Work Tables		30 0 0
,, Fuel, Light, Cleaning, &c.		124 17 7	,, Port Erin:—		
,, Books, Apparatus, Supplies		216 5 0	Admissions to Aquarium	302 14 1	
,, Sundries		6 3 7	Sale of Guides and Postcards	34 6 4	
,, Printing, Stationery, Postage		39 15 8	Sale of Specimens	3 18 1	
,, Boat hire		89 4 6			340 18 6
,, Rates, Taxes, Insurance		17 3 0	,, Rebate on Petrol Duty		12 11 0
,, Ordinary Repairs, Furniture		34 9 7	,, Grant from Tynwald Court		210 8 9
,, Legal Charges		2 2 0	,, ,, Development Fund, T'nsfer as below		60 6 8
			,, Bank Interest		12 12 6
					1089 14 7
			,, Balance, deficit to Balance Sheet		2 9 5
		£1092 4 0			£1092 4 0

Memoir Fund Account

To Expenditure to 31 July, 1921	£91 15 8	By Balance—31 July, 1921	£239 10 5
,, Balance carried to Balance Sheet	158 7 6	,, Sales and Net Proceeds of Publication	10 12 9
	£250 3 2		£250 3 2

Development Grant Account

To Transfer to General A/c to meet Salaries & Wages	£60 6 8	By Grant from Department Commission	£500 0 0
,, Balance carried to Balance Sheet	439 13 4		
	£500 0 0		£500 0 0

Extension Fund Account

To Balance carried to Balance Sheet	£37 4 9	By Balance—31 July, 1921	£37 4 9

PORT ERIN BIOLOGICAL STATION.

BALANCE SHEET, 31 JULY, 1921

LIABILITIES

	£ s. d.	£ s. d.
99 Years Lease of Port Erin Biological Station and Fish Hatchery from 5 July, 1920 ... ... (*Vide The Biological Station and Fish Hatchery Transfer Act*, 1920)		per contra
Donations:—		
Transfer from Liverpool Marine Biological Committee	909 14 3	
Mr. John Rankin	80 0 0	
		989 14 3
Memoir Fund		158 7 6
Development Fund		439 13 4
Extension Fund		37 4 9
		£1624 19 10

ASSETS

	£ s. d.	£ s. d.
99 Years Lease of Port Erin Biological Station and Fish Hatchery from 5 July, 1920 ... ... (*Vide The Biological Station and Fish Hatchery Transfer Act*, 1920)		per contra
Investments at Cost:—		
99 Shares in British Workman Public House Company, Limited	121 5 6	
Funding Loan 4 %, 1960-1990, £1135 16s. 7d.	788 8 9	
Victory Bond 4 %, £100	80 0 0	
		989 14 3
Cash in Isle of Man Banking Company, Limited, Port Erin Branch	582 16 2	
Cash in hands of Curator	50 0 0	
		632 16 2
Deficit on General Account		2 9 5
		£1624 19 10

We have examined the above Balance Sheet and certify that it is correct.

HARMOOD BANNER & SON,
Chartered Accountants.

LIVERPOOL, 27 *August*, 1921.

C. SYDNEY JONES,
Treasurer.

REPORT ON THE INVESTIGATIONS CARRIED ON IN 1921 IN CONNECTION WITH THE LANCASHIRE SEA-FISHERIES LABORATORY AT THE UNIVERSITY OF LIVERPOOL, AND THE SEA-FISH HATCHERY AT PIEL, NEAR BARROW.

EDITED BY

PROFESSOR JAMES JOHNSTONE, D.Sc.,

Honorary Director of the Scientific Work.

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INTRODUCTION.

The greater part of this Report consists of a summary and discussion of the results of two investigations that have now been carried on for a number of years: these are (1) the plaice research, commenced by the Committee in 1908 and then continued during 1919-21 as part of the work done under a special grant made by the Ministry of Agriculture and Fisheries, and (2) the biometric investigation of herring races, begun in 1913 as part of an international research. We think it desirable that these routine observations should now be suspended so that it may be considered what are the results and what they indicate. For the opportunity of publishing the complete results of the plaice work we are indebted to the Development Commissioners, who have kindly allowed us to spend the balance remaining over from the grant made for directed fishery research in the Irish Sea. In addition to these two series of data there remain Mr. Scott's numerous estimations of organisms present in the fourteen years' samples of plankton taken by Professor Herdman at Port Erin. These data are also being summarised and discussed, and it is hoped that the results may be ready in another year. It cannot be doubted that full consideration of the observations so far made will indicate new and fruitful lines of investigation, and it is probably inadvisable to continue working by purely routine methods without some interval of close criticism.

The Plaice Report.

This consists of :—

(1) A summary, brought up to date, of the measurements of Irish Sea plaice, made on the various fishing grounds, during the years 1908-1920, by the Officers of the Committee.

(2) A complete summary of all the results of the plaice-marking experiments made during the years 1906-1913.

(3) A summary of the results of observations made on board fishing vessels during the years 1919-1920. This work was arranged by the Oceanography Department as part of the scheme of "Directed Research in the Irish Sea."

(4) A general discussion of all the results obtained made from the practical administrative point of view.

The attitude taken up in the course of this work was that of the need for restrictions on seasons and methods of fishing should it appear that there is a progressive impoverishment of the Irish Sea plaice fisheries. The conclusions made from the work already done may be stated briefly (and rather dogmatically in the meantime) :—

(1) *Impoverishment of the Irish Sea Fishing Grounds.*

Nothing in the results obtained suggests that there has been such an impoverishment. There are ups and downs.

The causes of these fluctuations is an interesting, scientific problem, and one which may be solved—given sufficient resources for investigation.

(2) *Effect of War-time Restrictions on the Fishery.*

There is no evidence that the military restrictions, in operation in the Irish Sea in the years 1914-1918, had any observable effect on the abundance of the plaice there in 1919-1920.

(3) *Size-limits for Plaice.*

There is no evidence that a size-limit for plaice that may legally be landed would have any effect on the abundance of commercially valuable plaice on the Irish Sea fishing grounds.

A word or two may be said about what we regard as "evidence." *If* the Irish Sea plaice grounds are being impoverished by too much trawling ; *if* the military restrictions of 1914-1918 led to an accumulation of plaice in the Irish Sea, and *if* a size-limit could be shown to be useful in preserving the plaice grounds from impoverishment. *Then* the practical outcome of these findings would be administrative restrictions. These restrictions would create new legal offences, punishable by fines or imprisonments.

Therefore the scientific evidence that would justify us in making administrative restrictions and by-laws ought to be of the same nature, or just as convincing as would be the evidence required by the police courts for the conviction of a fisherman who would infringe these by-laws. We know what is the nature of the latter evidence, and we hold that the results obtained from these investigations have not the same degree of strength and ought not to be used for the establishment of new legal offences.

But the results that have been obtained may be strong enough to justify a fishery authority in spending money on what may be called fishery development. We do not say that it is because we do not know that any schemes of development are in contemplation. Also if a period of much greater exploitation of the fishing grounds should come about in the near future—say, as the result of a condition of severe food shortage—then the results that we give here will make it all the easier to find the point at which we may be taking more from the fishing grounds than the recuperative powers of the latter can stand. But we hope that the tendency of these investigations, and those others that they suggest, will be in the direction of culture and development.

The Natural History Results.

From the point of view of general marine biology the results indicated in the report raise very curious and fascinating (and perhaps economically significant) problems. The shallow sea off the Lancashire and Cheshire coasts, and the foreshore there, may be rather unattractive to the zoologist. The foreshore is mostly sand and mud; there is much pollution from the adjacent cultivated and densely populated land area, and the fauna and flora are commonplace from the point of view of the naturalist collector. But the entire region is one of extraordinarily high production because most of the organic matter, in the form of foodstuffs, that is consumed in the densely populated country draining into the Irish Sea off the coasts of Cumberland, Lancashire and Cheshire *is again converted into organic matter.* This enormous production of proteid, fat and carbohydrate that goes on in the sea, entirely from waste materials, is almost wholly beyond human control. Only in the case of the mussel transplantation experiments, made at Morecambe by the Committee, has there been any attempt at utilising this production from waste matters. The question of how still further to make use of the surplus production of the sea may well become one of prime importance in the future, and what appear now to be perfectly abstruse problems of pure marine biology may require to be studied in order that we may usefully control these powers of production of organic substance. Many things that are apparent in present economic tendencies suggest that this control over the regenerative power of the littoral seas simply must be acquired.

The conditions that we speak of result in a shallow sea densely *crowded* with marine organisms that have little or no economic value: mussels, cockles, and shellfish that are mostly unutilised; small plaice, dabs, flounders, solenettes, sprats, etc., that are not caught; "sea-weeds" that contain enormous stores of cellulose, chitine, and other substances that might be used, but are not—and so on.

Here we are only concerned with the plaice. The quantities that come into existence annually in the sea from the Solway Firth down to the coasts of North Wales are probably illimitable—in the sense that fishing operations, as at present carried on, do not appear to make any sensible difference in their abundance. Of all the plaice eggs that are spawned in the Irish Sea every year only a rather small percentage become transformed larvæ. A certain combination of conditions, temperature of the sea, density, strength and direction of resultant tidal streams and wind drifts, certain food organisms that appear just at the right time and in the right quantity, intensity of sunlight, etc.—probably all these and other conditions must co-operate in a timed manner in order that a large proportion of the fertilised plaice eggs produced during the spawning period may develop into baby plaice. Then, just for the few weeks that these larval plaice are living on the very shallow sea bottom just outside tide marks there must be plenty of the right kind of food organisms in the sand and in the water immediately over the latter—it will be no use if this plentifulness of food occurs a few weeks earlier or later than the very few weeks when the little plaice come close to the shore. A certain small proportion of the latter, therefore, are well fed and survive for a couple of years to be caught by the inshore trawlers, who, nevertheless, only catch a small fraction of the fish that are there. Further on, after the plaice have become about three years old, a small fraction of them migrate out into deeper waters, beyond the territorial limits, and are caught by the smacks and steam trawlers. Hitherto it is the fate of this latter fraction of a per cent. of the whole plaice population, annually coming into existence, that has been studied. Of the fate of the plus 99 per cent. that perish before they are big enough to be caught by a trawl-net we know hardly anything.

A very few, then, of the plaice that can be taken in a shrimp-trawl migrate out to sea, become big, valuable fish, spawn, and are sooner or later caught. This fraction consists of individuals that have greater "vitality," grow more rapidly, are more "restless," and are more precocious in their assumption of sexual maturity than are the average fish. The mediocre individuals—which constitute by far the greater number—are less variable, and they tend to remain longer on the overcrowded nursery grounds, where they develop and grow slowly. How to assist them in obtaining better conditions of life may well be the great task of fish culture of the future, and all experimental and observational work and all practical transplantation operations help to solve this problem. Then there is the greater problem of the utilisation of surplus, "waste" production. The substance of the hundredweights of plaice that die in the sea uselessly (in contrast with the ounces that are caught usefully) is not lost, but appears later in the forms of crabs, molluscs, worms, starfishes, sea-weeds, and a multitude of other organisms that have—*as yet*—no commercial significance for us: at the most we think about them as a possible form, or source, of manure! Fishery work of the future will probably be dominated by the impulse to utilise the waste production of the shallow seas, just as that of the past has been obsessed by the fear of depletion and has resulted in successive crops of restrictions of very doubtful value. This idea of making use of surplus production seem to us to be the one which must give the keynote to the scientific research of the near future and reconcile the administrators to investigations which, no doubt, seem abstruse and pedantic in the extreme.

Further Work on the Plaice.

Some other researches, which are not of a routine nature, have been made, or are in progress, but are not published here. A series of drift-bottle experiments and corresponding fish-marking experiments were made by W. C. Smith in the study of the Solway spawning grounds. These tend to show that the area of the Irish Sea, north from Isle of Man and St. Bees' Head, is a self-contained one, so far as the plaice is concerned. Along with this an account of the Cumberland sea-fisheries in 1919 has been prepared. Collections of small plaice were made on the Manx and Cheshire foreshores by W. Birtwistle and W. C. Smith, and the feeding of these has been studied by A. Scott, who has also identified the food organisms found in a large number of larval and post-larval plaice spawned and reared at Port Erin : the results of this latter investigation are being published elsewhere. Plankton is being collected from the spawning and rearing ponds at Port Erin, and this is being described by A. Scott, for comparison with collections being made simultaneously in the adjacent sea. It is hoped that some useful information as to the nutrition of larval plaice may thus be obtained. Some much-needed experimental work on conditions of metabolism of developing plaice eggs has also been commenced by Professor Dakin, but this research is still in the tentative stages. Finally, a study of morphological variability in plaice is also being made.

The Biometric Investigation of the Herring.

In 1913 the Ministry of Agriculture and Fisheries requested this Laboratory to take part in a general scheme of investigation into the various races of herring which were assumed to inhabit

North European Seas. It was previously known that herrings from the North Sea, Baltic, Norwegian coasts, etc., presented various peculiarities—mainly in the proportions of the parts of the body—and it was thought that these variations in form were good evidence in favour of the idea that each great sea area had a different " race " of herrings, and that there was little or no inter-mixture between these various races. The migrations and shoaling movements made by the fish were, it was thought, all local ones. It was assumed that by making large series of measurements certain bodily characters could be found which would serve to distinguish between these various races. The first series of measurements were made by Mr. W. Riddell in 1913 and 1914, and the research was then suspended until 1919, when it was resumed by Mr. W. Birtwistle and Miss H. M. Lewis.

It was suspected that even in such a small area as the Irish Sea there would be more than one race of herrings. It is known, of course, that there are at least two such races: one which shoals off the S.W., S. and S.E. Coast of Isle of Man sometime about May or June, and then spawns in August or September, when the shoals disperse. Another school of herrings shoals in Cardigan Bay sometime about October and November, and then proceeds to spawn. In this case the shoaling and spawning begin first at the southern extremity of Cardigan Bay and then takes place a little later in the year in Carnarvon Bay, and finally off the North Coast of Anglesey. This is the usual progress of the fishing, and what we know about it is derived from the catches made by the local boats, for we have never been able to make big fishing experiments ourselves. The herrings may, however, appear much earlier in the spring, off the Manx coasts, than May, when the commercial fishery usually begins, and it is quite possible that they are there from the beginning of the year, but their quality is so poor that it is not worth while catching them.

Thus there appeared to be two " races " of herrings in the Irish Sea—the Manx summer and the Welsh winter spawners. But the conditions are not quite so simple as this. It has been known for some years that herrings may be caught by means of trawl-nets, and big catches were so made, before the war, by steam vessels working in the North Channel (between Scotland and Ireland) and in St. George's Channel (off the Smalls). Some of these fish were examined in 1913 and it was found that they were different from those obtained from the Isle of Man and the Welsh Bays. Further, in 1921 quite unusual conditions were observed.

At various times in the past there have been commercial fisheries for herrings off the coasts of Cheshire, Lancashire and Cumberland, where the fish do not occur in the same regular way that they are found off the Manx and Welsh coasts. In 1894 they appeared in Liverpool Bay, and the Morecambe vessels followed them, catching the fish with drift-nets in the estuary of the Mersey itself and up the latter to near the entrance to the Manchester Ship Canal. Quite big catches were made for a time and then the herrings disappeared. At various times in the past, even in the eighteenth century, the herrings are recorded from the Lancashire and Cheshire coasts, and there are many records of their occurrence in the Minutes of Evidence of the various Fishery Commissions. Long ago there used to be a fishery off the coast of Cumberland, and the " Parton Herrings," caught a few miles north of Whitehaven, had a great reputation and have left a kind of legend in that part of the district. For many years, however, there have been no herrings off the Cumberland, Lancashire and Cheshire coasts, or, at least, not nearly enough to give rise to a distinct fishery. Now and then, of course, a few fish may be caught almost anywhere along these coasts, and the young ones, of one year old or less, are always there.

At the end of 1921, however, Morecambe Bay was reported to be " full of herrings," and about the same time they were being caught off the coast of Cumberland. Some small samples were obtained, but not regularly, for there was no drift-net fishery. (Quite big catches were, however, taken in the " baulks " at Heysham.) The fish were exceedingly lean and were very poor eating. Most of them were spent though so many were found to be " full " that it seems probable that these fish were shoaling and spawning. Apparently they were present all along the coast from the Solway down to Great Orme's Head.

Thus we have to consider (1) the regular summer herrings that spawn in the region between Ardglas, in Ireland, and the Isle of Man, and (2) the equally regular winter spawning in Cardigan and Carnarvon Bays : these two fisheries never appear to fail. Then there are irregular fisheries which occur off the Cumberland, Lancashire and Cheshire coasts after long intervals of time.

When the biometric investigations were commenced it was thought that each of these regular or irregular fisheries was that for a distinct " race " of fish. In order to establish the characters of these races a large number of fish had, presumably, to be measured and studied. There is so much individual variability between fish and fish that many hundreds would have to be measured in order to get reliable average values for each of the characters taken as diagnostic of the various races. Also the measurements were rather delicate ones, subject to some considerable, unavoidable errors ; the fish were not always in good condition when they were received ; even the examination of so small a sample as 50 was quite a long job ; different measurers did not always get precisely the same results ; we were never quite sure what were the best " characters " to measure—in short, the methods were not perfectly satisfactory ones and it was thought desirable to suspend the routine collection of data for a while and see what was to be made out of those already accumulated.

Believing that there were only the two main "races"—the Manx and Welsh ones—we thought the best method was to spread the collection of measurements over several years and to "lump" together all the samples obtained from Isle of Man, irrespective of the month or year of collection. So also with the Welsh fish. In that way we hoped to get such big series of data that the averages, and other statistical functions deducible therefrom, would be fairly representative ones. Now this method may be quite wrong.

Even with quite small samples taken in the same region, and after intervals of some weeks, there may be quite noticeable differences: differences as big as those obtained when we contrast the fish taken from Isle of Man with those taken from the Welsh coasts. This may, conceivably, be the case even if we hold that there are only the two main races. It may be that in taking the sample this week we have "accidentally" included more of the herrings that vary from the average in one direction while, in the next small sample, we may have included more of the herrings that vary from the average in the other direction. If this is so there is a test, based by Professor Karl Pearson on the statistical theory of random sampling, which can be applied.

But it is also possible, and some results of general biology make it quite likely, that there is another explanation. It may be that, instead of two main "races" there are really a number of "sub-races," or "genotypes," that is, strains of herrings, that are really permanent, or the same from generation to generation, except in so far as they may vary by inter-mixture with each other. This inter-mixture may, however, be regarded as rather improbable because of the tendency of the herrings to remain together as lonely aggregated schools. There are, then, a number of strains, or genotypes, of Irish Sea herrings differing from each other in those shapes, or proportional lengths of parts of the body which we call morphological characters, and those differences which we can observe in studying samples obtained month by month from the same fishery region may be due to the successive appearance of the various genotypes, or to the predominance of one or more of them in the samples. Further, the various genotypes may respond differently to the nature of the environment, the temperature and salinity of the water, or the reaction or some other physical condition. In the course of the Manx summer fishing, for instance, these physical conditions change markedly, and so there may be successive immigrations of different herrings—something like this is really what the fishermen appear to think is the actual case. If so, then, it will be wrong in principle to adopt a method of "lumping" together data obtained from the same region in order merely to get the big samples, which appear to be necessary from the statistical point of view.

It is with these considerations in mind that a critical study of the methods and data of the herring race investigation has been attempted by Mr. Birtwistle and Miss Lewis.

Shellfish Investigations.

Two troublesome questions arose in the course of the administrative work of the Committee: (1) the alleged overcrowding of some of the cockle beds in the neighbourhood of the Dee, and (2) the pollution of the mussel beds in the estuary of the Ribble. The former difficulty originated in complaints made by some fishermen that the cockles on certain beds were so small that most of them passed through the legal gauge. This was probably the case, but the matter was not to be remedied by reducing the legal size and so enabling a few men to glut their customers with small cockles fetching a much smaller price. In such circumstances the remedy must lie in transplantation. The beds were examined and counts made of the numbers of cockles present in a square foot of sand on various parts, but the investigation was not pressed since it had little interest except where associated with some other shellfish research, which we have not yet been able to start. It has now been shown by the past work of the Committee that conditions of local overcrowding and stunting of growth, both with regard to cockles and mussels, can easily and profitably be remedied by transplantation. The difficulties are administrative ones and are only to be removed by a rational system of control over the foreshore fisheries.

The Ribble Mussel Fisheries.

In 1921 the mussels taken from the Ribble Estuary again came under suspicion and several inspections were made by Messrs. Scott and Birtwistle, with the cordial assistance of the Harbour Authority. I saw this district in 1913, when there was also suspicion that mussels growing there were communicating typhoid fever. Very marked changes have occurred and these are due to the extension seaward of the training walls built in order to establish the new channel leading up to the Port of Preston. Charts marked then and in 1921 show these changes very clearly, and the altered conditions must be taken into account. The fact is that an almost continual revision of the charts representing the conditions of the mussel and other shellfish beds, channels and sewer outfalls is quite necessary in order that this question of sewage contamination may be studied in a really satisfactory manner. Every case that arises demands renewed local survey.

There are two implicated regions in the present case: (1) the mussel beds on the foreshore, adjacent to the St. Annes-Lytham shore, and (2) the mussels growing on the training walls, much further away from the primary sources of pollution. The precise locality under (1) in question in

1921 was that known as "Church Scar," and this is subject to recent and significant sewage pollution. The adjacent shore is the *locus* of a good, residential population, and it is a well-known holiday resort, so that the contamination of the sea in its vicinity cannot be said to be free from danger. It is a place where people may go to recuperate after illness, and so there is always the chance that convalescent typhoid patients, who are still in the infective stage, may be temporarily resident there. The distance between the mussel beds and the sewer outfalls is short, and so quite a small period of time may elapse between the discharge of dejecta into privies ashore and the fouling of the mussels with the resultant sewage, which is quite untreated. There has actually been a barge (with a privy on board) moored on the Scar and inhabited by workmen, but we are inclined to regard this contributory source of pollution as less objectionable than that resulting from the much better-off population living in the St. Annes-Lytham district.

The case is rather different with regard to the pollution of the channel adjacent to the training walls. Much of this must have its origin at Preston and the distance is therefore considerable and the pollution remote in point of time. Bacteriologically there is little difference between the two regions (1) and (2), but the strong impression made on Messrs. Scott and Birtwistle in 1921 and on myself in 1913 was that the bacteriological evidence might safely be neglected so far as the training wall mussels were concerned. Thus we disregard the bacteriological evidence, though the latter shows that the contamination both at Church Scar and on the training walls is gross in its degree. It is fair to say that the conditions on Church Scar are such that closure is to be urged, but this conclusion we are reluctant to make in the case of the other locality.

Something must therefore be said as to the general question of shellfish pollution by way of justifying these findings and also because this matter looks like again becoming one of public importance.

Enteric Fever and its Incidence.

It is instructive to notice the very remarkable way in which the mortality from enteric fever has diminished during the period of modern public health administration. The following figures have been extracted from the Report of the Registrar-General for 1919, and the decrease is most obvious :—

Death Rate, per Million Persons living in England and Wales, from Enteric Fever during the last 80 *years.*

1838–1842	1,053	1891–1895	174
1847–1850	1,246	1896–1900	175
1851–1855	983	1901–1905	113
1856–1860	842	1906–1910	70
1861–1865	922	1911–1915	47
1866–1870	850	1916	30
1871–1875	374	1917	28
1876–1880	277	1918	26
1881–1885	216	1919	16
1886–1890	179		

It is to be noted that the statistics from 1838 to 1870 include enteric fever, typhus fever and pyrexia, these diseases not being distinguished in the above data for the period in question. There can be little doubt that the contribution made by the two latter causes was considerable during the first half of the nineteenth century. The conditions due to the rapid development of the modern factory system, the overcrowding and insanitary housing of that period, unemployment and general malnutrition among much of the artisan and labouring classes during the "hungry forties"—these were, no doubt, responsible for the "destitution disease," which we now know typhus to be. About 1870, however, enteric fever became distinguished, and it alone appears in the table for the years subsequent to that date. During the latter half of the nineteenth century typhus fever practically disappeared from England—the result of better housing and nutrition, and plain, commonsense methods of sanitation.

But even when we take account of this qualification of the meaning of the table it is plain that the mortality from enteric fever has steadily diminished throughout the whole period, and this is so even during the war years 1914-1918 (for which years the death rate is calculated only for the civilian population). One might, at first sight, have expected some relaxation of public health administration during those years of strain, but this has not been the case—the rate of decrease is even greater than it was in the preceding decade. The entire record is a remarkable and very creditable one, and it ought to lead to a renewed appreciation of the medical service as it is organised in this country. It does not, at first, occur to one to reflect that this is the only profession which, by perfecting its work, tends always to render itself unnecessary !

It would be worth while, if there were the opportunity, to examine into the measures by which this notable reduction in the mortality from typhoid has been brought about. It is probable that no one line of public health work is to be singled out—for instance, prophylactic treatment only came into general use during the war period and was applicable only in the war services. What we have to thank for the effect noted has been the consistently maintained and always improved public health administration and a general, all-round effort to do all that is possible to minimise the chance that any person whatever in the population might contract epidemic disease, because with modern means of intercommunication the risk of infection has always tended to become greater, and class-distinctions tend to have no significance in this connection —it is all the same to the public health administrator what is the social standing of the patient : the labourer incubating for typhoid and using a privy on a barge moored on Church Scar has just the same " epidemiological value," neither more nor less, as has a Manchester millowner residing at St. Annes, if the latter also harbours *Bacillus typhosus.* This attitude has its significance: *any* person who is suffering from typhoid fever is a focus of infection ; the service is a *public* one, and its result has been the preservation of the health of the individual. And so, because of the existence of medical research, no one cause of dissemination of enteric has, for any great length of time, been over-estimated in value by the public health administration ; on the other hand fishery authorities have rather tended to become obsessed with the idea that mussels are *the* way in which typhoid is carried. It has been said that there still remains a persistent residue of the disease and that the cause is polluted shellfish, but in view of the now generally recognised fact that apparently healthy persons may be "typhoid carriers" this view cannot be maintained.

The evidence that Enteric Fever is conveyed by Shellfish.

Without doubt the consumption of sewage-infected oysters, mussels and cockles *is* a cause of enteric fever, but a candid survey of all the available evidence does not convince one that this is even a prominent cause. It must be remembered that the role of shellfish in conveying the infection has only been attentively studied since 1894, when the late Dr. H. T. Bulstrode made his well-known investigation into "oyster culture in relation to disease." Further, administrative measures designed to prevent communication of typhoid by this means cannot have been effectively applied until the first few years of the present century, yet a glance at the table on p. 79 will show that an enormous decrease in the mortality from the disease characterised the last decades of the 18's. For this decrease we must therefore look to other action than that taken with respect to polluted shellfish, and the same kinds of action have doubtless continued to be taken, and with the same success, during the last dozen years or more. The statistics show that the residue of enteric is certainly not a persistent one, and one need not hesitate to conclude that some of it, at all events, is due to the existence of "carriers," insanitary dwellings, slums, locally defective drainage, open middens, ashpits, flies, etc. It is probable that far more stringent sanitation in the overcrowded quarter of big towns will be necessary to reduce the mortality to vanishing point, than has been necessary to arrive at the present rate. The residue is small, but the risk of any one person dying from enteric is still appreciable, while the risk of illness is, of course, much greater; it is no consolation to the typhoid patient to reflect that his is only one of the dozen or two cases per million!

There is, of course, satisfactory evidence that typhoid fever is conveyed by means of polluted shellfish, yet it is very surprising to find that such satisfactory evidence is rather exceptional. If it were not for the well-known cases of epidemic illness following the two famous mayoral banquets at Winchester and Southampton (the cases investigated by Bulstrode) such evidence as is often adduced at the present time would lose a great deal of its force. These two classic investigations have, in fact, established a tradition which subsequent work can hardly be said to have maintained. It will be useful to quote some instances of the kind of evidence that has been regarded as proving the connection of typhoid fever and shellfish consumption :—

(1) *A* ate steamed mussels on September 1st and frequently from then to November 29th. Then he ate a raw mussel and said to his wife that it was not good. He became ill on December 4th. His blood reacted positively on December 27th. He died on January 12th.

(2) *B* ate cooked mussels on December 17th and he was ill seven days later. His blood gave a positive reaction on December 29th. He died on January 3rd.

He had influenza prior to November 24th. All his family ate cooked mussels on December 17th, but he was the only one who became ill.

(3) *C* ate raw and cooked mussels at the beginning of December. Other members of his household ate cooked, but not raw mussels. *C* was ill on Dec. 12th, and on December 31st his blood gave a positive reaction. He died on January 27th.

(4) *D* ate steamed mussels and a plate of oysters at a shop on December 21st. She was ill on January 3rd, and her blood gave a positive reaction on January 10th. She died on January 16th. Her three companions also had mussels at the same time, but they had had enteric fever about two years previously and they did not become ill.

(5) *E* ate cooked mussels on December 21st and was ill on December 28th. His blood reacted positively, and he died on January 24th. A friend who was with him also ate mussels, but did not become ill.

All the above are actual records and they may be regarded as quite typical of the kind of evidence that has been taken as establishing the connection between mussels and disease. "From a review of all these cases there appears to be little doubt but that the association between enteric fever and mussel consumption is something more than mere coincidence." That was the opinion of most Medical Officers of Health, and may be so still, but nevertheless there have been other ways of looking at the facts.

In 1910 there was an outbreak of enteric fever in the London districts of Bethnal Green, Stepney and Poplar. There are various criteria by means of which outbreaks due to personal infection, polluted water or milk can be recognised, and these criteria were applied by the London Health Officers in investigating the origin of these outbreaks. A process of "hypothetical deduction" applied during the enquiry showed that the epidemic was an "explosive one" (that is, a great number of cases occurred at the same time and not one after the other); therefore it was not due to personal infection (that is, the communication, by direct contact, from person to person). Further enquiry gave no reasons for supposing that contaminated water or milk were causes (in which circumstances the outbreak would have been "explosive"). Two articles of food, however, were consumed by a "considerable proportion" of the patients during the month preceding the onset of illness—these were mussels and fried fish—but further enquiry showed that the mussels might be disregarded. There remained, then, the possibility that fried fish were the means by which the disease had been communicated.

The fish implicated were plaice which had been caught on the "nursery grounds" of the North Sea, and, as a rule, they were poor quality fish. Plaice are very usually gutted, but it was suggested that, in this case, the process of gutting had been imperfect. These North Sea grounds are, it might be thought, very far away from sources of sewage pollution, yet it was concluded that the possibility of contamination "was not so remote as might at first be supposed." Further, the fish were fried, and this process may be imagined effectively to sterilise small plaice; nevertheless the contaminating germs assumed to be present in the tissues of the fish were also assumed to have survived the ordeal of boiling oil.

Such enquiries as this, and the other ones quoted above, are usually very well done. There is a regular technique, and the investigators employed are well-trained men who are thoroughly conscious of the great responsibility of their work and who therefore do that work consistently well. Yet here we have, on the one hand, enteric fever occurring in a mussel-eating population and a causal association established between the mussels and the disease, and, on the other, a group of cases occurring in a population consuming *both* mussels and fried fish, with the result that a causal association is set up between the fried fish and the disease. As a matter of fact the first population—that is, the one in which mussels were regarded as the cause of the disease—was also a fried-fish consuming one. We can hardly doubt that much the same conditions obtained in both populations and that there were various ways in which enteric fever might have been communicated, but that, in each case, the Health Officers took one particular aspect of the whole problem. In the first group they were influenced by the Bulstrode tradition, but in the other a spirit of scepticism with regard to accepted methods was allowed to gain force.

It is quite fair to say that the evidence which implicates mussels is "coincidence." A man eats mussels and, a week to a fortnight later, he shows that he is suffering from enteric fever. The typhoid germs require a week to a fortnight to "incubate" in the man's body and cause the symptoms of the disease. That may be "mere coincidence," but all scientific proofs are based on just such associations, coincidences in regard to events that happen simultaneously or after a certain period of time. The probability of a causal connection between two such events is small, and it has to be strengthened by the establishment of a series of other coincidences such as, for instance, those that were observable in the cases of the outbreaks following the mayoral banquets at Winchester and Southampton. The strength of the evidence in the latter cases was due to the *number* of coincidences, and its weakness, in the cases *A* to *E*, on pp. 82-83, is due to their paucity. A certain shop sells mussels which are, presumably, all taken from the same contaminated shellfish bed, and a man buys and eats these mussels and then takes enteric fever a week to a fortnight later. But we ought not to overlook the other coincidences, which seem to me to have just the same value as scientific evidence : a great many other people buy and eat just the same mussels, but they do not take enteric fever.

It is quite easy to make an explanation of this apparent contradiction. Probably infection by organisms setting up typhoid, and other infectious and contagious diseases, is far more common than used to be imagined. Many of these organisms are ubiquitous, and modern conditions of life must, in many cases, greatly increase the chances of their distribution. In no case do men and women yield easily to infection for the defences set up by the normal healthy body are fairly strong. The infection may not "take" at all (and pathologists must encounter such failures, even in experimental work), and if it does "take," it may successfully be resisted. There are many ways by which *Bacillus typhosus* may be distributed—by contaminated water, milk, vegetables and fruit, flies, carriers, shellfish, personal infection, and perhaps also fried plaice. Certainly some of these may be ruled out in many cases—water and milk in modern conditions of public health administration, for instances, but, as a rule, there must generally be more than one means. Further, it is probable that there are conditions which are necessary in order that the infection may take. It is probable that the bodily "soil" must be such that the pathogenic micro-organisms may grow : there may have to be symbiosis with some other organism ; or a condition of "rundownness" due to malnutrition, overcrowding, insufficient warmth or clothing, etc. ; or some set of environmental conditions which we do not understand. The progress of epidemics does suggest this : that a number of conditions must coincide and co-operate in order that the pathogenic organism (which is thus only the immediate "cause ") may be enabled to operate upon the bodily "soil." Thus public health practice, while it may not neglect these exciting, or immediate causes, may neither afford to neglect the essential co-operating ones. In short, the role of shellfish as a contributory cause of disease cannot be overlooked, but it can greatly be exaggerated. It is probable that entire exclusion of mussels from the public markets would not greatly reduce the incidence of enteric fever, while it is also possible that a very highly perfected system of public sanitation, in the widest sense, might reduce typhoid to the status of typhus without interfering *greatly* with the use of shellfish as human food.

The Administrative Procedure with regard to Contamined Shellfish.

The above discussion will throw some light on the utility of the present administrative methods ; these date back only to 1915, when the Local Government Board made the " Shellfish Regulations," under which action with regard to polluted mussels is now taken. Prior to 1915 little or nothing was done. Various Health Authorities were able to exclude mussels from the public markets under their control, and, apparently, they based their action on the inspectorial work done by their own officials (that is, they moved on the kind of evidence furnished by the quoted cases on pp. 82-83), or they took action on inspections made, and bacteriological analyses procured by the Fishmongers' Company of London. Obviously they could only exclude mussels from the public markets, but could not, in general, prevent the sale of the shellfish by hawkers, or in retail fish shops. Attention was drawn to the matter, but it is not certain that much more than that happened. There was no closure of the polluted shellfish beds prior to 1915 because no public authority possessed this power.

The " Shellfish Regulations " conferred this power on the Local Health Authorities, and the Central Authority is now the Ministry of Health. The procedure is interesting : if the local Medical Officer of Health " is in possession of information that any person is suffering, or recently has suffered, from infectious or other disease attributable to shellfish, or that the consumption of shellfish within the district is likely to cause danger to public health, he shall take such steps, etc." The steps are the holding of a local enquiry at which the fishermen are called upon *to show cause why the shellfish beds suspected should not be closed to ordinary fishing.* This procedure, which apparently bears rather hardly on the fishermen, does not do so in reality, for its result must usually be to put the local fishery administration on their side : the latter does not appear to have any definite *locus standi* in the matter in the course of the enquiry. Here, too, it is quite relevant to ask for the definite results of such enquiries and closures that have taken place, for the making of an order closing a certain mussel bed is not at all the same thing as the prevention of taking mussels from that bed. Have the "Shellfish Regulations" really prevented the marketing of polluted mussels ? We are enquiring into the causes of the decrease in enteric fever during recent years and so the question is a relevant one.

The important thing in the "Shellfish Regulations" is the phrase *attributable to shellfish.* What evidence satisfies the Medical Officer of Health that any particular case of typhoid fever has been caused by eating, say, mussels. Study of the cases quoted above will show, I think, that there is no satisfactory legal evidence at all. A man takes the disease, and the investigators discover that he has, during the two weeks previously, eaten shellfish, bought at a particular shop or stall or barrow in the streets. There is no possibility of proving that these particular shellfish were competent to cause infection, because it is only sometime after they have disappeared that their association with a case of disease was suspected. Enquiry, however, shows that shellfish of the same origin are still being sold, and these are analysed and are found to contain evidence of sewage pollution. Thus the outbreak of disease is "attributed" to them. Now the association thus set up is so loose and unsatisfactory that we are impelled also to consider the fact that just the same shellfish were eaten by a number of people *without detriment*, and this surely robs the original identification of the shellfish with the cause of the disease of much of its force. The proof cannot be regarded as satisfactory, and I think the "attribution" of disease-conveying properties to mussels, in some such case, ought to be challenged in the Courts in order that some legal decision as to what constitutes the proof should be obtained.

The Validity of the Bacteriological Evidence.

Nor can the results of a bacteriological analysis find legal proof that the illness was the result of eating mussels that contained typhoid bacilli, because when the illness is being investigated its presumed material cause no longer exists. It must be remembered that it is a very uncommon thing indeed to find *Bacillus typhosus* in mussels taken from the foreshore. I have found it myself, on one occasion, but even then the identity of the organism was not beyond doubt.* What the bacteriologist does look for, and usually find, is the presence of what he calls *Bacillus coli*. This may be backed up by finding that various other organisms of the same category, Streptococci and *B. enteritidis sporogenes*, are also present. The occurrence of these organisms is held to prove, and usually does prove, that the shellfish in which they were contained have been living in sea-water which contains sewage organisms proceeding, *via* sewer outfalls and drains, from human dejecta. None of these organisms, of themselves, convey enteric fever, and all that is shown by the results of the analysis is that the mussels were living in such conditions that they would have taken up (and retained for a short time) typhoid bacilli *had those bacilli been present in the sea-water in which* they were living. The proof, from bacteriological analysis, is really this: had a

* The biological characters were those of *B. typhosus*, but the agglutination test was not a very stringent one and the further proofs were not attempted.

person suffering from, or convalescent from, or a carrier of typhoid fever been living in the area drained by the sewer discharging near the mussel bed, *then* the shellfish *might have* become infected and persons eating those shellfish might have contracted typhoid fever.

But the bacteriological evidence is really weaker than has just been indicated, and I may quote Bulstrode with advantage: The Report on "Shellfish other than Oysters," of 1909-10, says: "It was found during the enquiry relative to oysters that bacteriological investigations yielded conflicting results, and it cannot be said that bacteriologists are in agreement as to the standard to be adopted, and this seems to be the case whether regard be had to the total number of organisms present, the percentage proportion of certain organisms or the mere presence of certain organisms. It has also to be added that there are at present no tests which will serve to distinguish sewage micro-organisms of human origin from those of animal origin, and even if it were practicable or desirable to distinguish between the two it would be difficult to fix reliable standards when dealing with estuarial waters draining a whole catchment area, much of which might be devoted to grazing purposes. . . ."

"It is necessary, too, to point out that the standards adopted by some bacteriologists would not improbably serve to condemn every shellfish bed round the littoral. Possibly the time may come when a standard of this nature may be regarded as desirable, but, in the meantime, a useful provisional standard is one based upon topographical and epidemiological evidence."

The above passage was written over a dozen years ago, but the matter remains precisely where it was then. The conditions at present are these:—

There is no generally recognised *routine* method of identifying and enumerating the "colon bacilli" found in shellfish.

There are no certain means of distinguishing between "colon bacilli" of human and lower animal origin, when such are found in shellfish.

All mussels are polluted by "sewage bacilli" to some degree.

There is no standard above which one is justified in regarding the degree of pollution as noxious.

In spite of the importance of the subject, the amount of administrative attention it has received and its susceptibility to scientific investigation this is still the case, as it was in 1910, when Bulstrode completed his second report.

So I do not recommend any action, on the part of the Committee, with regard to the mussel beds on the Ribble Channel training walls. The matter has been discussed at some length because it may again become very troublesome and analogous cases may have to be investigated. In such cases as that of Church Scar, where the pollution is gross, immediate, and patent, action may be taken, though, of course, it cannot be taken by the Fisheries Committee. In most other cases, however, the best policy may be for the Committee to oppose any further orders under the Shellfish Regulations should these be initiated in their District, unless the order carries with it an undertaking to provide facilities for cleansing the suspected mussels. If bacteriological evidence is adduced this should be controverted on the ground that there has been abundant time for investigation—which has not been made—and that without this investigation the methods of analysis at present practised are inadequate. A legal decision as to what is to be understood by the expression "attributable" in the Regulations ought to be obtained.

It has been shown by Professor Klein in 1904, by experiments made by this Committee in 1906-12, and by the results obtained at Conway by the Ministry of Agriculture and

Fisheries, since 1914, that highly-polluted mussels can be cleansed. Provision for such cleansing process ought, then, to go along with any order made under the Regulations. By itself an order is merely a restriction leading to a legal offence—if it is enforced. If it is to be enforced then it is fair to the fishermen to insist that the evidence on which the order is to be made should have the same weight as that which would be submitted to a magistrate against a delinquent who is to be prosecuted under the order.

Other Investigations in Progress.

Hydrographic Research.

The Liverpool Laboratory has now arranged for the monthly collection of sea-water samples and the observation of sea-temperatures in the Irish Sea. This is part of the scheme of " directed research " submitted by the Ministry of Agriculture and Fisheries. Three cross-channel steamship routes will be sampled: Fishguard to Rosslare; Holyhead to Dublin, and Liverpool to Isle of Man. It is expected that the work will begin in May.

The Life-history of the Cod.

This is also part of the scheme of directed research. Investigations have been going on since October. There are two main cod fisheries which go on during the winter and spring—off the Cumberland coast and round Isle of Man; the fish, of course, occurs nearly everywhere, but these are the main fisheries. The Whitehaven fishery this year was poor, but the Manx one was very good though the difficulties of transport were so formidable that the season has been an unprofitable one. The fishery, during the spring, both at Whitehaven and at Isle of Man is one for cod that come inshore in order to spawn, and by Easter the Manx fish had nearly all spawned. A very good series of measurements has been obtained by

Mr. W. C. Smith, and scales have been preserved for future study. A series of chemical analyses of the flesh and liver of Port Erin cod has also been made on samples obtained every few weeks, and it is hoped that these will fit into a bigger scheme of investigation of the seasonal changes in the metabolism of marine animals and plants in the Irish Sea area. The changes in general "condition" of the fish during the season have also been observed, and other lines of investigation will, no doubt, present themselves later on.

The Chemical Composition of the Mussel.

A preliminary study of the chemical composition of the common mussel has been undertaken by Mr. Daniel, and the results of this are published in the tables given on pp. 281-285. As this investigation has proceeded many interesting questions have been suggested—the nature of the substance which is called "glycogen," for instance. It cannot be doubted that this is not the same, chemically, as the glycogen of the warm-blooded animal, and difficulties and anomalies encountered in the course of the work suggest that an exhaustive research on the nature of the carbohydrates found in molluscs is very desirable and may be of economic value in view of the further utilisation, in some form or another, of the organic material found in mussels. The use of the molluscs as human food, in the fresh condition, has been decreasing for years past because of the somewhat bad reputation they have now received from the Public Health Authorities, and, as things are, their total exclusion from the food markets seem only to be a matter of time. Year by year, for instance, an increasing fraction of the great Morecambe supply goes to the East Coast as bait for the liners, and until a good method of cleansing them from sewage pollution can be generally applied this tendency will continue. We have to reckon, then, on finding some new use for the huge supply of material which the

Lancashire mussel beds can provide without diminution, and some means of converting the flesh of mussels into a food commodity ought not to be impracticable. The so-called glycogen, for instance, may possibly be extracted by some fairly simple, large scale process and applied to some useful purpose: so much Mr. Daniels' results seem to indicate. There are, of course, other purely chemical or bio-chemical problems that have arisen in the course of this research, but these must be left for more detailed work. In the meantime, and as a study preliminary to that more detailed work, this research on the seasonal variations in rough chemical composition is of indispensable value.

A good deal of histological work, dealing with the mode of distribution of fat and carbohydrate in the various tissues of the mussel, has also been done by Mr. Daniel. Here, again, all the methods given in the text-books and memoirs have had to be tried and varied to suit the particular nature of the tissue substances. Evidently we cannot speak simply about "fat" and "carbohydrate" in "molluscs" and depend upon the application of any general method of fixation and tissue-staining, for it seems probable that the precise chemical nature of these substances may vary from group to group of mollusca and even in the different species. Only in this way can the anomalous results obtained be explained. A great deal of preliminary work has, therefore, had to be done, and the results of this, and further research on the histology and morphology of the mussel, must fall to be recorded in later reports.

Other lines of work have been touched, but it is, perhaps, unnecessary to make reference to these in the meantime. The past two years have been a period of considerable difficulty, but it is to be hoped that they have also been preliminary to the complete re-development of the scientific work of both the Liverpool and Piel Fishery Laboratories. We have many pieces of research in contemplation—some of them having a far from indirect economic interest—and it is expected that the near future may give us the opportunities for the full prosecution of these researches. We acknowledge here, with much appreciation, the assistance given by the Development Commissioners and the Ministry of Agriculture and Fisheries, and look forward, with confidence, to the continued interest of these departments in the marine biological and fishery work, which has so long been carried on in the Irish Sea.

JAS. JOHNSTONE.

DEPARTMENT OF OCEANOGRAPHY,
UNIVERSITY, LIVERPOOL,
April, 1922.

CLASSES AND OTHER WORK AT PIEL.

By A. Scott.

Classes at Piel.

Two classes in Marine Biology and Navigation for fishermen were held in the spring of 1921. The first one met during the period 7th to 18th March, and was attended by fourteen men. The second was held between 18th and 29th April, and was attended by thirteen men.

The following are the names of the fishermen who attended these classes :—

7th to 18th March.—W. Rimmer, Blackpool; Victor Houghton, F. Woodhouse, H. Woodhouse, R. Woodhouse, R. Gardner, J. Parkinson, Morecambe; Robert Burrow, Bolton-le-Sands ; Robert Burrow, Isaac Burrow, F. Dickinson, Grange-over-Sands ; Thos. Wilkinson, Baicliff ; Thos. Butler, S. Benson, Flookburgh.

18th to 29th April.—J. H. Atkinson, Richard Wright (1), Richard Wright (2), Fleetwood; Fred Taylor, J. Baines, Bolton-le-Sands ; J. Dickinson, Silverdale ; Frank Dickinson, Allithwaite; P. Benson, M. Cowperthwaite, Flookburgh; H. Bayliff, W. Benson, Baicliff; Thos. Butler, Aldingham; W. J. Edmondson, Rampside.

Mr. R. J. Daniel, of the Oceanography Department, University, Liverpool, had charge of the whole of the teaching work.

In the interval between the fishermen's classes, Mr. R. H. Wardle, M.Sc., of the Zoology Department, Manchester University, brought a party of senior zoology students to examine the fauna and flora of the shore in the vicinity of the Laboratory. The following is the report supplied by Mr. Wardle at the conclusion of the visit. It gives an account of the work done and the facilities provided for workers.

Mr. Owen Hunt, one of the senior students, was unable to join Mr. Wardle's party, but came later, 2nd July, and spent a week investigating the shallow-water fauna.

Report upon Visit of Zoological Party to the Biological Station, Piel, Barrow-in-Furness, during April, 1921.

The party under my charge consisted of the following eight students :—Misses MacGill, Allen, Comstive, Bishop, Dutton, Wainwright, Mr. Hopwood and Mr. Lean.

The party left Manchester on Friday, April 8th, by the 10.25 train to Fleetwood, were met at Wyre Dock Station by a member of the crew of the " James Fletcher " and conducted to the vessel. Upon this steam trawler an exceptionally interesting and instructive nine hours were spent as the guests of Dr. J. T. Jenkins, Superintendent to the Lancashire and Western Fisheries Committee. At a point 1½ m. W. by N. from the Morecambe Bay Lightship an otter trawl was shot, was dragged for seven miles in a W. by N. direction, and was hauled at 5.30 p.m. A record was obtained of the 311 edible fishes caught, and the Invertebrate contents of the trawl were set aside for further examination ashore. The party were landed at the jetty, Piel Harbour, at 9 p.m.

Saturday was spent in examining the Invertebrate material and the tow-nettings obtained the day before.

Monday.—A collecting expedition to Foulney Island was organised, under the guidance of Mr. Andrew Scott, in the morning. The material thus obtained was examined during the afternoon in the laboratory ; living plankton, obtained by tow-netting from the end of the jetty, was also available for examination.

Tuesday : a hot, calm day.—The party, accompanied by Mr. Scott, boarded the police cutter at 10 a.m. and spent most of the morning and afternoon tow-netting in the Walney Channel, in charge of the Committee's Officer, Mr. J. Wright.

A beam trawl was shot and dragged for two hours, and the resulting catch examined and sorted out for examination ashore.

Wednesday: cold and wet.—The morning was spent collecting along the foreshore west of the harbour, but little was obtained.

Thursday.—The party went out in the morning under Mr. Scott and obtained a supply of Arenicola; the rest of the day was spent in examination and dissection of this material, and in examination of segmenting ova of the plaice.

Friday.—In view of the threatened railway strike, I decided to bring the party back to Manchester, and wired Dr. Jenkins to that effect. Otherwise, the party would have stayed until Monday, the 18th, and returned to Fleetwood on the "James Fletcher." During the morning a very interesting lantern lecture upon the Fisheries of the Morecambe Bay area was given by Mr. Scott. The party left Piel on the 1.13 train.

General Remarks.

In spite of the unfortunate curtailment of our visit, a surprising amount of work was carried out, and the visit was in every way a success. The muddy and shingly foreshore is far more plentiful in variety of animal life than would appear from a cursory examination, and to the assiduous and experienced collector is not greatly inferior to a rocky coast such as obtains at Port Erin.

Any inferiority of littoral fauna was, however, compensated for by the facilities afforded by the Fisheries Committee's steamer.

The laboratory facilities are equal to those prevailing in the University laboratory. There is bench accommodation for sixteen students, there are fifteen good Leitz microscopes and a Zeiss binocular, there is a plentiful supply of glassware, dishes, instruments, reagents, etc. In the adjoining fish hatchery is a series of tanks and bell jars into which living material may be placed and kept under observation. We were thus able to observe fully-expanded specimens of Alcyonium, Actinoloba, various Hydroids, Nudibranchs, etc. Attached to the laboratory is an excellent library, and in the laboratory itself is a very complete collection of preserved specimens of Irish Sea fauna, which is available for teaching purposes.

The success of the visit was undoubtedly very largely due to the energy and forethought shown by Dr. Jenkins and to the assistance of Mr. Andrew Scott, who sacrificed much time and trouble in conducting the party on collecting expeditions and in identifying obscure or out of the way species.

R. A. WARDLE.

Dr. Stuart Thomson, also of the Zoological Department, Manchester University, who had carried on an evening class in Marine Biology in the winter, which was attended by members of the Manchester Microscopical Society, brought a party of thirteen members. This party was at Piel from the 14th to the 21st May. The course consisted of lectures and demonstrations, examination of living material, shore collecting and photographing.

A class in Marine Biology and Navigation for school teachers was conducted by Professor Johnstone and Mr. Daniel from August 1st to 12th, and was attended by the following eight schoolmasters :—A. E. Morley, Scarborough ; P. H. Hall, Brigbtlingsea ; A. V. Phaisey, A. E. Johnson, E. D. Lowes, Swanley ; R. Fleming, R. S. Cleator, E. V. Lawson, Fleetwood. Mr. A. Harris, Chief Inspector of Navigation Schools, inspected this class. Dr. E. S. Russell, Director of Scientific Investigations to the Ministry of Fisheries, also visited the laboratory during the teachers' class and inspected the facilities for work.

Fish Hatching.

A stock of large plaice were collected in Luce Bay in October, and in due course conveyed to Piel. Adult flounders were trawled in Barrow Channel towards the end of 1920.

The plaice and flounders both began to spawn on the 6th of March, eighteen days earlier than in 1920, and continued to produce eggs until 30th April. The last fry (plaice) were set free on 24th May. Altogether 1,150,000 plaice eggs and 12,500,000 flounder eggs were collected and incubated; 1,000,000 plaice fry and 11,000,000 flounder fry were hatched and set free.

Re-survey of Shellfish Beds.

The mussel beds of the Ribble, in the vicinity of Lytham, were examined by Mr. W. Birtwistle and myself in July and again in November, 1921. On the first date a topographical survey of the sewer outfalls and their relation to the mussels was made. On the second visit samples of the mussels were collected and examined for sewage contamination. Reports were submitted in each case and were published in the Report of the Superintendent, Dr. Jenkins, for the quarters ending, 30th September and 31st December, 1921.

THE PLAICE FISHERIES OF THE IRISH SEA

BY

JAS. JOHNSTONE, D.Sc.; W. BIRTWISTLE AND W. C. SMITH

CONTENTS

CONTENTS—*continued.*

PART I.

The Pre-War Period, 1908-1913.

(1) Introduction.

This report is primarily a summary of certain fishery investigations carried out in the Irish Sea region during the years 1908-1920. Its object is to provide a series of data which can be consulted for the purpose of assessing the usefulness of any practical legislative proposals as to size-limits or closed grounds. It also endeavours to provide a picture of the present condition of the plaice-fisheries on the fishing grounds mentioned below. If we had such a picture for the period 1870-1890, the information so afforded would be of the utmost value in the discussions that are now going on with respect to questions of impoverishment, size-limits, etc. We think it very useful, therefore, to summarise here what has been the outcome of the investigations made by the vessels and officers of the Lancashire and Western Sea-Fisheries Committee during the last twenty years or so, as these observations will, at the least, record the present conditions and give a basis for comparison with those that may possibly be made some twenty or thirty years hence.

The essential part of the report consists of the tables of measurements, etc., that are given on pp. 137-148.

In addition to these we have added a summary of the results of a series of marking experiments and some additional observations. In order, however, to present the general attitude adopted a rather full discussion of the methods used has also been written, and the general bearing of the conclusions reached are also discussed on pp. 231 and following. The impression obtained is that the time has not come for any legislative-restrictive action in this part of the sea. That impression is, however, personal to those of us who have been concerned in carrying out the investigations, and does not necessarily represent the opinions of the Committee. The reasons for our opinion are given fully on pp. 231-243 of this report.

The Area Investigated.

The fishing grounds on which the observations and experiments have been made are as follows :—

(1) The Solway Firth, including Luce Bay and Wigton Bay, and the fishing grounds between the Isle of Man and the coast of Cumberland. Permission to work on these regions was kindly given by the Scottish Fishery Board and the Cumberland Sea-Fisheries Committee.

(2) "Morecambe Bay." This includes the territorial waters off the Lancashire coast, from the estuary of the Duddon to Formby Point, and the offshore region out to the Morecambe Bay Light Vessel.

(3) "Liverpool Bay." This includes the estuaries of the Mersey and Dee, and the adjacent sea out to the twenty-fathom contour line.

(4) "Red Wharf and Beaumaris Bays." This is the region situated just off the coasts of Denbigh, Flint, Carnarvon, and Anglesey, as far south as about Holyhead, and seaward to about the twenty-fathom contour line.

(5) Carnarvon and Cardigan Bays.

(6) The inshore waters round Isle of Man. Work was done there by arrangement with the Insular Fisheries Board.

(7) The offshore regions in general, about and outside the twenty-fathom contour line.

The various geographical terms are employed rather approximately and much in the same way as they are used by fishermen. The whole region investigated is quite a small one, but it is a typical, rich, inshore plaice fishing area of sea, and it is one about which more is known than any other similar region in the British fishing regions. The summary that we provide cannot, therefore, fail to be of much interest and practical importance.

The sketch-chart, Fig. 1, represents the various grounds mentioned.

FIG. 1.

Nature of the Fishing Grounds—their Regulation.

Most of the region investigated lies inside the three-miles' limit, and trawling by steam vessels is everywhere prohibited within this zone. In addition, trawling by any kind of vessel is prohibited in Luce Bay by the Fishery Board for Scotland. Trawling by motor-propelled vessels is permitted, by licence issued by the Lancashire and Western Sea-Fisheries Joint Committee, in Carnarvon and Cardigan Bays. There are regulations with respect to the size of trawl-mesh, which is now measured all round the mesh in the Lancashire and Western District and in the Cumberland District. Trawling by steam vessels is prohibited in the three-miles' zone round the Isle of Man. Vessels fishing for shrimps employ a trawl-mesh of 2 inches, and they are not supposed to retain any fish if these are less than 8 inches in total length. The mesh of stake-nets is also regulated, and is 7 inches measured round the four sides. There are no restrictions on the times of the year when trawling that is otherwise legal may be practised, and there are no restrictions on the sizes of fish of any species that may be landed and offered for sale.

Most of the whole region in question is what is called a "nursery ground." This is particularly the case in the Solway Firth, in the estuary of the Duddon, in Morecambe Bay, and in the estuaries of the Ribble, Mersey, and Dee. Here there are enormous tracts of sand-banks, which are laid bare at each ebb-tide, and there are innumerable shallow channels through these banks. The water is rather cold in the winter on these shallow estuaries and rather warm in the summer—that is, the extremes of temperature are greater in the bays and estuaries than they are in the sea, just offshore. Sometimes there is considerable ice formation in Morecambe Bay. The higher temperature in the spring, summer, and autumn, and the lowering of the specific gravity of the water by that coming from the land are very favourable conditions. Water draining down from cultivated land and from domestic sewerage systems carries essential food substances on which many lower organisms feed, and these lower animals and plants are the food of others, which are then eaten by the young fishes which inhabit the nursery grounds.

The tidal streams are unusually strong and tend to run inwards to the Solway and Morecambe Bay from the channel between Ireland and Scotland. The tidal streams coming and going from St. George's Channel also tend to and from the "Liverpool Bay" region—that is, the coast containing the Dee, Mersey, and Ribble estuaries. Off the mouths of these are extensive sand-banks, penetrated by shallow channels. Plaice and other fish spawn offshore and the eggs and developing larvae are carried by the tidal streams to the grounds that we have mentioned.

The extensive sand-banks in the bays and estuaries are "alive" with small Crustacea (Copepods), cockles, other small bivalve shellfish, and small worms. In the channels, and on the foreshores where the ground is rough there are enormous accumulations of mussels forming "beds" or "skears." These animals, when young and small, are eaten by plaice, dabs, flounders, and other fishes, and their presence and great powers of regeneration are the principal reasons why the region in question constitutes one great nursery ground. The supply of fish-food, represented by bottom-living Copepods, worms, and small molluscs, is almost illimitable, and could doubtless support a much greater fish population than that actually present on the nursery grounds. This fish population itself, we have reason to believe, is only a small fraction of that which is theoretically possible of existence.

In fact, such an area as that which we are now describing is certainly one of the most "productive" that exists, being capable of yielding far more organic food substance than any equal area of cultivated land. The annual quantity of mussel-flesh, for instance, that can be raised on a suitable Lancashire foreshore is greater by far than the quantity of beef or mutton that could possibly be raised on the same area of the best grazing land.

This is the general nature of the North-west inshore fishing grounds, but some of the sub-regions differ from the above description. Luce Bay is such a nursery ground (in certain places), but it also contains large numbers of big plaice, up to over 60 cms. in length. Something in the nature of the Bay, and its water and food supply, may be associated with this remarkable distribution, but the main factor is preservation. The Bay has, for a long time, been closed against trawling by the Scottish Fishery Board, and the amount of other fishing (by " gill-nets ") that goes on is insufficient to deplete the area of the large fish.

The fishing grounds of North Wales, lying just off the coasts of Carnarvon and Anglesey, between Great Orme's Head and Point Lynus (Conway Bay, Beaumaris Bay, Red Wharf Bay), are not nurseries to the same extent as are the grounds mentioned above. Here medium and big plaice are caught, principally during the months of October to January. There are nurseries in Carnarvon and Cardigan Bays, but not to the same extent as off the Cumberland, Lancashire, and Cheshire coasts. Medium to big plaice may be caught in the great Welsh Bays at the beginning of the year and in the summer and autumn months.

What we may conveniently call the " offshore grounds " are situated outside the twenty-fathom contour line on the English side and between this and the Isle of Man ; also out from the same depths in " Channel Course "* and St. George's Channel, and between Cumberland, Isle of Man, and the South Coast of Scotland. Plaice occur over most of this region, but

* " Channel Course " is the sea in the neighbourhood of the general track followed by vessels entering Liverpool from St. George's Channel.

in much smaller numbers than on the zone of sea within the twenty-fathom contour line. In fact, we may neglect most of the Irish Sea outside this limit as a plaice ground—though it would, of course, be difficult to give statistical data demonstrating this. By far the greater part of the plaice caught come from the shallow water less than twenty fathoms in depth.

Distribution of the Different Species of Fish.

Even in such a small area as that which we are considering—it is all included within 3° of latitude and 2° of longitude—there are quite noticeable differences in the predominant kinds of fish present on the fishing grounds. This is illustrated by the following tables and graph, which represent the results of a number of fishing experiments made in the Firth of Clyde and Luce Bay (by permission of the Fishery Board for Scotland) as well as in the Irish Sea. The experiments were rather rough ones, being made at different times and by different vessels, so that the results are not precisely comparable. Still, I have no doubt that very much the same general ratios would be obtained even by carefully standardised trawlings.

Table I. Results of Trawling Experiments carried on during the months of Feb.-May, 1898-1904 and Sept.-Nov., 1908-13.

Kind of Fish.	Firth of Clyde.	West from Isle of Man.	Offshore grounds.	Cardigan Bay.	Liverpool Bay.	Luce Bay.
Witch	4,164	430	17	...	...	...
Plaice	1,093	27	346	1,203	3,544	4,548
Dab	354	70	1,717	574	2,920	1,015
Lemon Sole	119	34	60	40	...	28
Sole	116	10	509	411	18	...
Brill	33	1	42	42	7	21
Flounder	14	...	638	36	107	27
Megrim	9	152	8	...	...	...
Turbot	6	...	2	2	...	4
Longrough Dab	...	4	...	...	...	...
Haddock	1,121	65	1,427	...	99	...
Hake	148	4	...	...	...	...
Whiting	70	493	940	154	...	...
Cod	41	13	141	2	116	70
Coalfish	42	4	1	...	...	22
Ling	8	4	3	...	...	...
Pollack	...	4	1	...	...	12
Poor Cod	...	39	36	...	...	1
Grey Gurnard	759	466	519	115	101	30
Red Gurnard	47	27	190	17	...	4
Yellow Gurnard	1	9	34	27	16	20
Conger	4	11	11	...	1	2
Ray	347	123	434	761	669	610
Skate	10	6	130	20	108	3
John Dory	1	...	...	...	...	1
Angler	...	...	...	...	...	1
Herring	...	...	...	...	...	12
No. of hours' trawling	103	45	242	41	45	27
Mean depth	22	32	21	12	6·5	7
Total edible fishes	8,507	1,996	7,208	3,404	7,706	6,431
No. of Species	22	22	23	14	12	19

Table II. The same data as on p. 110, but expressed as numbers of fish caught per hour's trawling (If less than one fish results from the calculation the species is omitted).

Kind of Fish.	Firth of Clyde.	West from Isle of Man.	Offshore grounds.	Cardigan Bay.	Liverpool Bay.	Luce Bay.
All edible fishes ...	83	44	30	83	171	239
Witch	40	10	...	...	...	...
Plaice	11	1	1	29	79	168
Dab	4	1	7	14	65	38
Lemon Sole	1	1	...	1	...	1
Sole	1	...	2	10	...	...
Brill	...	...	...	1	...	1
Flounder	...	...	3	1	2	1
Megrim	...	3	...	...	...	...
Haddock	11	1	6	...	2	...
Hake	1	...	...	...	...	...
Whiting	1	11	4	4	...	...
Cod	...	...	1	...	3	3
Coalfish	...	...	...	...	...	1
Grey Gurnard	7	10	2	3	2	1
Red Gurnard	...	1	1	...	...	...
Yellow Gurnard......	...	...	...	1	...	1
Ray	...	3	2	19	15	23
Skate	...	...	1	1	2	...
Mean depth	22	32	21	12	6·5	7

The first of the above tables gives the actual numbers of hauls and hours of fishing, and the numbers of fish of different species that were caught. The second table simplifies the former one in that it gives the numbers of fish caught per hour's trawling, in all the trials, and neglects all results in which less than one specimen—on the average—has been taken. A further simplification is rendered possible by the following diagram, which takes account only of about two-thirds of all the fish caught—that is, it gives us a fair idea of the *prevalent* kinds and abundance of trawl-fish present in our whole region.

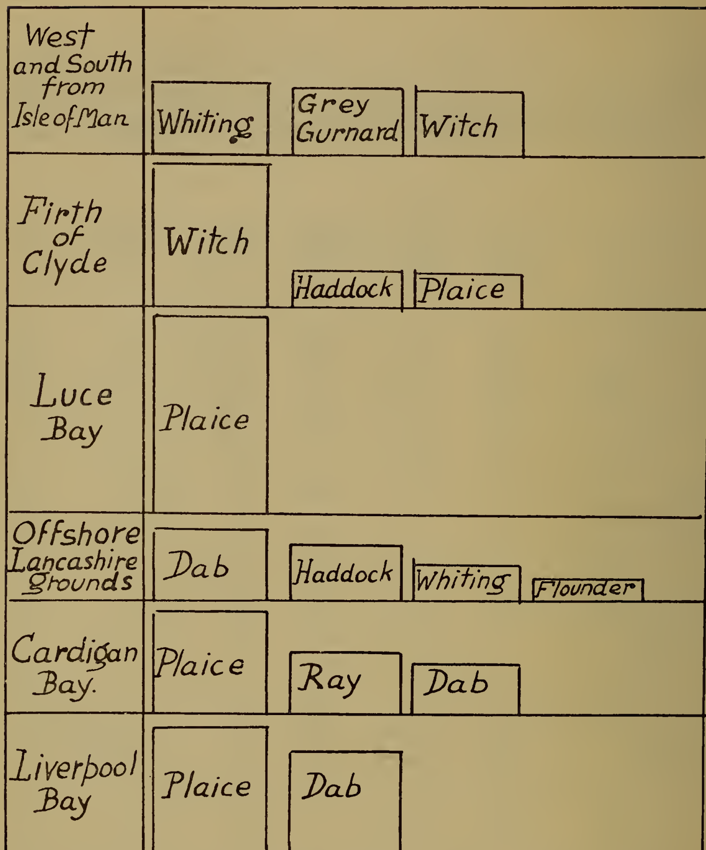


Fig. 2.

Note, then, that whiting, gurnards, and witches are characteristic of the deeper grounds to the West and South from Isle of Man, witches, haddock, and plaice of the Firth of Clyde,* and dabs, haddock, whiting, and flounders of the offshore grounds outside the shallow coastal waters of Lancashire. We find plaice, rays, and dabs are characteristic of the fishing grounds in Carnarvon and Cardigan Bays, and plaice

* That is, the Clyde between Stranraer and the South of Arran.

and dabs in Liverpool Bay. Luce Bay, it will be seen, is far more characteristically a plaice ground than any of the others.

Some qualifications, with regard to this statement of distribution, will be found below.

Seasonal Fisheries.

The various fisheries are all seasonal ones.

The great plaice fishery is that off the coasts of Lancashire and Cheshire in the summer and autumn months. Sometime about May or June plaice become abundant just off the mouth of the Ribble Estuary, and then this abundance becomes extended to the grounds North and South. About the beginning of August the fish usually appear in great numbers round about the banks off the entrance to the estuaries of the Mersey and Dee. By November these fisheries begin to fail.

About the same time, or even earlier, plaice become abundant off the coast of North Wales, anywhere between Rhyl and Red Wharf Bay, on the north of Anglesey. This winter fishery ends about December or January, sometimes very abruptly. Then good catches of fairly big plaice may be obtained inshore in Carnarvon and Cardigan Bays.

After that there follows a period when plaice are relatively very scarce everywhere. Some, of course, are always caught wherever there is trawling, but, in comparison with the well-marked summer and autumn fishery off the Lancashire coast and the equally well-marked North Welsh winter fishery, the plaice are very scarce. About the month of January medium-sized and big fish appear on the banks to the north-east of Isle of Man, and there may be a good deal of trawling there. A little later, however, these grounds may become "as bare as a billiard ball." Following that again the bigger plaice are to to be found on the ground called the "Slaughter," just off the mouth of the Solway. Here they spawn and the shoal disperses. Sometime about March and April, then, large numbers of plaice disappear from the Irish Sea fishing grounds, and there is always much speculation among fishermen as to where they go. There is little doubt that they " dawk "—that is, bury themselves in the sand in the channels offshore and among the sand-banks. Here they remain during the period of the year when the temperature is at or little above its minimum value, and when food has become scarcer than usual. Noting all these facts as to the seasonal nature of the plaice fishery, and comparing them with the results of the marking experiments—to be stated on pp. 174-196 of this report—we have little difficulty in making a general picture of the migrations of plaice in the Irish Sea regions (see p. 194).

The Migratory Fishes.

It will be noticed haddock are mentioned in the tables on pp. 110-111, though if a similar series of experiments were to be made at the present time this fish would be much scarcer—and it might not be represented at all in some of the aieas. A number of species are migratory ones, entering the region we are considering and then moving away again. Some of these species come back every year with a certain amount of regularity and others only return after a more or less prolonged period. Although we are dealing mainly with the plaice in this report it may be useful to say a few words about these migratory species.

H a k e .

Specimens of hake may be obtained now and then from most parts of the Irish Sea, but the fish is only (relatively) abundant to the west and south of the Isle of Man in the autumn months (usually July, August, and September). It migrates up from St. George's Channel, in the South, with the rising temperature of the sea and moves southwards again when the temperature falls. The fishery is, however, not a very important one.

Sea-Perch (*Labrax lupus*) and Mackerel.

So also with these fishes. They come into the Irish Sea at variable times, but generally about May or June, and they stay till about August and September. They also come up from the South and retreat back there again. Hake, sea-perch, and mackerel we may regard as southern fishes, and take their northern limit of distribution to be some particular isotherm in the sea. This isotherm, whatever it may be, changes from South to North as the summer advances and then changes back to the South as the sea temperature begins to fall, rather rapidly in September and October.

Herring.

This is a well-known migratory species, but the conditions that rule the movements of the fish are very complex and are not clearly known as yet. There are two main herring fisheries in the Irish Sea area: (1) the Welsh winter, and (2) the Manx summer fisheries. The Welsh winter herrings appear in Cardigan Bay in October and the shoals gradually move to the North as the season advances, disappearing off the North Coast of Anglesey sometime in January. The fish are mature ones and are "full" when they first come on the coasts; later on they spawn, and by the end of the season they are usually in the spent condition.

The Manx herrings are sometimes found off the coasts of the Island as early as February, but not in abundance. About May they begin to become abundant and are to be caught on the west, south, and east of Isle of Man. In July to September they spawn, and soon after that the shoals disperse and the fishery comes to an end.

The Sprat.

The sprat is found everywhere along the Lancashire and Welsh coasts and in the Solway, but during the summer months it is mainly immature fish that one sees. About October mature sprats begin to shoal and are abundant enough to provide the material for a fishery. They are probably to be found all along the coast, wherever suitable gear may be used, but the only fishery is that prosecuted at Morecambe during the period October-March. The fish are mature ones about to spawn. Just before spawning they disperse and the fishery comes to an end.

The Cod.

Cod are found over all the region and generally at all periods of the year, but there are local fisheries where the fish is more abundant than elsewhere. About March fair catches are made off the coast of Cumberland and even further South, and about the same time there is a fishery off the West Coast of Isle of Man. In both cases the migration is a spawning one and the fish are full-roed ones. At the best, however, the cod fisheries in the Irish Sea are not of very much importance. The fish is a northern one, and this is near its southern limit of range.

There are, of course, other migratory species of less importance—thus, whiting move about in much the same way as the cod. Large numbers of whiting, cod, and other species are to be found in the early stages on the nursery grounds during the summer and back-end. Garfish (*Belone*) come in from the South during the summer and the long, rough dab (*Drepanopsetta*) comes down from the North in the early spring. The sole is, to some extent, a migrant, having its place of greatest abundance to the south of our area. Some species of ray are also periodically migratory.

Long-Period Fluctuations.

Two species (at all events), the herring and haddock, are very capricious in their movements. The Welsh and Manx herring shoals are constant in their appearances and disappearances, but there have been other herring fisheries which come and go. About 1890 and later herrings appeared off the coasts of Lancashire from Morecambe Bay to the Mersey Estuary, and were fished for, by drift-nets, in the latter area as far up as near the entrance to the Manchester Ship Canal. Before that time there was a fishery near the mouth of the Solway, and the "Parton Herrings," taken just north of Whitehaven, were well known and highly esteemed. Since then, and until last year (1921), these fisheries did not exist and only occasional herrings were taken. In the winter of 1921-22 the herrings came back to the Cumberland and Lancashire coasts in fair abundance and were taken at Maryport, at Morecambe, in Morecambe Bay, and all down the coast as far as Great Orme's Head. Thus, there has been a period of about thirty years during which the fish disappeared almost entirely. Before the 'nineties of last century there were other long-period fluctuations—thus somewhere about 1774, herrings were abundant in the estuary of the Dee—and doubtless elsewhere on the Lancashire and Cheshire coasts. In 1840, they appeared in the Mersey. No definite information is, however, now obtainable with regard to these fluctuations.

Haddock came into Liverpool Bay in great abundance about 1890 to 1895. Since then they have been practically absent, only an occasional specimen being taken.

(2) The Methods of Investigation.

The work was begun in 1908 and the methods employed were, briefly, as follows :

(*a*) Trawling experiments were made on the various grounds by the L.W.S.F. patrol vessels "John Fell" and "James Fletcher," and also by some of the police cutters. All the plaice caught were measured immediately after the net was cleared. Lengths were recorded in centimetre groups, all fish which were over n and less than $n+1$ cms. being recorded as n ·5 cms. The principal grounds sampled were

Luce Bay (in October, November, and December), the Cumberland coastal grounds, the "Nelson Buoy" grounds, the "Mersey Estuary," the "Red Wharf-Beaumaris Bay" region, Carnarvon and Cardigan Bays.

(*b*) Trawling experiments were made continuously from 1890 to 1920 by the sailing vessels employed on police work in the Mersey Estuarine area. All these experimental hauls were made by the same officer, Capt. George Eccles, a highly-experienced fisherman. Two series were made, one with the ordinary small trawl-net of 6-inch mesh, and the other with the ordinary shrimp-trawl net of 2-inch mesh. Some other similar series of hauls were also made in other parts of the District.

(*c*) Comparative hauls with trawl-nets of 4-inch, 6-inch, and 7-inch meshes were made.

(*d*) Samples of the plaice caught on the various grounds were regularly sent to the Liverpool laboratory. These were examined in detail:

They were measured as above and sorted into groups of n to $n+1$ cms.

The whole lot of fish in each group was weighed to the nearest gram and the total weight was divided by the number of fish. Average weights were so recorded.

The length-weight coefficient "k" was then calculated (see *Ann. Rept. Lancashire Sea-fish. Laby*. for 1911, p. 17).

Each fish was dissected; the sex was determined, as well as the stage of maturity; the age was determined by inspection of the rings on the earstones and the food contents of the stomach and intestine were often identified.

(*e*) Observations were made by the "Fish-Measurers," W. C. Smith, A. E. Ruxton, and G. Sleggs, on board steam trawlers, smacks, and half-decked trawlers. This work began in 1920. It was mostly restricted to the offshore grounds and to the shallow water area of the Solway Firth.

(*f*) Marking experiments were made. These began in 1906 and were carried on until 1913. Two areas were seen to be of much importance: the grounds off Nelson Buoy and those in Red Wharf and Beaumaris Bays, and most of the experiments were made there. In 1920 and 1921 the experiments were renewed and plaice were marked on the grounds between Isle of Man and the Solway Firth. In all cases the English form of mark was used; at first the bone button and brass label, and later the vulcanite buttons and labels.

(*g*) In 1921 the larval and post-larval plaice were studied. Catches were made by means of the Lancashire "push-net," which is used to catch shrimps, being pushed along the sea bottom, in water of two feet or so in depth, by a man wading. The flat fishes collected in this way (from the Cheshire coast and the coast of the Isle of Man) were identified and measured and their food contents were recognised. Larval and post-larval plaice from the Hatchery at Port Erin were also collected and their food was examined.

(*h*) Other investigations (Embryogeny, variability) were contemplated, but have not so far been adequately made.

(3) Treatment of the Data.

Not very much was to be made out of a direct comparison of the numbers of fish caught per hour's trawling, on the various grounds, and at different times. The standardisation of the fishing gear and vessels and of the canditions under which the experimental hauls were to be made, were too difficult. In no case have we had, at our disposal, a vessel used exclusively for scientific research, and all the work had to be done on board the police steamers and sailing boats, or on board steam trawlers, smacks, and inshore trawlers. It was, of course, very gratifying that the L.W.S.F. Committee allowed us the use of their vessels, and we are also much indebted to the owners and masters of the commercial boats, who allowed the fish-measurers to go to sea with them and make records of the fish caught. Still in no case were we in control and fully able to choose the grounds and times for the hauls. Scientific work on board the police vessels had, of course, to be dependent on the nature of the official duties that were to be performed. In the circumstances the results that were obtained are very satisfactory.

One can, of course, make certain conclusions of value merely by comparing *average* catches taken at different times, and on different grounds, with each other. No doubt these experiments do give us rough general pictures of the abundance of fish from time to time and, so far as they go, they must represent the experience that an observant fisherman would acquire. Thus the tables on pp. 110-111, giving the relative abundance of the different species of fish on the various grounds, are certainly to be regarded as representing the natural conditions in an approximate manner. So also, the series of hauls made in the Mersey by Capt. G. Eccles, give some very valuable information. Too much, however, must not be made of the ordinary periodic trawlings on which the present report is based, as representing variations in abundance from year to year.

What has been done has been to seek to get the information we require by a study of the measurements of the fish themselves, rather than by mere counts of the numbers taken per haul. These relative lengths, ages, etc., are independent of the actual numbers of fish taken. It will be seen that they do give us valuable and, we believe, reliable data. Combined with the results of the fish-marking experiments and the information given by the official statistics, they enable us to deduce conclusions that are of value for the administrators.

The statistical methods employed.

When the measurements of the fish sampled are arranged as follows :—

Mean length = 10·5, 11·5, 12·5, 13·5, etc., cms.
Nos. caught = 2, 5, 13, 46, etc.

we obtain a series called a "frequency distribution." There are many ways of forming such distributions from the same data. The "mean-lengths" 10·5, etc., represent the middle points of the groups of measurements, that is 10 to 11 cms., 11 to 12 cms., etc., but these groups might have been 10 to 12, 12 to 14, 9 to 11, 11 to 13, etc., or they might also have been 4 to $4\frac{1}{2}$ inches, $4\frac{1}{2}$ to 5 inches, etc., or even 4 to 5, 5 to 6 inches, etc. If we were to make such alternative series of measurements from the same sample of fish and then plot curves from the various distributions we should not get graphs of the same form. Nor should we get quite the same averages and other statistical results. It is convenient to measure the fish in centimetre groups, but such a method has no superiority over any other arrangement except its convenience.

If the series of measurements is a very big one—say several thousands of fish—it will not matter much what way we express the data. But every now and then small samples, 50 or 100 fish, say, must be studied. Therefore we require some way of avoiding the errors which arise because of the alternative methods of grouping the measurements.

This means that the crude distributions must be "smoothed" in some manner. In general, a series such as the above one is irregular and these irregularities affect whatever form of average we adopt. If we calculate the latter and then re-measure the fish and arrange them in a new way we may get different irregularities which affect our averages (or other statistical conclusions) in different ways. Which results are we to accept? In social and political controversies we do all these things and then accept the results that are the most welcome ones! But this kind of statistics is that which "can be made to prove anything," and we must avoid it "like the plague."

"Smoothing" might be effected by taking overlapping averages. Thus, instead of the frequency, 5, at mean length 11·5, in the above example we might take $\frac{2 + 5 + 13}{3} = 6·7$; instead of 13, at mean length, 12·5, we might take $\frac{5 + 13 + 46}{3} = 21·3$ and so on, all through the series. In some cases this method has an approved basis; it means that we are generally in doubt that any fish we measure is properly measured: it may really belong to the group in front, or that behind the group in which we have placed it. This is so with a number of fish in every sample. If one is very near 11 cms., say, it may be really a little less than 11, so little less that our necessarily hurried methods may not enable us to be sure. But it is only a few of the fish about which we are in doubt, in this way. That means that we ought to employ a smoothing formula of this kind,

$$\frac{f_{n-1} + mf_n + f_{n+1}}{2 + m}$$

where m is a small number, say 2 to 5.

Pearson Probability Curves.

The really scientific way to smooth such series as we have is to calculate a theoretical distribution and then use this instead of the crude series obtained by the measurements. Pearson curves are based on the theories of probability. The different results that are got in playing games of chance are explained by assuming that these results are due to the operation of a great number of small causes. The number of sixes one gets on throwing a dozen dice at the same time, or the number of heads we get when we throw a dozen pennies into the air, are chance effects due to a great number of small, independent causes, which are usually beyond our powers of control. The theory of probabilty enables us to calculate such chance results beforehand, and the calculated result agrees surprisingly with the actually-observed result, when the number of trials is fairly large. Even when the chance results are due to the operation of a number of small causes, some of which *can* be controlled (say the " loading " of the dice, or the cutting away of the metal from some of the sides of a " put and take " top), the theory does not fail us. When the causes of variation are quite beyond our control we obtain a symmetrical curve of a certain mathematical form, and most biological variation curves approach more or less closely to this form (the normal curve of error). Human biological inequalities (say variability in stature, or in the ability to pass an examination) come very close to this symmetrical form. On the other hand, social inequalities (say the annual value of the house a man inhabits; the income on which he pays tax, etc.) are entirely different, for the curve of variability in such cases is an asymmetrical, " J-shaped," exponential one. The meaning is that the causes of wealth and poverty have come under our control, and that the control endeavours to bring about the observed form of inequality.

In many of its applications (insurance and actuarial calculations) the theory is sound. When it is applied to the results of the study of organic variability it must also be regarded as sound. Obviously, when we apply it to finding out how much we are to qualify the results of taking a sample of something we are also on the right lines. Now these observations which we study here are samples. There are some millions of plaice on a certain fishing ground and we want to know their average length as well as the numbers that differ from the average by definite gradings above or below the average. We take a sample of, say, 1,000 plaice from this population and measure them and find the average and the variations from the average. But we cannot be certain that our sampling has been representative: some of the size-groups are always over-sampled and others are under-sampled.

Repeat this sampling again and the same misrepresentation occurs, but it is *different* groups that are under- and over-sampled.

If this were all we could apply Pearson curves to such data as are here given. But the theory supposes that the population that is sampled is an *homogeneous* one in respect of the characteristic that we measure. One could not legitimately measure the stature of all the individuals in a crowded church, say, and then base a Pearson curve on the results. A number of the people are full-grown men, others are full-grown women, and others again are boys and girls of different ages. Thus there are groups in this church population, and the mode of variability from the average is not the same in every group. We ought to measure and classify the full-grown men separately from the women, etc., making a separate curve for each. The assemblage is an *heterogeneous* one.

All fishery samples are, in general, heterogeneous, consisting of fish of one, two, three, etc., years of age. We find this by examination of a sample. It is, in general, quite impracticable to attempt to separate the sample of plaice caught and measured into its year-classes. Therefore we cannot (in general, again) apply the method of Pearson curves to treatment of the statistics, and this is fortunate, in one sense, because the arithmetic that is involved is "colossal." Still there are samples in which *one* year-class may preponderate so greatly as to smother all the others. So some of the distributions in this report have been "Pearsonified," with the object of illustrating this discussion.

The Construction of Summational Curves.

The method that has been adopted has been to smooth the observed frequency-distributions by making summational series from them. Then all the information required is obtained from the latter curves. The methods actually used will best be described by an example.

Example : Table V, June, 1908-1913.

(1) Mean length.	(2) f	(3) f °/₀	(4) Σf °/₀₀	(5) y	(6) Σy
13·5	1	0·5	1000·2	...	...
14·5	12	6·4	999·7	2·1	998·8
15·5	39	20·7	993·3	21·6	996·7
16·5	106	56·2	972·6	64·4	975·1
17·5	205	108·8	916 4	111·9	910·7
18·5	304	161·3	807·6	143·0	798·8
19·5	263	139·5	646·3	149·9	655·8
20·5	231	122·6	506·8	136·7	505·9
21·5	228	121·0	384·2	112·6	367·2
22·5	183	97·1	263·2	85·7	256·6
23·5	124	65·8	166·1	61·3	170·9
24·5	67	35·5	100·3	41·6	109·6
25·5	45	23·9	64·8	27·1	68·0
26·5	24	12·7	40·9	17·0	40·9
27·5	20	10·6	28·2	10·4	23·9
28·5	9	4·8	17·6	6·2	13·5
29·5	14	7·4	12·8	3·6	7·3
30·5	5	2·7	5·4	2·0	3·7
31·5	3	1·6	2·7	1·1	1·7
32·5	2	1·1	1·1	0·6	0·6
...	1,885	1000·2	...	998·8	...

The plaice have been grouped into one cm. classes, 13 to 14, 14 to 15, and so on : Col. (1) gives the middle points of these class-ranges ; Col. (2) gives the actual numbers of fish measured and belonging to each class-range, and Col. (3) gives these frequencies expressed as numbers per 1,000. Thus all the series given in this report can be graphed on the same scale, and the graphs can be superposed for comparison. But the actually-observed frequencies are necessary whenever we require to find the "probable errors," so they must be stated. Col. (4), "Σf °/₀₀," gives the results of the process of summation : thus the entry, 17·6, opposite the length, 28·5 cms., is the sum, 4·8 + 7·4 + 2·7 + 1·6 + 1·1, of the frequencies opposite 17·6 and below the latter. In this case the summation begins at the bottom of the column, but it might as well begin at the top. The entries in Col. (4) are to be read in this way: 1,000·2 °/₀₀ fish are 13 or more than 13 cms. in length; 999·7 °/₀₀ are 14 or more than 14; 993·3 °/₀₀ are 15 or more than 15 cms., and so on. Or, again: 263·2 °/₀₀ plaice are 22 cms. or over 22 cms. in length and 506·8 °/₀₀ are 20 or over 20 cms. long. Therefore 506·8 − 263·2 = 243·6 (that is, about one-quarter of the entire catch) are over 20, but less than 22 cms. long.

Col. (5) in the table, "y," represents the theoretical frequencies as calculated by Pearson's method of curve-fitting. Now let these theoretical frequencies be summed in the same way as Col. (3) has been obtained: we thus get Col. (6), "Σy." It will be seen that this is very similar to Col. (4), which gives the result of the summation of the crude frequencies. The crude Σf's are more like the theoretical Σf's than the crude f's are like the theoretical f's, and this is because, in the process of summation we have automatically got rid of the errors of random sampling—or, at least, to some extent. How this comes about is easily seen: if one class, say the fish of 18 to 19 cms., is over-represented in the sample, then all the other classes will, on the average, be under-represented. Now in the summing we add together at each stage over- and under-sampled classes, and so the error of random sampling, apparent in the frequency series, tends to disappear from the summational ones. Therefore, in graphing these various columns it will be seen (fig. 3) that the crude and theoretical summational series are nearly the same.

From the summational series, made in this way, smoothed frequency series can easily be constructed. First of all the summational series must be graphed on a fairly big scale. The curve must not be drawn free-hand, but by means of some device that enables us to lay a spline, or steel spring, evenly among all the points plotted. The curve should pass as nearly as possible to *all* the points, but without necessarily passing actually through any of them. It should be drawn by running a pencil trace along the spline, and the trial curve so obtained must then be inspected. When the points are connected by short, straight lines it will be seen that there are a number of polygons, some situated above the curve and others below it : the combined area of the polygons above the curve should be equal to that of the polygons below the curve. If this is not so the curve should be redrawn.

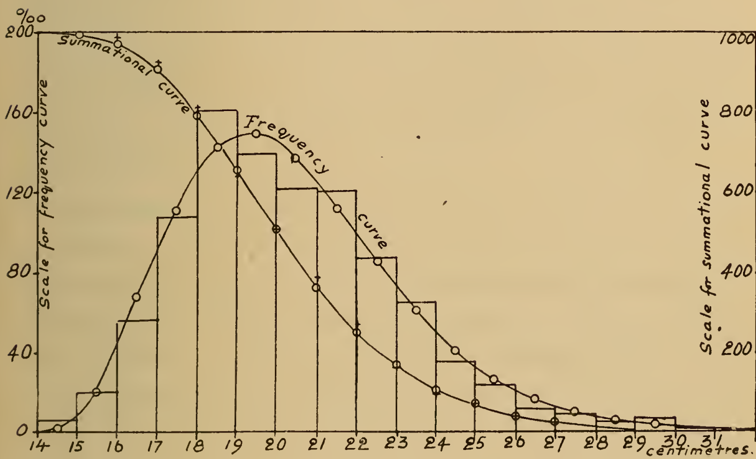


Fig. 3.

The changes of curvature should be as gradual as possible. We must first resolve whether the summational curve is simple or compound. Usually it is simple—that is, it should present one part which is all concave to the horizontal axis and another part which is all convex (as in Fig. 3). There will be a portion which has no sensible curvature—that is, it looks like a straight line sloping in one direction or the other, according to whether the summation begins at one end of the distribution or the other. At the ends the summational curve is sensibly parallel to the horizontal axis. Sometimes there is a hump on the summational curve, formed by *several* points—say 3 to 6. When this is so the curve should endeavour to follow these points, and in that case it will be seen that there are now *two* places where the summational curve is concave, and other two where it is convex to the horizontal axis. The frequency series from which the summation has been made must now be regarded as consisting of two simple, superposed series.

In doing all this we are adopting a definite formula of interpolation. In making the smoothed curve pass evenly among all the plotted points we are making its total area equal to the total area of the polygon formed by connecting the plotted points by short, straight lines : in the Pearson method of calculating a theoretical curve we must first assume that the total unsmoothed frequency shall be equal to the total smoothed frequency. Further, the equation of the curve which is thus calculated by Pearson's methods is graphically represented by a certain *form*, and this form, for our smoothed, summational curve, is given by the line of *gradually* changing curvature, which is *everywhere* as near as possible to the plotted points. The elasticity of the spring (which we assume to be the same everywhere in it—not always the case, however, in a much-used one) confers on the curve this gradual, unforced change of curvature.

The actual, smoothed curve, which is to be used further, is drawn with a ruling-pen filled with red ink, and obviously a fine trace is made. The points where the curve intersects the vertical scale lines of the graph paper are now pricked and the ordinates are read off on the vertical scale. These are written down to replace the unsmoothed Σf series. This smoothed series is next differentiated so as exactly to reverse the process of summation, as it was carried out on the unsmoothed f series, and the result is a smoothed, frequency curve. It is not quite smooth, however, because it is rather difficult to read off the ordinates very precisely on the vertical axis. There is never any difficulty, for all that, in drawing a smooth, frequency curve through the points found by this process, for we can easily find three other important characters of the curve—its maximum and its points of inflexion.

Very often the smoothed, frequency curve so found is very like the Pearson one which can be calculated but it is often significantly different in form. When this is the case the smoothed curve found graphically is, we think, to be preferred. Undoubtedly, there are plaice frequency series which do not give a Pearson curve with sufficient "closeness of fit" to satisfy the criterion proposed by the statisticians, and this may be the case even when the measurements are numbered by thousands. (Obviously the law of variability is not that stated by Pearson's fundamental, differential equation with four constants.)

Use of the Summational Curves.

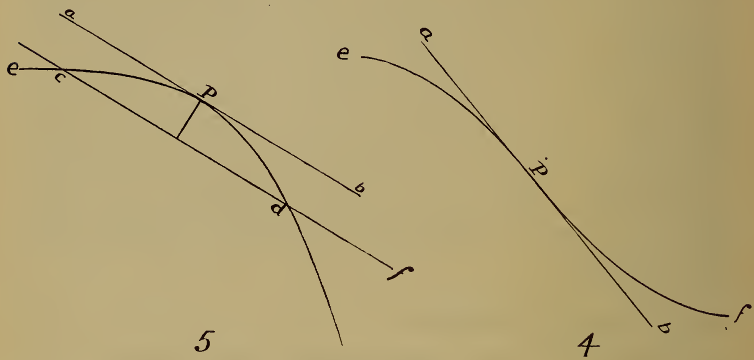
These curves can be used to obtain the numbers of fish between any two sizes. This is possible from the summational series themselves when the sizes in question are whole numbers of centimetres (or otherwise the numbers representing the ends of the groups or classes). From the curve, however, we can interpolate graphically and find the frequency between any limits whatever—the method is an obvious one and is illustrated on p. 133.

The Mode or Maximum.

This is the position of greatest frequency—the peak or hump of the frequency curve. It can be found graphically as follows :—

A fine, straight line is scratched on a strip of transparent celluloid (a set-square, for instance) and the extremities of the line are neatly pierced by fine holes made with a needle. The set-square is laid on the graph, scratched line downwards, and then it is rotated, so to speak, on the curve. Where the latter changes from convex to concave there is a "point of inflexion," and here the tangential line will cross the summational curve.

The set-square is now held in this position and the apertures at the ends of the line are pierced so as to make points on the graph paper. The set-square is taken away and a fine line in red ink is ruled on the graph : this will appear to coincide with



FIGS. 4 and 5.

that part of the summational curve which is sensibly straight. By inspection we find the points where curve and tangential line begin to diverge, and half-way between them we may take to be approximately the point of inflexion. This point is marked and a perpendicular is dropped from it to cut the horizontal axis. This latter point of intersection, read off on the scale of lengths, gives the abscissa of the mode, or maximum, of the frequency curve.

The Points of Inflexion.

Let the summational curve be supposed simple. There will be two places on it where its curvature is greatest, and these can be found graphically as follows :—

Rule two parallel lines, about 1 cm. apart, on a transparent set-square and rule another line perpendicular to both at about the mid-points of the parallel lines. Graduate the lower line in mms. Rotate the ungraduated line on the set-square on the summational curve at the places of greatest apparent curvature and find the point where the chord, as given on the graduated line, is of least length. This point is approximately the portion of greatest curvature. Drop a perpendicular from this to cut the horizontal axis and the point of intersection, read off on the scale of lengths, will be the abscissa of the point of inflexion on the frequency curve.

Measures of Dispersion.

There are a number of such measures—for instance, Standard Deviation, Probable Error, Interquartile Range, Semi-Interquartile Range, etc. We cannot properly speak about "the length" of the plaice inhabiting any sea area in any particular period of time for these lengths may be anything between the extreme lengths actually observed. But we see that all these sizes of plaice do not occur with equal frequency—for instance, the table on p. 125 shows that the plaice on the area in question, and at the particular time, ranged from 13 to 33 cms. in length. Nevertheless, about 25 per cent. of all were over 20, but less than 22 cms. in length. Evidently, then, we attach importance to a limited range of lengths, the ends of which are situated somewhere on each side of the maximum of the distribution: this range gives us the *prevalent length* of the fish at that time and in that area.

The commonly used measures of dispersion are conventional ranges of this kind. The "probable error" and the "interquartile range" are supposed to represent a short range of lengths near the mean length (or near the mode, or near the "median"), such that within this range are contained one-half of all the fish in the sample. The "probable error" is calculated from the "standard deviation," which is calculated on the assumption that the frequency curve representing the distribution is what is called the "Gaussian" one. It seldom is in any of the distributions that we have found. Therefore the use of the standard deviation and probable error has no theoretical justification, and, indeed, it may be very misleading.

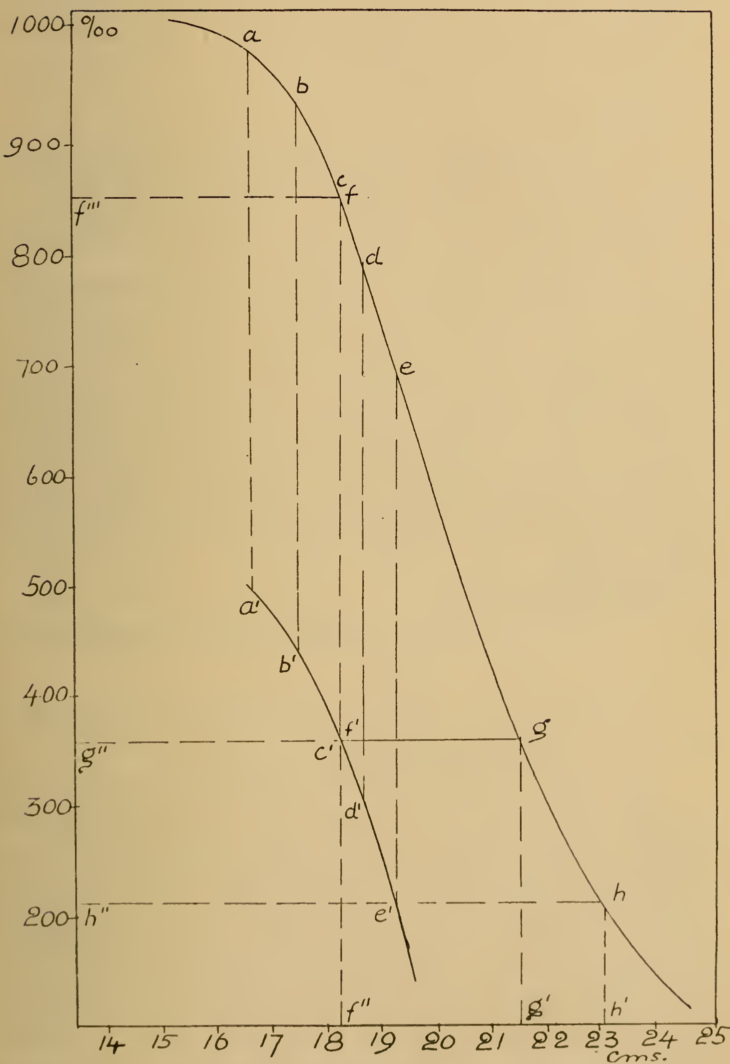
The interquartile range is calculated by finding the "median" and "quartiles." The arithmetic is simple and easy. The method is applied to the crude frequencies and it is therefore affected by the errors of sampling and by the errors that arise from grouping. If different methods of grouping are adopted—in the cases of small distributions—different medians and quartiles are obtained, and any one of them, found by different methods of grouping, is equally probable. If we group only in one way we get only one interquartile range, but, obviously, there are other equally admissible interquartile ranges which we have not calculated !

What measure of dispersion is to be adopted ? This depends on the plan of the investigation for the measure in question is only a means to some conclusion or other. Here we adopt the measure called the "shortest half (or two-thirds, or three-quarters) range."

The Shortest Half-range.

The total area of the frequency curve (or the sum of the frequencies) is taken as 1,000 (for we are converting the observed frequencies into "per-milles"). We take the summational curve figure and then take one-half of the total vertical scale (or 500) on a pair of dividers and, with this, measure off the distances aa^1, bb^1, cc^1, etc., along the vertical scale lines and from the points where the latter intersect the summational curve. Thus we get the points a^1, b^1, c^1, d^1, e^1, and then (with a "french curve") we draw a smooth curve through them.

Next, with a pair of dividers, we find the shortest distance, measured along some horizontal scale line, between the curve a^1, b^1, c^1, d^1, e^1 and the summational one. Perhaps there are several scale lines all sensibly the same in length and then we approximate by finding the middle one. The places are marked where this shortest horizontal line cuts both curves : they are g and f^1 in Fig. 6. From g and f^1 perpendiculars are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22
23
24
25
Cms.

FIG. 6.

dropped to cut the horizontal axis, and these latter points, read off on the scale of lengths, give the abscissae of the shortest half-range : the latter is about 18·5 to 21·5 cms., and within this range of lengths one-half of all the fish in the catch are contained.

We now go further. From the point g'', on the vertical scale, 150 units are measured downwards getting the point h''. A horizontal line $h''\ h$ is drawn to cut the summational curve in h and a perpendicular hh' is drawn to cut the horizontal axis in h'. Between g' and h', that is, between about 21·5 and 23 cms., another 15 per cent. of all the catch is contained. Next we prolong the vertical line, $f''f'$, upwards to cut the summational curve in f, and then a horizontal ff''' is drawn across to cut the vertical axis in f'''. From the latter point 150 units are measured upwards on the vertical axis giving a point on the latter at about 1,000. Therefore a further 15 per cent. of the fish are contained within the range of lengths 14 and 19 cms.

Summarising we find :

One-half of all the fish are over 19 and less than 22 cms. in length ;

80 per cent. of all are greater than 14 and less than 23·5 cms. in length.

Obviously we can extend the method. We might repeat the above construction, using two-thirds of the vertical scale length, or three-fourths : these figures would give us the shortest two-third and three-fourths' ranges. Or we may take the point 20 cms. on the horizontal scale, draw a perpendicular upwards to cut the curve and then a horizontal across to cut the vertical axis in the point 600. That shows that 60 per cent. of all the fish are 20 cms., or more than 20 cms. in length. Or, again, we may find the mode and then draw a horizontal across to cut the vertical axis. Stepping off 25 per cent. of the latter scale on either side we get two additional points.

From them horizontals are drawn to cut the curve, and from the points of intersection perpendiculars are drawn to cut the horizontal axis. The latter points are the two quartiles.

It must be noted that the degree of accuracy of such determinations of the modes, points of inflexion, or measures of dispersion depends upon good draughtsmanship. This is not difficult to attain. There will be some personal differences in the results,* but we submit that these are usually smaller than any differences *that ought to* affect the conclusions that are to be made. These conclusions are to have certain probabilities: for instance, we lay it down that it is to be 2 to 1 that the fish caught on a certain area, in a certain month, and with a 6-inch mesh trawl-net, are (say) between n and m cms. in length. Then we find n and m, or we wish to find what fraction of the whole catch of fish are between n and m cms. long in the same area and in the same circumstances. Then n and m being postulated we find the corresponding probability. Extensions will readily suggest themselves.

Characteristic Lengths of the Plaice Caught During the Pre-War Period, 1908-1913.

We now give a series of tables, 3 to 13, which summarise the results of the trawling experiments made during the six years 1908-1913. These data are intended as a record of the condition of the plaice population on the eastern side of the Irish Sea during the years immediately preceding the war, and they will enable us to make a comparison with the condition

* Analytical methods can always be employed to find the mode (dy/dx a maximum on the summational curve), and the points of inflexion (dy^2/dx^2 maximal and changing sign on the summational curve). We think such treatment would be pedantic. Measures of dispersion must be approximate so long as we do not know the equation to the frequency curve.

that followed the partial cessation of fishing which occurred during the years 1914-1918.

The arrangement of the data is as follows :—

Tables 3 to 10 record the lengths of plaice caught in a trawl-net of 6-inch mesh, throughout the year, on the regions Luce Bay, Morecambe Bay, etc., Blackpool to Liverpool Bar, Mersey Estuary, Beaumaris and Red Wharf Bays, etc., Carnarvon Bay and Cardigan Bay. The actual frequencies of occurrence of each one-cm. group and the frequencies per thousand are given.

Table 11 gives the same kind of data for plaice caught off the Mersey Estuary in a shrimp trawl-net of 2-inch mesh.

Table 12 gives the same data for a number of hauls made with trawl-nets of 4-inch, 6-inch, and 7-inch meshes on the same grounds and at about the same times.

Table 13 gives the dispersions, calculated by the methods indicated in the previous section of this report, for the distributions of Tables 3 to 12.

Table III. Luce Bay, Sept.-Dec., 1908-1912.

Mean length.	f	f °/oo	Mean length.	f	f °/oo
10·5	2	0·2	37·5	173	22·3
11·5	6	0·8	38·5	155	20·0
12·5	7	0·9	39·5	119	15·4
13·5	9	1·2	40·5	91	11·7
14·5	22	2·8	41·5	58	7·5
15·5	79	10·1	42·5	66	8·5
16·5	271	34·8	43·5	42	5·4
17·5	372	48·0	44·5	51	6·6
18·5	412	53·2	45·5	18	2·3
19·5	523	67·5	46·5	27	3·5
20·5	538	69·5	47·5	17	2·2
21·5	454	58·6	48·5	13	1·7
22·5	412	53·2	49·5	12	1·5
23·5	380	49·1	50·5	5	0·6
24·5	306	39·5	51·5	6	0·8
25·5	290	37·4	52·5	3	0·4
26·5	292	37·7	53·5	6	0·8
27·5	257	33·2	54·5	2	0·2
28·5	231	29·8	55·5	...	...
29·5	259	33·4	56·5	2	0·2
30·5	239	30·8	57·5	1	0·1
31·5	218	28·1	58·5	3	0·4
32·5	276	35·6	59·5	...	...
33·5	299	38·6	60·5	...	...
34·5	264	34·1	61·5	...	...
35·5	251	32·4	62·5	2	0·2
36·5	207	26·7			
			Totals	7,748	999·6

Table IV. Morecambe Bay, &c., 1908-1913.

	Morecambe Bay.						Estuary of the Duddon.	
	June.		July.		August.		March—May.	
	f	f °/oo	f	f °/oo	f	f °/oo	f	f °/oo*
10·5	...	...	...	...	...	...	6	...
11·5	...	...	...	...	...	...	7	...
12·5	...	...	...	...	...	...	9	...
13·5	...	...	1	0·9	1	0·7	23	6·3
14·5	9	3·8	3	2·6	5	3·3	82	38·2
15·5	39	16·6	36	31·1	21	13·7	205	75·3
16·5	78	33·3	75	64·9	69	45·1	302	100·6
17·5	171	72·9	135	116·8	101	66·0	390	117·2
18·5	302	128·8	101	87·4	116	75·8	482	118·8
19·5	305	130·1	147	127·2	128	83·7	413	111·1
20·5	416	177·4	180	155·7	141	92·2	315	97·6
21·5	345	147·1	111	96·0	137	89·5	221	81·9
22·5	303	129·2	113	97·7	178	116·3	170	66·2
23·5	183	78·0	65	56·2	157	102·6	178	51·7
24·5	90	38·4	71	61·4	151	98·7	102	39·2
25·5	50	21·3	42	36·3	123	80·4	84	29·0
26·5	23	9·8	32	27·7	74	48·4	68	20·9
27·5	18	7·7	18	15·6	67	43·8	44	14·6
28·5	5	2·1	10	8·7	30	19·6	43	10·5
29·5	3	1·3	7	6·1	16	10·5	32	6·9
30·5	2	0·9	4	3·4	9	5·9	27	4·6
31·5	1	0·4	...	...	3	1·9	8	3·0
32·5	1	0·4	1	0·8	2	1·3	4	1·9
33·5	1	0·4	3	2·6	1	0·7	4	1·2
34·5	...	...	...	...	...	...	4	0·7
35·5	...	...	1	0·8	...	...	....	...
	2,345	999·9	1,156	999·9	1,530	1000·1	3,223	997·4

* Calculated frequency curve.

Table V. Blackpool to Liverpool Bar. 1908-1913.

	June.		July.		August.		September.		October.	
	f	f °/oo	f	f °/oo*	f	f °/oo*	f	f °/oo*	f	f °/oo
11·5	...	...	...	...	1	...	1	...	...	...
12·5	...	...	2	...	6	...	1	...	1	0·4
13·5	1	0·5	1	...	25	...	9	3·9	10	4·0
14·5	12	6·4	8	...	57	3·8	34	12·1	19	7·7
15·5	39	20·7	30	4·8	131	24·3	111	31·9	75	30·3
16·5	106	56·2	129	29·7	267	55·9	269	57·7	201	81·3
17·5	205	108·8	320	85·4	473	89·4	459	82·9	231	93·4
18·5	304	161·3	601	139·3	740	106·0	517	101·7	250	161·1
19·5	263	139·5	838	162·9	794	114·0	542	111·2	196	79·3
20·5	231	122·6	676	154·2	839	111·5	557	111·3	167	67·5
21·5	228	121·0	495	127·7	681	101·8	506	103·6	152	61·5
22·5	183	97·1	433	93·0	571	88·2	449	91·2	160	64·7
23·5	124	65·8	320	69·4	444	73·3	339	76·3	164	66·3
24·5	67	35·5	254	47·9	338	58·9	311	61·1	177	71·6
25·5	45	23·9	159	32·3	262	46·0	245	47·1	156	63·1
26·5	24	12·7	83	21·5	231	35·2	176	35·1	140	56·6
27·5	20	10·6	63	14·1	182	26·4	128	25·4	122	49·3
28·5	9	4·8	25	9·3	146	19·4	88	17·8	97	39·2
29·5	14	7·4	22	6·1	86	14·1	54	12·1	61	24·7
30·5	5	2·7	6	4·0	63	10·0	34	8·1	37	15·0
31·5	3	1·6	14	2·8	36	7·1	18	5·2	22	8·9
32·5	2	1·1	15	1·8	34	5·0	18	3·3	8	3·2
33·5	...	...	5	1·2	28	3·5	4	2·0	11	4·4
34·5	...	...	6	0·8	21	2·4	6	1·3	5	2·0
35·5	...	...	5	0·5	12	1·6	5	0·7	4	1·6
36·5	...	...	1	0·4	11	1·1	6	0·4	2	0·8
37·5	...	...	3	0·3	3	0·8	1	0·2	2	0·8
38·5	...	...	2	0·2	7	0·5	1	0·1	1	0·4
39·5	...	...	...	...	1	0·3	...	...	...	...
40·5	...	...	...	...	1	0·2	...	...	1	0·4
41·5	...	...	...	...	1	0·2	...	...	1	0·4
	1,885	1000·2	4,516	1009·6	6,492	1000·9	4,889	1003·7	2,473	999·9

* Calculated frequency curves.

Table VI. Off Mersey Estuary. 1908-1913.

Mean length.	May.		June.		July.		August.		September.		October.		November.		December.	
	f	f °/oo*	f	f °/oo*	f	f °/oo*	f	f °/oo*	f	f °/oo	f	f °/oo	f	f °/oo	f	f °/oo
11·5	3	0·2	...	...	...	...	...	0·1	1	0·2	...	...	...	...	1	0·7
12·5	8	0·7	...	0·1	2	0·2	2	0·4	8	1·1	1	0·2	...	...	2	1·5
13·5	10	2·5	8	1·3	5	0·7	17	1·6	41	5·7	5	0·9	1	0·4	17	12·6
14·5	39	8·4	42	9·0	39	3·7	56	5·2	260	36·3	21	0·4	3	1·4	71	52·9
15·5	112	19·3	144	40·4	95	12·0	96	13·5	714	99·5	187	33·9	44	21·3	188	140·0
16·5	256	57·4	476	107·5	228	41·9	159	28·6	1,010	140·8	516	93·7	129	62·7	279	207·7
17·5	499	107·5	661	174·7	409	103·1	291	50·7	852	118·7	493	89·5	133	64·4	214	159·4
18·5	756	155·0	775	195·1	738	173·6	510	76·6	659	91·8	666	120·8	158	76·5	139	103·4
19·5	864	174·8	601	165·9	897	191·7	768	101·1	550	76·6	718	130·3	151	73·2	85	63·3
20·5	682	158 6	518	117·8	803	158 6	870	117·8	610	85·1	633	114·9	162	78·4	95	70·7
21·5	541	110·3	283	74·8	624	110·0	846	122·3	499	69·6	644	116·8	140	67·8	79	58·7
22·5	407	80·5	196	44·4	412	69·6	717	117·0	438	61·1	421	76·4	144	69·7	68	50·6
23·5	242	48·8	109	25·3	213	42·3	611	101·8	288	40·2	326	59·1	124	60·7	32	23·8
24·5	131	27·9	59	14·2	114	25·5	562	82·6	265	36·9	214	38·8	80	38·7	30	22·3
25·5	71	15·3	24	7·9	53	15·4	366	62·1	224	31·2	167	33·1	105	50·8	20	14·9
26·5	34	8·3	14	4·5	28	9·4	351	44·1	197	27·5	120	21·7	100	48·4	9	6·7
27·5	18	4·4	6	2·5	17	5·9	222	29·6	177	24·6	99	16·1	101	48·8	6	4·5
28·5	14	2·2	3	1·5	12	3·8	158	19·0	126	17·5	89	15·6	103	49·9	1	0·7
29·5	3	1·3	6	0·9	4	2·4	73	11·6	104	14·4	74	13·4	95	46·1	2	1·5
30·5	5	0·4	2	0·4	3	1·6	48	6·8	52	7·3	31	5·6	93	45·1	...	...
31·5	5	0·3	3	0·3	4	1·1	20	3·9	36	5·2	24	4·4	71	34·3	...	...
32·5	2	0·1	1	0·2	5	0·8	13	2·2	14	1·9	26	4·7	48	23·3	...	...
33·5	...	...	1	0·1	2	0·5	4	1·1	19	2·6	10	1·8	40	19·3	1	0·7
34·5	...	...	1	0·1	3	0·4	4	0·7	10	1·4	9	1·6	21	10·2	...	...
35·5	...	...	...	...	2	0·3	6	0·3	7	0·9	5	0·9	7	3·4	...	...
36·5	...	...	...	...	3	0·2	1	0·2	...	...	2	0·4	5	2·4	1	0·7
37·5	...	...	...	...	1	0·1	...	...	5	0·6	2	0·4	1	0·4	1	0 7
38·5	...	...	...	...	1	0·1	...	...	4	0·5	...	...	1	0·4	1	0·7
39·5	...	...	...	...	3	0·1	...	...	3	0·4	1	0·2	1	0·4	...	...
40·5	...	...	...	...	3	0·1	...	...	...	...	5	1·0	3	1·4	1	0·7
	4,702	984·2	3,933	988·9	4,723	975·1	6,771	1000·9	7,173	999·6	1,343	1000·0	2,064	999·8	421	999·4

Table VII. Beaumaris Bay, Red Wharf Bay, &c. 1908-1913.

Mean length.	January.		June.		July.		August.	
	f	f °/oo	f	f °/oo	f	f °/oo	f	f °/oo
12·5	...	...	...	...	2	1·0	2	1·0
13·5	4	2·9	2	0·9	1	0·5	3	1·5
14·5	9	6·7	3	1·5	3	1·6	3	1·5
15·5	28	20·7	32	15·8	26	14·3	12	5·9
16·5	43	32·1	92	45·3	43	23·7	51	28·3
17·5	63	47·0	213	104·9	124	68·4	145	71·9
18·5	81	60·4	261	128·5	207	114·0	231	114·6
19·5	91	67·9	259	127·6	273	150·3	318	157·7
20·5	70	52·2	237	116·8	255	140·4	282	139·8
21·5	82	61·2	153	75·4	216	119·1	260	129·0
22·5	85	63·4	113	55·7	156	85·9	170	84·3
23·5	69	51·5	77	37·9	113	62·2	127	63·0
24·5	60	44·8	75	36·9	86	47·3	105	52·1
25·5	69	51·5	64	31·5	65	35·8	67	33·2
26·5	78	58·2	47	23·1	42	23·1	50	24·8
27·5	84	62·7	52	25·6	37	20·4	37	18·3
28·5	67	50·0	56	27·6	36	19·8	34	16·9
29·5	67	50·0	47	23·1	31	13·5	29	14·4
30·5	68	50·7	44	21·7	23	12·1	26	12·9
31·5	62	46·3	45	22·2	17	9·3	20	9·9
32·5	44	32·8	56	27·6	18	9 9	15	7·4
33·5	28	20·9	37	18·2	14	7·7	7	3·5
34·5	34	25·4	19	9·4	7	3·8	6	2·9
35·5	14	10·4	16	7·9	8	4·4	1	0·5
36·5	16	11·9	8	3·9	5	2·7	3	1·5
37·5	2	1·5	6	2·9	2	1·0	2	1·0
38·5	4	2·9	5	2·4	6	3·2	2	1·0
39·5	5	3·7	6	2·9	...	...	1	0·5
40·5	3	2·2	5	2·4	...	...	1	0·5
41·5	2	1·4	...	...	1	1·0	...	...
42·5	1	0·7	...	...	...	...	...	...
43·5	1	0·7	...	...	...	...	...	...
44·5	1	0·7	...	...	...	...	...	...
45·5	2	1·4	...	...	...	...	...	...
46·5	1	0·7	...	...	...	...	...	...
47·5	1	0·7	...	...	...	...	...	...
48·5	1	0·7	...	...	...	...	...	...
	1,340	998·9	2,030	999·6	1,817	996·4	2,016	999·8

Table VIII. Beaumaris Bay, Red Wharf Bay, &c. 1908-1913.

Mean length.	September.		October.		November.		December.	
	f	f °/oo	f	f °/oo	f	f °/oo	f	f °/oo
11·5	3	0·6	...	...	...	...	...	...
12·5	8	1·6	3	0·3	...	...	1	0·4
13·5	20	3·9	14	1·5	5	0·8	2	0·8
14·5	68	13·3	76	8·7	29	4·9	10	4·0
15·5	158	31·0	421	48·4	146	24·5	20	7·9
16·5	291	57·0	1,197	137·9	350	58·8	66	26·1
17·5	438	85·8	1,493	171·7	413	69·4	94	37·2
18·5	396	77·6	1,155	132·2	360	60·5	158	62·5
19·5	430	84·3	802	92·3	343	57·6	175	69·2
20·5	392	76·8	579	66·6	341	57·3	218	86·3
21·5	319	57·0	502	57·7	362	60·8	201	80·5
22·5	342	67·0	405	46·6	345	58·0	224	88·6
23·5	296	57·9	310	35·6	339	56·9	211	83·5
24·5	337	66·0	268	30·8	363	61·0	162	64·1
25·5	299	58·6	261	30·0	349	58·6	154	60·9
26·5	286	56·0	275	31·6	336	56·4	152	60·1
27·5	278	54·4	219	25·2	312	52·4	117	46·3
28·5	217	42·5	215	24·7	361	60·6	120	47·5
29·5	153	29·9	161	18·5	341	57·3	81	32·1
30·5	131	25·6	107	12·3	272	45·9	109	43·1
31·5	85	16·6	81	9·2	176	29·6	68	26·9
32·5	59	11·6	52	5·9	137	23·0	59	23·3
33·5	37	7·3	39	4·5	73	12·3	29	11·5
34·5	22	4·3	22	2·5	60	10·1	28	11·1
35·5	17	3·3	12	1·4	38	6·4	15	5·9
36·5	7	1·4	12	1·4	30	5·0	12	4·7
37·5	7	1·4	4	0·5	14	2·3	8	3·2
38·5	3	0·6	4	0·5	8	1·3	12	4·7
39·5	1	0·2	2	0·2	14	2·3	10	4·0
40·5	4	0·8	1	0·1	14	2·3	6	2·4
41·5	...	...	3	0·3	6	1·0	4	1·6
42·5	...	...	...	...	2	0·3	1	0·4
43·5	...	...	2	0·2	1	0·1	...	...
44·5	...	...	...	...	2	0·2	...	...
45·5	...	...	...	...	4	0·4	...	...
46·5	...	...	1	0·1	1	0·1	...	...
47·5	...	...	...	...	3	0·3	...	...
	5,104	994·3	8,697	999·4	5,950	999·9	2,527	1000·8

Table IX. Carnarvon Bay. 1908-1913.

Mean length.	May.		June.		July.		August.		September.		October.	
	f	f °/oo	f	f °/oo	f	f °/oo	f	f °/oo	f	f °/oo	f	f °/oo
15·5	...	...	...	...	...	...	...	...	4	16·5	5	20·2
16·5	2	3·9	11	25·1	3	3·6	...	...	18	32·8	11	44·5
17·5	11	20·8	30	71·2	14	21 3	10	25·8	75	156·3	18	72·9
18·5	55	108·9	65	154·2	40	60·9	35	90·2	50	106·6	28	113·3
19·5	69	136·3	74	177·8	63	95·9	50	128·9	45	95·9	16	64·7
20·5	77	152·5	72	171·0	78	118·7	79	204·1	52	110·9	21	85·0
21·5	45	89·1	46	109·2	87	132·4	57	147·0	35	74·6	23	93·1
22·5	46	91·1	38	90·3	95	144·5	49	126·3	32	68·2	19	76·9
23·5	38	75·3	20	47·5	78	118·7	43	110·9	38	81·0	25	101·2
24·5	28	55·5	13	30·9	42	63·9	38	97·7	28	59·7	22	89·0
25·5	17	33·7	10	23·7	36	54·7	11	28·3	13	27·7	11	44·5
26·5	16	31·7	10	23·7	32	48·7	10	25·8	11	23·4	11	44·5
27·5	16	31·7	12	27·8	26	39·6	3	7·7	14	29·9	13	52·5
28·5	14	27·7	6	14·3	19	28·9	2	5·2	16	34·1	5	20·2
29·5	14	27·7	2	4·7	6	9·1	1	2·6	22	46·9	8	32·4
30·5	11	21·8	2	4·7	6	9·1	...	...	7	14·9	2	8·1
31·5	8	15·8	2	4·7	8	12·2	...	...	1	2·1	2	8·1
32·5	6	11·8	4	9·5	6	9·1	...	...	5	10·7	2	8·1
33·5	4	7·9	...	...	6	9·1	...	...	1	2·1	1	4·0
34·5	6	11·8	1	2·4	4	6·1	...	...	1	2·1	1	4·0
35·5	7	13·8	2	4·7	2	3·0	...	...	...	...	...	...
36·5	4	7·9	...	...	1	1·5	...	...	...	...	1	4·0
37·5	5	9·9	1	2·4	1	1·5	...	...	...	...	2	8·1
38·5	...	...	...	...	1	1·5	...	...	1	2·1	...	...
39·5	1	1·9	...	...	...	...	...	...	...	...	...	...
40·5	1	1·9	...	...	...	...	...	...	...	...	...	...
41·5	...	...	...	...	1	1·5	...	...	...	...	...	...
42·5	1	1·9	...	...	1	1 5	...	...	...	...	...	...
43 5	...	...	...	...	...	...	...	...	...	...	...	...
44 5	1	1·9	...	...	...	...	...	...	...	...	...	...
45·5	...	...	...	...	...	...	...	...	...	...	...	...
46·5	...	...	...	...	...	...	...	...	...	...	...	...
47·5	1	1·9	...	...	...	...	...	...	...	...	...	...
48·5	1	1·9	...	...	1	1·5	...	...	...	...	...	...
	505	998·0	421	999 8	657	998·5	388	1000·5	469	998·5	247	999·3

Table X. Cardigan Bay, 1908-1913.

Mean length.	Near New Quay Head. Jan.—March.		April—May.		June.		July.		Tremadoc Bay.		Near Patches Buoy.	
	f	f ‰	f	f ‰	f	f ‰	f	f ‰	f	f ‰	f	f ‰
12·5	6	11·3	...	...	...	...	...	...	...	...	...	...
13·5	7	13·2	...	...	...	...	...	...	1	2	...	...
14·5	9	17·0	1	0·7	1	1·6	...	...	...	...	...	...
15·5	...	...	5	3·6	1	1·6	...	...	1	2	...	...
16·5	8	15·1	5	3·6	6	9·7	1	1·4	3	5	1	4
17·5	11	20·8	39	28·5	20	32·3	1	1·4	12	21	2	8
18·5	11	20·8	108	78·8	22	35·5	10	14·4	20	35	5	19
19·5	5	9·5	100	72·9	28	45·2	13	18·7	25	44	1	4
20·5	11	20·8	122	89·1	54	87·2	36	51·7	48	84	2	8
21·5	7	13·2	107	78·1	49	79·1	32	45·9	43	75	3	11
22·5	17	32·1	115	83·9	46	74·3	55	79·0	48	83	7	25
23·5	19	35·9	100	72·9	46	74·3	73	104·9	61	106	5	19
24·5	18	34·0	128	93·4	40	64·6	90	129·3	55	96	9	33
25·5	22	41·6	125	91·2	58	93·7	80	114·9	38	68	10	37
26·5	29	54·8	102	74·4	53	85·6	81	116·4	37	64	19	70
27·5	26	49·2	81	59·1	53	85·6	61	87·6	39	68	13	48
28·5	34	64·3	69	50·4	75	121·2	50	71·8	31	54	22	81
29·5	50	94·5	57	41·6	28	45·2	35	50·3	31	54	28	103
30·5	36	68·1	40	29·2	17	27·5	31	44·5	27	47	22	81
31·5	34	64·3	25	18·2	9	14·5	21	30·2	19	33	20	74
32·5	27	51·1	22	16·1	3	4·8	12	17·2	12	21	19	70
33·5	29	54·8	9	5·8	2	3·2	7	10·0	5	9	17	62
34·5	19	35·9	3	2·2	1	1·6	2	2·9	3	5	11	40
35·5	19	35·9	2	1·4	1	1·6	2	2·9	3	5	12	44
36·5	13	24·6	2	1·4	1	1·6	...	...	3	5	7	25
37·5	12	22·7	...	...	2	3·2	1	1·4	1	2	8	29
38·5	10	18·9	...	...	1	1·6	2	2·9	3	5	4	14
39·5	8	15·1	3	2·2	...	...	...	...	3	5	6	22
40·5	2	3·8	...	...	...	...	...	...	...	...	1	4
41·5	5	9·5	...	...	...	...	...	...	...	...	2	8
42·5	4	7·6	...	...	...	...	...	...	...	...	1	4
43·5	2	3·8	...	...	1	1·6	...	...	...	...	1	4
44·5	6	11·3	...	...	...	...	...	...	...	...	4	14
45·5	6	11·3	...	...	...	...	...	...	1	2	4	14
46·5	5	9·5	...	...	...	...	...	...	...	...	...	...
47·5	2	3·8	...	...	...	...	...	...	...	...	...	...
48·5	...	...	...	...	1	1·6	...	...	1	2	5*	19
	529	1000·1	1,370	998·7	619	99·95	696	999·7	574	1002	271	999

* 50·5, 1 ; 51·5, 1, ; 52·5, 1 ; 60·5, 1 ; 61·5, 1.

Table XI. Off Mersey Estuary, 2-in. mesh. 1908-1913.

Mean length.	November to March.		May to July.		August to October.	
	f	*f* °/oo	*f*	*f* °/oo	*f*	*f* °/oo
4·5	610	17·9	55	15·3	10	2·2
5·5	4,796	141·2	71	19·8	172	38·6
6·5	6,821	200·1	27	7·5	436	97·9
7·5	7,723	227·3	37	10·3	418	93·8
8·5	5,928	174·5	125	34·9	179	40·2
9·5	2,527	74·4	289	80·6	153	34·4
10·5	1,134	33·4	268	74·7	308	69·0
11·5	1,104	32·5	304	84·8	415	93·2
12·5	776	22·8	352	98·1	418	93·9
13·5	583	17·2	368	102·6	535	120·1
14·5	466	13·7	444	123·8	409	91·8
15·5	471	13·8	327	91·2	402	90·3
16·5	347	10·2	338	94·0	236	52·9
17·5	235	6·9	213	59·4	131	29·4
18·5	159	4·7	163	45·4	75	16·8
19·5	111	3·3	101	28·2	52	11·7
20·5	76	2·2	53	14·8	36	8·1
21·5	41	1·2	21	5·8	29	6·6
22·5	26	0·8	12	3·3	17	3·8
23·5	11	0·3	11	3·1	12	2·7
24·5	18	0·5	6	1·7	10	2·2
25·5	10	0·2	1	0·3	1	0·2
	33,973	999·1	3,586	999·6	4,454	999·8

Table XII. Comparison of Catches made with different trawl-meshes; Mersey Area. 1908-1913.

Mean length.	4″-mesh.		6″-mesh.		7″-mesh.	
	f	f °/oo	f	f °/oo	f	f °/oo
10·5	1	0·2	...	...	...	...
11·5	...	...	...	...	...	...
12·5	16	6·3	7	3·7	...	...
13·5	82	31·5	24	7·3	...	...
14·5	262	97·1	80	23·6	1	0·8
15·5	420	144·2	133	41·9	2	1·7
16·5	418	141·9	222	70·0	8	6·9
17·5	342	106·9	388	126·0	29	24·8
18·5	296	86·7	421	138·0	54	46·3
19·5	202	56·8	359	110·3	108	92·5
20·5	234	72·7	368	108·7	138	118·2
21·5	220	62·4	300	82·9	113	96·8
22·5	242	64·8	283	78·0	115	98·5
23·5	186	43·6	209	54·2	119	102·0
24·5	123	30·1	191	48·0	146	125·7
25·5	102	25·1	125	32·1	110	94·3
26·5	46	9·7	96	25·2	82	70·3
27·5	37	9·1	68	20·9	63	54·0
28·5	17	3·9	37	10·4	35	30·0
29·5	16	3·1	22	7·3	17	14·2
30·5	7	1·4	11	4·3	7	6·0
31·5	2	0·4	9	3·1	4	3·4
32·5	4	0·8	3	1·6	11	9·4
33·5	1	0·2	2	0·9	3	2·5
34·5	...	...	3	1·6	2	1·7
35·5	...	...	...	...	...	...
36·5	2	0·2	...	...	...	...
	3,277	999·1	3,361	1000·0	1,167	1000·0

Table XIII. Dispersions, 1908-1913.

(a) *The Length-frequency Distributions, 6-inch Trawl-net*, 1908-1913.

Season.	Shortest half-range	*Minus* 15 %	*Plus* 15 %	*Over* 20·5 cms.	*Under* 20·5 cms.	Fishing Ground.
				%	%	
September—December	21·0—34·0	19·0—21·0	34·0—40·5	74·0	26·0	Luce Bay.
March—May	16·0—20·4	...	20·4—22·1	39·0	61·0	Duddon Area.
June	19·0—22·0	17·8—19·0	22·0—24·7	51·0	49·0	Morecambe Bay.
July	18·0—22·0	16·3—18·0	22·0—24·0	48·0	52·0	
August	20·0—24·8	18·0—20·0	24·8—27·2	66·0	34·0	
June	17·6—21·1	...	21·1—22·6	42·0	58·0	Blackpool to Liverpool Bar.
July	18·2—21·5	...	21·5—23·2	50·0	50·0	
August—September	17·6—22·4	15·2—17·6	22·4—26·3	55·0	45·0	
May	17·9—21·0	16·1—17·9	21·0—22·2	36·0	64·0	Mersey Area.
June	17·1—19·8	14·8—17·1	19·8—20·7	22·0	78·0	
July	18·1—20·8	16·2—18·1	20·8—22·2	35·0	65·0	
August	20·3—24·6	18·2—20·3	24·6—26·5	77·0	23·0	
January	20·0—29·0	17·8—20·0	29·0—32·5	73·5	26·5	Beaumaris and Red Wharf Bays.
June	17·9—21·9	...	21·9—23·9	54·0	46·0	
July—August	18·3—21·9	...	21·9—23·8	51·0	49·0	
September	18·7—22·1	16·9—18·7	22·1—26·1	60·5	39·5	
October	16·2—19·9	...	19·9—22·1	37·5	62·5	
November	19·9—24·1	17·5—19·9	24·1—27·8	69·9	31·1	
December	19·0—25·4	...	25·4—28·1	74·5	25·5	
May	18·4—22·4	...	22·4—24·4	63·0	37·0	Carnarvon Bay.
June	18·3—21·2	...	21·2—22·7	43·0	57·0	
July	19·8—23·5	...	23·5—25·6	73·0	27·0	
August	19·5—22·2	...	22·2—23·6	66·0	34·0	
September	17·0—21·6	...	21·6—23·8	52·0	48·0	
October	17·9—23·6	...	23·6—25·5	63·0	37·0	

Table XIII—*continued.*

(*a*) *The Length-frequency Distributions, 6-inch Trawl-net,* 1908-1913—*continued.*

Season.	Shortest half-range	*Minus* 15 %	*Plus* 15 %	*Over* 20·5 cms.	*Under* 20·5 cms.	Fishing Ground.
				%	%	
January—March	25·5—33·5	21·0—25·5	33·5—39·0	88·0	12·0	Off New Quay Head.
April—May	23·3—27·7	21·0—23·3	27·7—30·0	94·0	6·0	
June	22·8—28·5	20·8—22·8	28·5—31·8	82·0	18·0	
July	23·0—27·5	20·7—23·0	27·5—29·5	94·0	6·0	

(*b*) *Comparison of 2″, 4″, 6″ and 7″ Trawl-meshes,* 1908-1913

May—July	11·6—16·5	...	...	2·5	97·5	2-inch trawl-mesh.
August—October	10·9—15·9	...	...	1·5	98·5	Do. do.
November—March	6·1— 8·1	...	...	...	100·0	Do. do.
August—September	14·6—18·7	...	...	27·5	72·5	4-inch trawl-mesh.
Do.	17·0—21·2	...	...	42·5	57·5	6-inch trawl-mesh.
Do.	20·6—25·2	...	...	75·5	24·5	7-inch trawl-mesh.

(*c*) *Age-Groups O to IV.*

Age-Group.	Shortest half-range.	Shortest ⅔-range.	Mean.	Standard deviation.
O	5·75—7·5	5·65— 8·1	7·29	±1·58
I	13·5—17·8	12·5—18·5	15·28	3·18
II	18·5—22·5	17·7—23·7	21·01	2·63
III	23·9—30·2	22·5—31·0	26·84	4·34
IV	30·8—35·8	29·6—36·5	32·48	3·70

Prevalent Lengths of Plaice on the Various Grounds.

There is no need to consider the data of these tables in the present place—they are intended as a permanent record and can be used in many conceivable ways. Here we only point out some of the more obvious characters of the fish taken on the regions investigated.

Luce Bay.

One-half of all the plaice taken were over 21 and under 34 cms. in length and another 15 per cent. were over 34 cms. and under 40·5 cms. These are the biggest fish taken in any inshore area on the eastern side of the Irish Sea. Why ?

It is to be noted that observations were only made during the months of September to December. The hauls were made with the object of getting spawning fish for the hatcheries at Port Erin and Piel, and the Bay was fished by permission of the Fishery Board for Scotland. As we have no records for the other months it is impossible to say whether or not there is any marked seasonal variation.

The Bay is well protected from S.W. to N.W. winds, and this may be a condition of importance. But we think that the reason why there are bigger plaice in Luce Bay than elsewhere in the district studied is mainly that the region is closed against trawling by all kinds of vessels. Only a small amount of fishing, by means of gill-nets, goes on, and the plaice are protected. Luce Bay is a closed area, and it is interesting on that account.

The New Quay Grounds in Cardigan Bay.

Inside the three-miles' limit, and extending to the N.E. for several miles along the coast of Cardigan Bay, are the New Quay grounds. Here also are relatively large plaice during the early months of the year. They are not so abundant as in Luce Bay, for trawling by sailing vessels is permitted. The shortest half-range is from 25 to 34 cms., and 65 per cent. of all the fish caught were over 25 and under 39 cms.

Beaumaris and Red Wharf Bays.

This also is an inshore fishery, mostly inside the three-miles' limit. The main season is in the late autumn—about October to January. We shall show later that this autumn fishery depends on a migration taking plaice from the regions to the N.E. The fish are bigger than on the other grounds in Liverpool Bay and off the Lancashire coasts, the half range being from 19 to 28 cms.

Carnarvon Bay, Mersey Estuary, Liverpool Bar to Blackpool, Morecambe Bay (inshore).

All this area may be regarded as a single, natural one. The fishery is carried on mainly by half-decked vessels, a few smacks, and an occasional steam trawler. It is mostly inside the three-miles' limit, though there is also a considerable area of plaice-ground outside this contour. The main fishing season is from about July to October. The whole ground may be regarded as a typical small-plaice one.

The characteristic lengths of the plaice caught in the months August to October are:

Carnarvon Bay	18 to 24 cms.
Liverpool to Blackpool ...	18 to 22 cms.
Mersey Estuary	20 to 24 cms.
Morecambe Bay	20 to 25 cms.

These are the shortest half-ranges, comprising 50 per cent. of all the fish caught.

There is a fairly well-marked seasonal variation in length. Thus, taking the Mersey Estuary, we get :

May	18-21 cms.
June	17-20 cms.
July	18-21 cms.
August	20-24 cms.

These are also the shortest half-ranges. The differences are due to the natural growth of the plaice and also to successive waves of migration of small fish from the more crowded, very shallow waters, to the sea just offshore. This we refer to in the section dealing with migrations.

The Nursery Grounds.

These we refer to when dealing with the life history of the plaice in the Irish Sea.

PART II.

The Life-History of the Plaice.

We next consider the available knowledge as to the life-history of the plaice on the eastern shores of the Irish Sea. There is, of course, much that has still to be investigated with respect to this: the embryology, the possible existence of local races, and the possible spawning-grounds in St. George's Channel and the Welsh Bays. The information that is at our disposal, however, enables us to make such a general picture of the life-history as may be of use to the administrators.

The Spawning.

Plaice eggs are found in the plankton collected almost everywhere offshore, between the Solway and Cardigan Bay, in the months of February, March, and April. Exceptionally the eggs have been found in January as the result, we think, of the spawning of fish well to the southward in St. George's Channel. Spawning occurs in the pond at the Port Erin Hatchery during the months of March, April, and exceptionally in May. The fish kept in the tanks at Piel, Barrow-in-Furness, spawn a little later, usually about the end of March, in April, and in May. April is the best month for the fish in the tanks, but in the open sea March is perhaps the best month. There is, of course, much variation, from year to year, in the time of spawning, and this is to be associated mainly with the temperature of the sea at the time of spawning and during the previous months, when the reproductive organs are most rapidly developing. It also depends on feeding, as is shown by our experience in the hatcheries, where the fish must be well fed if the roes are to develop fully. A close study of the variations in the temperature of the water (both in the tanks and in the sea) and in the abundance of the eggs found would be most interesting, but this calls for very exhaustive experimental and observational work.

We think there are two sources of the plaice eggs that are found in the plankton of the Irish Sea: (1) somewhere to the S.W. in St. George's Channel, and (2) the grounds near the entrance to the Solway Firth. The reason for attributing by far the larger share of plaice eggs to the St. George's Channel grounds is the direction of the tidal streams in this area and in the Irish Sea. The flood-stream sets in a northerly direction in St. George's Channel, with indraughts into Cardigan and Carnarvon Bays. It clings strongly to the Anglesey promontory and then sets towards the East, round into the Liverpool Bay area. Near a line crossing the Irish Sea from Morecambe Bay to about Ramsey the northerly flowing flood-stream slackens, and there is a general tendency for the drift of wreckage and other floating objects to be arrested on the North Lancashire and Cumberland coasts, between Morecambe Bay and about Drigg, in Cumberland. The ebb-stream runs in nearly the opposite directions, but there is also a general tendency to a drift from South to North, so that more water enters the Irish Sea with the flood-tide from the South than leaves it with the ebb-tide. Approximately the whole contents of St. George's Channel and the Irish Sea are changed every year, the water flowing out through the North Channel and entering by the South.

Plaice eggs spawned in St. George's Channel will, therefore, tend to drift slowly to the North and East, round Anglesey, into the shallow-water region between the North Coast of Wales and the "head of the tide," between Morecambe Bay and Ramsey, in Isle of Man.

Such a southerly spawning area is thus to be deduced from a knowledge of the effect of the tidal streams, but it has yet to be actually observed. The existence of northerly spawning grounds has long been asserted by the trawlers. It is said that plaice spawn just offshore from Peel, in Isle of Man, and in the entrance to the Solway Firth. In 1920 we were able to investigate the latter ground. During the months January to April the Lancashire and Western Sea-Fisheries Committee allowed us the partial use of the s.s. " James Fletcher," and about thirty hauls were made on the region between Ramsey Bay, in Isle of Man, and the entrance to the Solway Firth; 100 drift-bottles were set free, and 367 plaice were marked and liberated. The results of these investigations enable us to describe the northerly spawning ground under the conditions of 1921.

It lies about eight miles to the west of St. Bees' Head, in Cumberland, extending North and South for about eight to nine miles. Its bearings are:

Centre, 7 miles W. by S. from St. Bees' Head.
Northern end, 9′ N.W. from St. Bees' Head.
Southern end, 9′ W. by S. from St. Bees' Head.

Its depth varies from 15 to 20 fathoms. It is situated in nearly the coldest part of the Irish Sea (during February and March). There are several banks off the N.E. of Isle of Man (" Bahama," " King William," and the " Shoals "). Between these banks and the fishing ground in the entrance to the Solway, called the " Slaughter," there is an interchange of plaice, such that the bigger fish tend to migrate from the " Shoals," about February, over to the " Slaughter," where they spawn. The spent fish then disperse, many of them returning to the Shoals' area and to the South-west.

In February of 1921 mature plaice were found between the " Shoals " and the spawning ground. In March they were found in greatest abundance on the spawning ground, and at the middle of April no mature fish at all were found there, but spent plaice were then to be taken on the " Shoals." About March 21st the spawning season culminated, and by April it was practically over.

The numbers of mature female plaice caught per hour's trawling* were as follows :—

On the "Shoals": in February, 8·5; March, 5·2; April, 7·9.

On the "Slaughter": in February, 8·9; March, 9·4.

On the southern part of the "Slaughter": in February, 4·8; March, 3·0; April, 6·3.

South from the "Slaughter": in February, 5·9; April, 2·2.

The proportions of the female fish taken in the mature condition on the various grounds were as follows :—

(1) On the "Shoals": February, 16 %; March, 31 %; April, 64 %.

(2) On the "Slaughter": February, 86 %; March, 81 %; April, 37 %.

The sizes and ages of the fish dissected on board the vessel are given in the three following tables—which are of much interest :—

Sizes and Ages of the Female Plaice Examined.

Length (cms.).	IV	V	VI	VII	VIII	IX	X	XI	XII
25-30	1	...	...	...	...	...	...	...	...
31-35	2	...	1	...	...	...	...	...	...
36-40	7	7	7	...	...	...	...	...	...
41-45	1	6	9	3	2	...	...	...	...
46-50	...	...	5	3	...	...	...	...	...
51-55	...	...	2	...	1	1	1	2	...
56-60	...	...	...	...	...	...	...	...	...
61-65	...	...	...	...	...	...	...	...	1

Sizes and Lengths of the Male Fish Examined.

Lengths (cms.).	III	IV	V	VI
25-30	1	1	...	...
31-35	...	...	1	...
36-40	...	2	6	1

* By an otter trawl-net of about 40 feet in spread.

Percentages of Mature Female Plaice at Various Sizes.

	Immature.	Mature.	Percentage of Mature.
25-30	73	7	8·7
31-35	25	47	65·3
36-40	3	92	96·8
41-45	1	45	97·8

In general, female plaice were observed to be mature at about 33 cms. in length and at about Age-group IV. (IV, V, etc., mean over 4 years and under 5, over 5 and under 6, etc.)

At the same time that these hauls were made a number (100) of surface drift-bottles were set free, the object being to ascertain in what directions the plaice eggs spawned on the "Slaughter" grounds would be carried during the period when they, and the larvae hatching out, would be pelagic in habit. About half of these drifters were ultimately recovered and all of them were picked up along the South Coast of Scotland.

This is what is to be expected, because the prevailing winds during the late winter and spring are from the South to West in this region. There were also some East to North winds, and these might have been expected to carry the bottles down towards the coasts of Isle of Man and Lancashire, but this was not the case. The tidal streams in the Irish Sea, North of the line joining Ramsey and Morecambe Bays, set in and out through the North Channel (between Mull of Galloway and the Antrim coast) and then North and South between Isle of Man and the Cumberland coast. Further, we see that there is a gradual, resultant drift of water, from the sea off the Lancashire coasts, up through between Isle of Man and Cumberland and then out through the North Channel. Therefore an unusual spell of North to East winds might, indeed, drive the drifters down to the

South of the "head of the tide," but, on the backing of the wind again to West and South, they would be carried back again into the Solway and South Scottish coast.

It is reasonable to conclude, therefore, that plaice eggs spawned on the Solway "Slaughter" ground will be carried mostly into the Solway Firth and into Wigton and Luce Bays (on the Scottish coast). The shallow water grounds here are pre-eminently "small plaice" grounds, or nurseries, to at least as great an extent as are those off the Lancashire and Cheshire coasts (see the tables, "Solway Firth"). The northern part of the Irish Sea is therefore supplied with small plaice, which are spawned and reared in the same sea region.

Hatching and Transformation Stages.

The plaice eggs found in the tow-nets are, from our experience, always fertilised. Now an unfertilised plaice egg will generally remain alive and buoyant, floating at the surface of ordinary sea-water for about a week. If they were present in notable numbers in the plankton they would certainly have been observed, but there is no doubt that such unfertilised plaice ova are very rare. It is fairly certain, then, that there is definite pairing in the sea, or at least that ripe males and females come together in the same local shoals, at the time of spawning. Thus we account for the absence of unfertilised eggs.

The period of incubation varies from about three weeks, at the beginning of the hatching time, to about ten days, in April. The sea-temperature in the region between Morecambe Bay Light Vessel and the Lancashire coast rises about 4° C. (from 5° C. to about 9° C.) during the period 1st March to 30th April. But the differences are considerable in the various regions: thus the temperature at 1st March may be one or two degrees lower at the Solway Light Vessel and at least a degree higher at Carnarvon Bay Light Vessel. There are also considerable differences from year to year, and there are minor differences even at places a few miles apart, at the same time, these latter variations being due to cold water ebbing back from the land (which is always colder at this time of year than is the sea). We cannot say, precisely, how long it takes a plaice egg to incubate in the Irish Sea because of all the above variations. The plaice at Port Erin Hatchery always spawn several weeks earlier than they do at Piel, in the Barrow Channel because of the higher sea (and land) temperature at the former station. There is a rather well-marked mathematical relation between the temperature and the incubation period of a fish egg: the higher the temperature, the shorter the incubation period. So far, however, we have not made experiments stating this relation exactly in the case of Irish Sea plaice.

Neither has the time required for the later development been made out, though it is known that the baby plaice in the Port Erin spawning ponds have usually become transformed by the end of April. The fish hatches out from the egg as a *larva*, carrying a large yolk sac, and in the course of about two weeks this organ becomes very small, and then, later on, quite disappears. About the time of its disappearance the transformation (or metamorphosis) occurs; the body begins to flatten from side to side, and the left eye begins to show on the right-hand side of the head, because of the twisting (from left to right) of the bone between the mouth and the brain-case. In about a month from the date of hatching the metamorphosis has been completed and the fish is become definitely flat. At all stages between the egg and the fully-transformed larva, however, the latter can be identified as a young plaice, though it is very like the flounder and dab.

The First Shore Stages.

At about the end of May and the beginning of June, according to the nature of the season, the young plaice first come on to the shore as "sixpenny flukes." They can then be seen in the shallow shore-pools left by the receding tide. They are very active, but can easily be caught. They must be present on the shores of Cheshire, Lancashire, and Cumberland at this time of year in enormous numbers. The mortality must also be very great at this stage, for the little, shallow shore-pools are apt to dry out as the tide recedes, or soaks into the sand, and when the sun is hot the larvae must perish. No precise observations have been made enabling us to state the time when the transformed larvae first come shorewards, and in what relative abundance; but undoubtedly both conditions vary from year to year. It is certain, however, that it is *nearly* always about the same time (the very end of May) when the plaice first come on to the Lancashire shores, and it is probable that this is so even though there may be bigger differences, from year to year, in the dates of spawning and hatching. It is very likely that a certain combination of conditions (sea-temperature, sunlight, food) must be present in order to enable the baby fish to survive when they abandon their drifting, pelagic life, go to the bottom and seek the very shallow-water grounds close inshore.

Food of the Larvae and Transformed Plaice.

In general, the larvae first feed on algal spores (but this remark applies to observations made on the larvae hatched out and transformed in the Port Erin ponds). Later on they feed almost entirely on Copepods (Harpactids chiefly) though other organisms are, of course, eaten. A full report on the food of the larval plaice collected from the spawning ponds and from the shore has been prepared by Mr. Andrew Scott and will appear in a forthcoming part of the Journal of the Marine Biological Association.

Growth of Plaice during the First Year.

This we were able to make out by measurements of little plaice reared in the Port Erin tanks. The results are as follows :—

31-40 mm.,	1 ;	61- 70 mm.,	8
41-50 „	3 ;	71- 80 „	5
51-60 „	11 ;	81- 90 „	2
		91-100 „	4

Thus, there is considerable variation between individual fish as one might expect. This variation continues, and even becomes greater in subsequent stages of the life-history. In 1921 we made collections* of young plaice (and other flat fishes) in the shallow bays in Isle of Man, and on the Lancashire and Cheshire coasts. In May, the length varied from 13 to 50 mm. in the case of the Manx fish. From now onwards the plaice grow rapidly, increasing in length about six or seven-fold by the end of the autumn. Precise measurements (averages) for Cheshire shore plaice are as follows :—

June, 42·2 mm. ;	July, 46·5 mm. ;
Aug., 52·5 mm. ;	Sept. 58·6 mm. ;
Oct., 67·4 mm. ;	Nov., 65·5 mm. ;
Dec., 61·1 mm. ;	Jan., 66·2 mm.

These are all first-year plaice, for each was examined by inspection of the otoliths (or earstones). The latter are, of course, very small, but it can easily be seen that they consist only of the central, opaque " nucleus." Towards the end of the year this central white spot becomes surrounded by a semi-transparent ring, and thereafter an opaque white ring is formed during each summer and autumn, and a semi-transparent ring during each winter and spring. (Chemical tests showed that

* The ordinary haul " push-net " used by shrimpers in Lancashire was employed. The collector wades in water of about 2-feet depth and pushes the net in front of him. The fish can often be seen. The method is a very admirable one for the collecting of small shore fishes on a shallow, sandy coast.

the substance of the otoliths was made up of the modification of calcium carbonate, known as aragonite. It contains about 98 per cent of $CaCO_3$, the remainder being organic matter and water.)

During June the " sixpenny flukes " leave their foreshore and very shallow-water habitat and migrate further out to sea. In July and onwards they can be taken in the shrimp trawl-nets, and their abundance there has been, for a long time, *the* interesting feature in the life-history of the plaice from the point of view of fishery regulation. A great deal of attention has been devoted to this question in Lancashire : whether or not shrimp-trawling does more harm to the general fishing industry than it is worth ? From the beginning of their period of control the Lancashire Sea-Fisheries Committee made many observations on the relative abundance of plaice and other fishes in the catches made by the shrimp-trawlers in their district. The late Superintendent, R. A. Dawson, devised a special form of the shank-net, designed to permit the capture of shrimps while allowing young, flat fishes to escape, but this instrument never became adopted. In 1899 the Committee applied to the Board of Trade (which was then the Central Fishery Authority in England) for confirmation of a By-law restricting trawling by fine-meshed nets in the important nursery ground off the estuary of the Mersey, but this measure was very seriously opposed by the local fishermen, and the Board refused to sanction it. Since then the question has not been raised again.

Table 11, gives a summary of the results of the measurements of plaice made in the experimental hauls carried out by the officers of the Committee on the Mersey grounds during the period 1908-1913, and there is a detailed report on a series of observations made by Capt. G Eccles during the years 1899-1920, which gives a very fair idea of the conditions on this nursery ground. First, as to the sizes of the plaice taken :

this varies, of course, according to the time of year. During the winter months, November-March, the fish are smallest, because then they belong mostly to those hatched in the previous year. The prevalent length is about 7 cms. (2¾ ins.), and 50 per cent. of all are between 6 cms. and 8 cms. in length (2½ ins. to 3¼ ins.). During the months May to July there are three maximal lengths, or prevalent sizes: about 5 cms. (2 ins.), 9·5 cms. (3¾ ins.), and about 14 cms. (5½ ins.). That means that a great number of the plaice caught in May to July are those that have been hatched in the same year (they are two to four months old). Then there are plaice that are one and two years older (that is, about 1¼ and 2¼ years old). It is impossible to be more precise as to the ages of fish caught in the shrimp-trawl (on pp. 195-6 we discuss the general question of the growth rate of the fish), but the following results are useful: half of all the plaice caught during May to July are from 11½ to 16½ cms. long (that is, 4½ to 6½ ins.), and half of all those taken during the months August to October are from 11 to 16 cms. long (that is, 4½ to 6½ ins.). This will give a good idea of the kinds of plaice caught in the course of shrimp-trawling.

Next, as to the numbers caught. A summary of the results of the Mersey experimental hauls is given by R. J. Daniel,* and this shows the actual numbers per haul, per hour's fishing, etc., taken between 1898 and 1920. The number per haul varies between 14,697 (in 1½ hour's drag) and 0. The *average* number per hour's fishing per annum varies between 1,197 (in 1911) and 64 (1904 and 1916). There is a very evident periodicity in abundance of young plaice on this ground, and to this question we return later in the report (p. 200).

The short statement made here will show, however, what an extremely heavy toll shrimp-trawling makes on the plaice population of the inshore nursery grounds in the Irish Sea.

* *Ann. Rept. Lancashire Sea-Fish. Laby.* for 1919 pp. 51-71.

Whether that amount of destruction of small fish is a thing to be restricted or prevented is not so easy a question to answer as it appears to be at first sight. To that again, we return in a later section of this report (see p. 231)

The Nursery Grounds and their Conditions.

These extensive shallow-water nursery grounds are of extreme importance to the fisheries, and it may well be the case that the attention of future fishery authorities will be directed to them far more than to the offshore regions, which at present almost monopolise investigation. From the natural history point of view they are of surpassing interest, and we feel that far too little research goes on here. They are by far the most " productive " zone of the sea, and that is, of course, the reason why they are fish nurseries. The conditions that make them productive are: (1) The drainage from the land carrying fresh water which brings down enormous quantities of organic substance, in solution or as a sediment (*all of this is utilised by living organisms*); (2) The low salinity of the water; (3) The relatively high temperature, and (4) The greater degree of sunlight. The sand everywhere contains abundant vegetable life in the form of Diatoms, Flagellates, and Dinoflagellates (microscopic plants and " plant-animals "), and one can, nearly everywhere, see this as a yellow-brown or greenish scum on the surface of the sand. Beneath the surface the sand is, nearly everywhere, blackish in colour as the result of the action of sulphuretted hydrogen produced by the decomposition of dead organic substance. In the surface layers of the sand and in the water just over that layer there are numerous Copepods and small worms. Nearly everywhere there are very numerous shellfish—cockles, small mussels, *Mactra*, *Scrobicularia*, *Nucula*, etc. A minute fragment of zoophyte may contain dozens of small mussels about the size of a very small pinhead, and on some suitable bottoms the zoophytes and polyzoa growing there may appear as if they were thickly dusted over with such minute mussels. Some counts made recently showed that extensive areas of sandbanks contained little cockles in such numbers as several hundreds per square foot, while the number of small mussels on a square foot of suitable "skear" ground may run into the thousands. Such invertebrate communities are the feeding grounds of shrimps, crabs, starfishes, and young fish of various kinds (plaice, flounders, dabs, soles, cod, whiting, sprats, etc.). Here small plaice feed greedily upon Copepods, small worms, little periwinkles, and very small bivalve molluscs, while the larger fish eat the small *Mactra*, *Scrobicularia*, and cockles that are nearly everywhere present in the sand. In the spring and early summer months the temperature of the water on the nursery grounds rises several degrees higher than it is offshore; the tides run more strongly and so distribute the dissolved food substances used by the Diatoms, Flagellates, and Dinoflagellates. The sunlight penetrates to the bottom layers of water, overlying the sand, better than it does offshore, and this is favourable to the nutrition of the microscopic plants and plant-animals. The latter are then eaten by the shellfish and the smaller Crustacea and worms, which are, in their turn, eaten by the small fishes, large fishes, and invertebrates. As fast as the fundamental food substances in solution are taken from the water by the organisms that exhibit the vegetable mode of nutrition they are renewed by the drainage coming down from cultivated land and from domestic sewage entering the estuaries and then the open sea. The higher temperature on the nursery grounds accelerates the rate of growth of all animals living there. Further, the conditions, as regards temperature and density of the water, are more variable than they are offshore because of the more rapid tidal streams, freshets entering the estuaries, and the greater agitation of the water by wind action. This variability in external conditions is itself a stimulus to growth and reproduction, and to the maintenance of a condition of health.

The shallow-water grounds off the coast, between low-water mark and about 5 to 10 fathoms of depth, are therefore the place of origin of all the young fish in this neighbourhood. For about three years the plaice of the Irish Sea live here moving a little out to sea in the warm summer months and then returning inshore again for the period of the winter and spring. They roam about to a marked extent, making quite long, winter, longshore migrations, possibly in search of food and possibly just from the general "restlessness" that is a fundamental feature of animal life. In certain months, about December to March, there is an evident scarcity of the small plaice on the nursery grounds, and it is highly probable that they "dawk" in the sand at the bottoms of the deeper, inshore channels, covering themselves up so that only the mouth is visible. Respiration slows down, the fish cease to eat, and their functions are as nearly at a standstill as possible. The weight of the body, in proportion to the length, decreases. If we call w the body-weight in grams, l the total length in centimetres, and c a constant, then we get the following formula:

$$c = \frac{100\,l^3}{w}$$

Now when we find the value of c for the various months throughout the year we see that it varies from about 0·8 to 1·2. When it is small, at the period of about lowest sea-temperature, the plaice is thin and in poor condition, and when it is large, at about the period of highest sea-temperature, in the autumn, the fish become plump. The decrease in the magnitude of c means that the fish does not feed and that the substance of its body is being used up to keep the heart and respiratory organs in action. Therefore there is a wasting of the body during the coldest months of the year.

The Rate of Growth of a Plaice.

The *age* of a plaice is found merely by looking at the otoliths (or earstones). The *sex* is found by holding the fish up to a strong light and observing whether or not it has a roe : the latter is deeply pigmented and shows through the translucent body and skin. The earstone has always a little opaque spot in the centre surrounded by opaque and translucent rings : thus—

Nucleus alone—the fish is one summer old.

Nucleus + translucent ring—one summer + one winter.

Nucleus + translucent + opaque rings—one summer, one winter, one summer, and so on : a translucent ring is added during each winter and an opaque ring during each summer.

The plaice in the Irish Sea are always hatched out in February, March, and April, but, for the most part, in March. Therefore, a fish caught in July, and having a nucleus only, is four months old, one caught in September, and with only a nucleus in its earstone, is six months old. So also, a fish caught in October, and having a nucleus, two opaque rings and two translucent ones, is two years and seven months old. Usually we called the plaice 0, I, II, III, etc., years old, meaning over 0 and less than 1 year of age, over 1 and less than 2, over 2 and less than 3, and so on. For the first year we state the age in months, the number of the latter being the number of the months that have elapsed from the middle of March up to the date of capture.

The growth, then, for the first year is as follows :—

Up to middle of June	... ...	42·2 mms.
„ *July*	... ...	46·5 „
„ *August*	... ...	52·5 „
„ *September*	...	58·6 „
„ *October*	... ...	67·4 „

After October the growth ceases until the following April, when it begins rather slowly, increases up to about the middle of July, then falls off and finally ceases again about the middle of October.

Now the growth is very variable. Even in the same season some fish of the same age grow more rapidly than others. Plaice reared in Port Erin tanks showed this to a remarkable extent, some (of the same year's spawning) being actually twice as long as others: this is *individual* variability. There is seasonal variability: thus, fish of, say, two years of age may grow more rapidly in one year than do the fish of two years of age in another year. Finally, there are local variations: thus, the English workers obtained the well-known result that plaice grow about twice as long, in the same period of time, on the Dogger Bank than they do just off the Dutch coast.

The following table (No. 14) gives the results of the measurements of 7,724 plaice, all caught on the nursery grounds and on the inshore grounds, and mostly within the territorial limits. The table, therefore, represents very well the kind of plaice to which regulations, restrictions, and prohibitions, of any kind, would apply.

A few words of explanation are necessary:

These are all plaice caught by shrimp-trawls (of 2-inch mesh) and fish-trawls (of 6-inch mesh). Now a shrimp-trawl will, in theory, catch plaice up to any length, but if it does take a fish of over about 25 cms. long, say, there is always the chance that the latter may swim out again through the mouth of the net: this is because there is not a very great "draught" of water through the very narrow and close meshes of a shrimp trawl-net. Therefore the latter tends to *under-sample* the *larger* fish that are on the ground over which it is dragged. On the other hand the 6-inch meshed fish-trawl will not catch many plaice less than 10 cms. in length, and this is because most plaice less than that length, and many of those between

Table XIV. Length Frequencies for Age Groups, O to IV, 1908-1916.

Mean Length.	O	I	II	III	IV
4·5	20	...	...	...	...
5·5	213	...	...	...	...
6·5	368	13	...	...	...
7·5	317	24	...	...	...
8·5	151	26	...	...	...
9·5	65	56	1	...	...
10·5	32	95	2	...	...
11·5	20	151	2	...	...
12·5	16	189	9	...	...
13·5	6	258	25	...	...
14·5	3	276	17	...	...
15·5	...	300	71	...	...
16·5	...	272	165	...	...
17·5	...	256	278	1	...
18·5	...	213	428	3	...
19·5	...	118	479	19	...
20·5	...	65	490	21	...
21·5	...	31	425	34	...
22·5	...	18	364	24	...
23·5	...	13	280	22	...
24·5	...	8	207	32	...
25·5	...	3	148	29	1
26·5	...	...	92	35	1
27·5	...	...	65	43	...
28·5	...	...	39	36	2
29·5	...	...	23	38	6
30·5	...	...	9	29	5
31·5	...	...	11	20	6
32·5	...	...	5	24	1
33·5	...	...	1	10	2
34·5	...	...	2	8	8
35·5	...	...	...	5	7
36·5	...	...	...	5	2
37·5	...	...	...	1	2
38·5	...	...	...	3	2
39·5	...	...	...	...	1
40·5	...	...	...	...	...
41·5	...	...	...	...	2
Totals	1,211	2,385	3,638	442	48
Mean Lengths	7·3	15·3	21·0	26·8	32·5
Standard Deviations...	1·58	3·18	2·63	4·34	3·70
Shortest Half-ranges...	5·8—7·5	13·5—17·8	18·5—22·5	23·9—30·2	30·8—35·8

10 and 25 cms. in length, can escape out through the meshes. Thus the fish-trawl tends to *under-sample* the *smaller* fish inhabiting the ground over which it was dragged.

We cannot allow for this by using *both* a shrimp-trawl and a fish-trawl at the same time, for we don't know exactly how much time to give to each method. We cannot employ a compound net, that is, a small-meshed one laced round about a wide-meshed one, for the small-meshed net restricts the flow (or draught) of water through the large-meshed one and so impedes the action of the latter. Table 15 shows that we get a different result for the Age-group I, according as we use the shrimp-trawl or the fish trawl. Therefore we have added together the results of the fishing of these two instruments and then made some rather arbitrary corrections, which, however, are probably "quite all right." Thus we get the Column "I" of Table 14.

Observe here that we are dealing with a characteristic "small-plaice" area. We might sample Luce Bay, the Solway spawning grounds, Beaumaris and Red Wharf Bays, each at its appropriate season, and get much bigger plaice. *Still*, in regard to the operation of any restrictions or prohibitions, Table 14 shows us what are the kinds of plaice which will be affected.

It will be seen that a plaice of length of 25·5 cms. may be 1, 2, 3, or 4 complete years of age—and this represents an apparently wide range of variation. *But* the table also shows that, in all, 181 plaice between 25 and 26 cms. in length were measured (that is, 181 out of 7,724 fish that were examined); *that* 3 of these belonged to Group I, 148 to Group II, 29 to Group III, and 1 to Group IV. *Therefore*, the chance that any plaice caught at random belongs to Group II are 148 in 181; that it belongs to Group I, 3 in 181; that it belongs to Group III, 29 in 181, and that it belongs to Group IV, 1 in 181. These are the "odds" in favour of the ascription of the fish

Table XV. Age Groups : Data for Group I, 1908-1916.

Mean Length.	Caught in 6″ mesh.	Caught in 2″ mesh.	Total.	Formed by completing last series.
6·5	...	13	13	13
7·5	...	24	24	24
8·5	...	26	26	26
9·5	1	55	56	56
10·5	4	91	95	95
11·5	6	145	151	151
12·5	11	178	189	189
13·5	12	151	163	258
14·5	26	136	162	276
15·5	91	89	180	300
16·5	186	68	254	272
17·5	215	40	255	256
18·5	193	20	213	213
19·5	110	8	118	118
20·5	65	...	65	65
21·5	29	2	31	31
22·5	17	1	18	18
23·5	13	...	13	13
24·5	8	...	8	8
25·5	3	...	3	3
Totals	990	1,047	2,037	2,385
Means	...	...	15·38	15·28
Standard Deviations	...	...	3·405	2·142

to any particular group. Really the odds will be a little different when we apply certain necessary corrections, but we shall only do *that* when required by the administrators. This, then, indicates the way in which this (and the other) tables ought to be used practically.

Fig. 7 is a graph of the results of Table 14. It shows the average lengths of plaice of Age-groups 0 to IV, and also the "dispersions," so that some idea of the significance of the overlapping of the various group-lengths may be obtained. The graph is not a straight line, but a logarithmic curve of a kind, and to see how this is we must consider the sizes of plaice of each monthly age during the first year of life. So far, however, we have hardly enough data to enable us to do so satisfactorily.

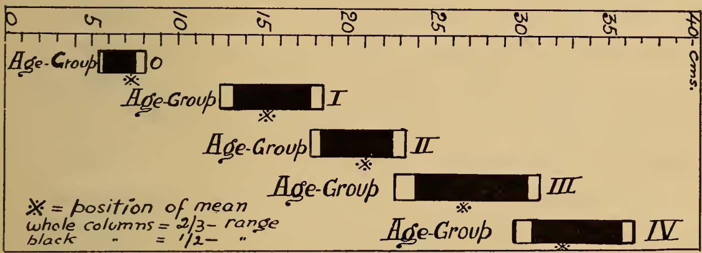


FIG. 7.

The Ratio of Males to Females.

We don't know what is the ratio of males to females in the first year of life, but it is probably one of equality. This is also the case (probably) for any year group up to about III. After that, however, a very curious thing happens ; the males diminish in number relatively to the females. This is shown by the following statement, based on the numbers of mature females and males over 23 cms. in length captured on the Solway spawning grounds and adjacent regions in the spring of 1921 :—

Size in cms. ...	24,	25,	26,	27,	28,	29,	30,	31,	32,	33,	34,	35,	36,	37,	38
Females	0,	0,	1,	0,	2,	2,	2,	8,	5,	13,	11,	10,	17,	25,	11
Males	51,	55,	64,	51,	51,	65,	51,	48,	45,	43,	46,	44,	37,	30,	22

Size in cms. ...	39,	40,	41,	42,	43,	44,	45,	46,	47,	48,	49,	50,	51,	52,	53
Females	19,	20,	16,	29,	20,	25,	22,	8,	19,	3,	6,	4,	3,	6,	5
Males	19,	8,	3,	3,	2,	0,	1,	0,	0,	0,	0,	0,	0,	0,	0

Size in cms.	54,	55,	56,	57,	58,	59,	60,	61,	62,	63,	64,	65
Females	0,	3,	0,	0,	1,	0,	0,	0,	0,	1,	0,	1
Males	0,	0,	1,	0,	0,	0,	0,	0,	0,	0,	0,	0

Thus, the females caught are always bigger and older fish than the males. They grow a little faster. The interesting thing is that the males apparently die off at a greater rate than do the females, and this probably represents a general law among the marine animals. Everywhere the female is the dominant sex : usually bigger in body, longer-lived, and predominantly the more actively metabolic animal of the two. This is so in such fish as the plaice, sole, turbot, etc., where the mass of material converted into sexual products by the female is always much greater than in the male. The ovaries in most fishes are bigger than the testes. The herring, however, may be an exception, for here the two "roes," hard (or ovaries) and soft (or testes), are of the same size.

The Sizes at which the Plaice become Sexually Mature.

Not so much has been done on this point as we would like, but some observations will be found on p. 156. The smallest mature female found was 26 cms. long and the largest immature female was 42 cms. long. A general limit may be taken at 33 cms. : above that the majority of Irish Sea plaice are sexually mature, while below it the majority are immature. As to the males we are still rather uncertain, but the general size at first sexual maturity (puberty) is less than in the case of the females.

The Migrations of the Plaice.

Migratory fishes fall into several general types :—(1) Sturgeon or shark, which roam over wide regions of ocean in an arbitrary way. (2) Herring, mackerel, hake, sprat, etc., which migrate at fairly regular intervals, the latter being determined by sea-temperature, density of the water, and possibly other physical events. The migrations may occur yearly, as in the case of most herring fisheries ; or after longer periods of time, as in the case of the Irish Sea winter herring fishery (30 or 40 years) ; or after periods of over a century, as in the case of some of the winter herring fisheries off the Swedish coast. (3) Plaice, sole, etc., where the migrations are small and occur seasonally, the fish following fairly regular paths according to the depth, nature of the sea-bottom, coast line, etc.

The causes of migration are intrinsic ones (that is, they depend on something in the organisation of the fish itself), or extrinsic (when they depend on the nature and order of the events that occur in the sea, in the atmosphere, etc.). Intrinsic causes are, for instance, the ripening of the eggs in the ovary or the sperms in the testes. These changes produce "internal secretions," which get into the blood-stream, are carried over the body and stimulate the latter in many ways. Thus the changes in the bodies in boys and girls that occur at the age of puberty are caused by substances that originate in the developing testes and ovaries and are then carried through the body by the blood-stream. Restraint of sexual development is the result of secretions elaborated in the pineal gland (in the brain); acceleration of sexual development comes from production of an internal secretion by the brain structure called the pituitary gland; extreme under-production of the secretion of the thyroid gland leads to dwarfing and a form of idiocy; over-production of the secretion of the thyroid leads to general excitability and other well-known effects, and so on. Changes in "temperament" and "personality" accompany the above physiological ones. It cannot be doubted that such causes operate also in fishes—thus, an American zoologist stated, long ago, that the internal secretion from the ovaries caused a certain "auto-intoxication," which was the immediate stimulus to the migration of the salmon into fresh water.

Added to this there is a general "restlessness" in all animals, expressing itself in undirected, random movements.

The extrinsic causes are chiefly the changes in the temperature and salinity of the sea-water. In every animal there are certain "optimum" conditions, that is, certain external circumstances which suit the make-up of the animal better than any others. Thus a fish, like the mackerel, does best in water of much the range of temperature of that off the S.W. Coasts of Ireland, or outside the entrance to the English

Channel. In the summer the temperature to the North (say, in St. George's Channel) rises and approaches that which suits the fish. Its general restlessness then leads to it enlarging the region of its movements into the new zone of water of suitable temperature, so that it migrates up into St. George's Channel and the Irish Sea.

"Feeding migrations" are a consequence of external causes. Plaice, for instance, are always "on the move" during spring, summer, and autumn. Let there be a certain region of rough ground on which there is no "feed": plaice doubtless cross this in various directions, but don't stay there. If, however, there is a "strike" of small mussels on the region the plaice which cross it will tend to stay there to eat the shellfish, and so there will appear to have been a migration on to this region from the surrounding ones. Old fishermen know these conditions very well and expect migrations when they foresee a strike of mussels.

"Spawning migrations" are the results of the development of internal secretions. In some way or other these cause the fish to "prefer" water of a certain depth (pressure) and temperature. It is unlikely that a plaice which is ripening sexually for the first time knows where to find these conditions, but its general restlessness leads to its exploration of the whole region in which it lives, and having found the agreeable conditions it stays among them.

"Shoaling migrations." The causes that lead one fish to seek certain conditions also impel others, thus we get shoals. Probably fish are not "gregarious" in the sense that they want each other's society: the shoal is brought about by the occurrence of external conditions that affect all mature plaice at the same time.

Plaice-marking Experiments.

Much has been made out as to the movements of plaice, and other fishes, by studying their sizes and density on different grounds and at different times. The same kind of results can, however, be obtained by making direct experiments. Plaice were marked in the Irish Sea in small numbers, the region itself being a small one, and there were two principal series of experiments, in the area just off the estuary of the Ribble and in Red Wharf and Beaumaris Bays. The numbers of fish marked are as follows :—

(1) Offshore from the Ribble Estuary (" Liverpool Bay ") :

13th July, 1905	... ...	31 plaice.
12th June, 1906	... ...	40 "
9th July, 1906	... ...	50 "
3rd July, 1907	... ...	147 "
5th June, 1912	... ...	212 "
3rd October, 1912	... ...	153 "
3rd June, 1913	... ...	134 "
17th July, 1913	... ...	65 "
17th September, 1913	... ...	297 "
Total	... ...	1,129 plaice.

(2) In Red Wharf and Beaumaris Bays :

12th Nov., 1904	... ...	42 plaice.
12th Nov., 1904	... ...	49 "
1st Feb., 1906	... ...	44 "
21st Feb., 1906	... ...	8 "
19th Sept., 1906	... ...	41 "
6th Feb., 1907	... ...	92 "
24th Oct., 1907	... ...	120 "
20th Nov., 1913	... ...	220 "
Total	... ...	616 plaice.

The methods employed were those adopted by the English investigators. The mark was a bone button on the white side of the fish and an oval, concave, hard brass disc on the coloured side. These two marks were connected by a silver wire passed through the body about ½ inch below the edge of the fin on the dorsal margin. Fixing the mark was very easy, and we were unable to trace any serious injury to the patient. Later on the label in use now was employed, that is, a button of vulcanite above and below instead of the bone and brass discs. It has no advantages over the old mark, and is more expensive. Details of all these experiments, and of most of the fish recaptured, have been given in various reports of the Lancashire Sea-Fisheries Laboratory, but all the data are now summarised for the first time and unnecessary detail is avoided.

(1) The Liverpool Bay Experiments.

It was soon noticed that the results of the experiments repeated themselves from year to year. Therefore they are all combined and are regarded as one. All the Junes are thrown together, and the recaptures from these experiments are all recorded in the same way. Then all the Julys are combined, and the recaptures of plaice taken in July (in general) are made to give us the migrations of the fish liberated in June and July, and so on—the details will become easily grasped by studying the charts given hereafter. The places of recapture for any one month (which are rather approximate, of course) are plotted on a chart and then a contour line is drawn round about these positions. This method of treatment was suggested to me long ago by J. O. Borley, and it is a very convenient one.

Note, first, the sizes of the fish liberated and recaptured :—

Mean Lengths.	Numbers Liberated.	Numbers Reported.	Mean Lengths.	Numbers Liberated.	Numbers Reported.
16·5	4	0	28·5	17	12
17·5	18	0	29·5	5	14
18·5	31	1	30·5	2	7
19·5	89	2	31·5	0	4
20·5	250	12	32·5	3	2
21·5	200	32	33·5	1	5
22·5	183	39	34·5	1	4
23·5	97	39	35·5	1	1
24·5	96	33	36·5	0	1
25·5	47	25	37·5	0	2
26·5	38	24	38·5	0	0
27·5	23	21	39·5	0	1
				1,116	281

(A few cases where the lengths of liberations, positions of recapture, etc., have obviously been mis-recorded are omitted.)

Condensing this table we get :—

Ranges of Lengths.	Numbers Liberated.	Numbers Reported.
	%	%
Less than 19 cms.	5	0
" 20 "	13	1
" 21 "	34	9
" 22 "	54	16
20 to 23 cms.	50	...
21 to 25 "	...	50

This means that the smaller fish do not stand the marking operation well (and, of course, that they grow between the time of liberation and that of recapture). The two lower lines of the last table are read as follows : Half of all the fish liberated were between 20 and 23 cms. in length and half of all those reported were between 21 and 25 cms. in length.

One must remember that the position of recapture reported is always approximate, for the skipper cannot tell, to a mile or two, exactly where he is, and also the fish may have been caught anywhere on a ten to twenty-mile drag. We have no reason to suspect any misleading information as to the places of recapture : on the other hand skippers were always most willing to give full details, and very often eager to know where the fish had been marked. We assume, generally, that the plaice moved straight from where they were set free to where they were caught, but this must hardly ever be the case : the fish, doubtless, "backs and fills" in its movements. For small periods of a month, however, it is quite permissible to assume that the migrations path is directly from the one spot to the other.

The June-July Migrations.

The data from which these are to be deduced are given in the following synoptic chart :—

FIG. 8. Recaptures of marked plaice reported for June and July.

The following explanation will serve for this, and the other charts illustrating the migrations. Each recapture is indicated by a black dot, and the number underneath the latter gives the length of the fish, as recaptured, in centimetres. The area where the fish were liberated is outlined by a broken line enclosing the words "area of liberation." An irregularly-curved contour line, marked "June and July," is drawn round the places of recaptures in these two months so that we may understand that the fish liberated have spread out, in all directions, from the "area of liberation" to the area enclosed by the "June-July" boundary line. During June and July, plaice previously inhabiting the shallow-water region immediately offshore are migrating out to the West, North-west, and South-west from shallower into deeper water, and from a warmer into a colder region of sea.

Certain temperature contour lines are drawn on the chart, but these will be explained later on.

The August Migrations.

It is fair to assume that all the plaice caught and liberated on the "area of liberation" in June and July have now left that region and have migrated outwards as just explained. No recaptures are reported from the "area of liberation" in August, though there was plenty of fishing going on there, and this means that during June, July, and August there is a continual streaming out of plaice from the Ribble Estuary, and all the adjacent nursery grounds. As the plaice grow up to about 20 cms., or thereabouts, in the summer months, they abandon the nurseries for the more open sea offshore. The chart shows an irregular area marked by the dotted line "June-July": this was the region where the marked fish were recaptured in those months. A number of black dots are seen in this area and to North and South of it, and these are the positions of recaptures in August. Therefore the plaice, which were within the "June-July" boundary in those

FIG. 9 Synoptic chart showing the recaptures of marked plaice in August.

FIG. 10. Synoptic chart showing the migrations of marked plaice in September.

months and which had come from the "area of liberation," tend now, either to remain where they were, or to move to North and South, still remaining offshore and in water of much the same depth. Note also a very interesting feature: the water is warmer inshore and colder offshore, and it is still rising in temperature, but it is rising more rapidly inshore than it is rising offshore.

The September Migrations.

As before, the boundary line marked "August" shows where the plaice caught in June-July, on the "area of liberation," were in August. Only a very few fish were caught in September on the latter area, but it will be seen that large parts of the August region of recapture are also vacant. The marked plaice are now evidently drawing in from the extensive region mostly just outside the ten-fathom contour line and are tending to move back inshore again. This is the plain meaning of the chart.

The October Migrations.

Clearly the inshore retreating movements observed in September continue during October. The boundary line marked "September" surrounds the region where the marked fish were in that month, and it will be seen that the inshore migrations from the September region is very well indicated. The "area of liberation" is now obviously invaded, but in addition plaice are spreading both to the North and South. There are two main trends in this North and South migration which are more clearly shown in the November and December recaptures.

The November Migrations.

There are now three distinct migration paths :—

(1) Inshore directly to the "area of liberation" and to the other shallow-water grounds in the Bays and Estuaries (Morecambe Bay, the Mersey and Dee)

FIG. 11. Synoptic chart showing the migrations of marked plaice in October.

(2) Towards the N.W., to the banks just off the N.E. Coast of Isle of Man.

(3) Towards the S.W., to the winter plaice fishing grounds in Red Wharf, Beaumaris, and Conway Bays.

Fig. 12. Synoptic chart showing the migrations of marked plaice in November.

The December Migrations.

Clearly there were three main regions where the fish were recaught in November: (1) In "Liverpool Bay," that is, from about the Liverpool Bar Light Vessel up to near Blackpool and mostly within the five-fathom contour line; (2) In Morecambe Bay, and (3) Offshore and mainly between the

FIG. 13. Synoptic chart showing the migrations of marked plaice in December.

ten- and twenty-fathoms' contour lines. From regions (1) and (2) the plaice are still moving closer inshore, and from (3) they are moving down into the Red Wharf-Beaumaris Bay area. A new path is clearly indicated—that from the grounds just offshore from the original area of liberation up to the banks offshore from Ramsey Bay, in Isle of Man.

The Autumn and Winter Migrations.

We may now summarise the results obtained so far : these are represented in Fig. 14 in a very general way. Each arrow, tipped with a black dot, represents the approximate position of an actually-recaptured marked plaice, while some other, untipped arrows on the chart merely suggest the general directions of the migrations. All the marked fish recorded as recaptured in this chart were liberated in the region indicated as the " area of liberation " in Figs. 8 to 13 : this is the region in Fig. 14 where the tipped arrows are most densely crowded.

First, then, we have the summer offshore migration. The plaice, of sizes about 20 to 25 cms., stream outwards from the Lancashire coast to the S.W., W., and N.W., and by the end of August they have come to occupy a region of sea, just outside the ten-fathom contour line and extending from about Morecambe Bay Light Vessel down to Liverpool N.W. Light Vessel. There is an active plaice fishery all over this region, while outside it and up to the N. and N.W. there is also an active fishery for soles. This offshore migration, then, is the first half of the total migratory movement of Lancashire shore plaice.

Next, there is a retrograde movement, and this reversal occurs about the time when the temperature of the sea, having attained its annual maximum, is now beginning to decrease again. The retrogression is indicated by the successive contour lines—" September-October," " November-December," and " January-February." Each of these lines is a boundary, showing the region into which the marked plaice have spread, from the region occupied during the previous two months. We see, then, that there are three directions of migration: (1) The retrograde one back to the "area of liberation" and the

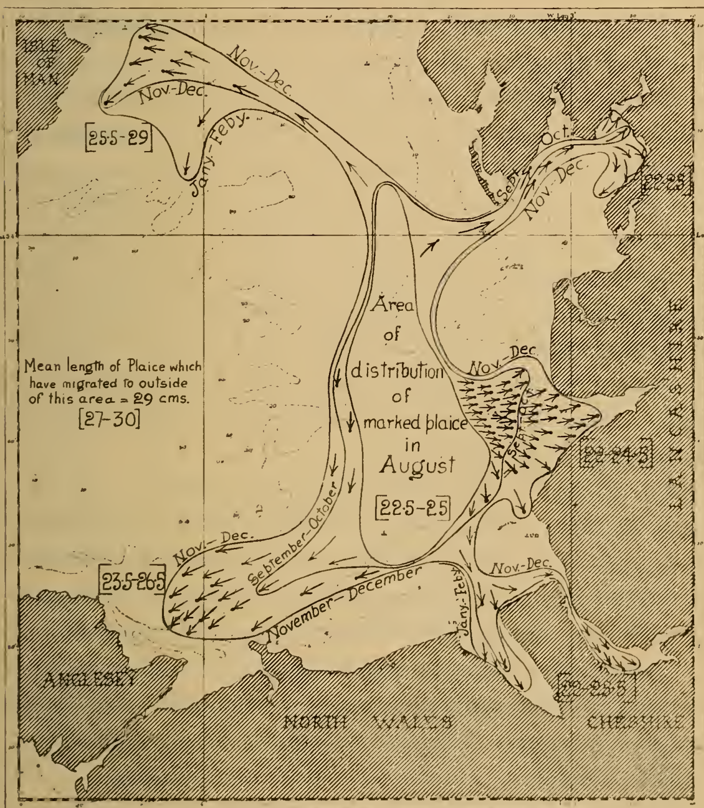


FIG. 14. General synoptic chart showing the migrations of marked plaice during the months August-December.

similar regions to North and South of the latter—this is very evident in the months November and December, and it still continues during the months January and February. The plaice are seeking the shallow-water regions just off the estuaries, and they are preparing to adopt a semi-hibernate habit for the remainder of the winter months. ("Winter" in the sea means the months January, February, and March.) (2) In addition to the retrograde movement there are, however, two others. Some plaice are migrating up to the N.W. towards the extensive, late winter, fishing area, between Ramsey Bay, in Isle of Man, and the entrance to the Solway Firth, while others are migrating to the S.W. towards the "back-end" plaice fishing region, just off the coasts of Anglesey and Carnarvon (Red Wharf, Beaumaris, and Conway Bay regions). The S.W. migration begins in September and October and culminates in December, while the N.W. movement begins in November and December and culminates in February. Here, then, we have a continued offshore migration in direct contrast to the retrograde one mentioned above. To elucidate it further we must now look into the sizes of the recaptured, marked plaice. Fig. 14 shows that the prevalent lengths (shortest half-ranges) of the latter were :—

22·5 to 25 cms. on the offshore region in August.
22 to 25·5 cms. on the inshore region in October to December.
23·5 to 26·5 cms. on the N. Welsh region in November-December.
25·5 to 29 cms. on the Manx region in January-February.
27 to 30 cms. outside the Irish Sea in the following year.

This latter point is one to which we return later. A certain number of the larger plaice leave the Irish Sea altogether and do not return. They are recaught in St. George's Channel and elsewhere.

Further Recaptures.

So far we have only considered the recaptures reported during the months July to February, immediately following the months of liberation—that is, the eight months or so after the times of the experiments. Further, we have combined the results of experiments made in different years—a deliberate policy. When we take the various experiments separately we see that just the same results are obtained as when they are all combined, though the data are, of course, fewer in number. The fact that, year after year, we get the same general results leads us to attach the greater importance to the summaries with which we have so far dealt.

Something must be said about the recaptures reported in the years following those of liberation. The marked plaice may be recaptured even after three years, but in very small numbers, of course. Now all those taken during the months January, February, March, and April in the year following that of liberation have been put on a separate chart (not reproduced here). There are three main regions in which the recaptures occur: (1) Round about the "area of liberation," and in Morecambe Bay, the Mersey, and Dee; (2) On the "Shoals," that is, N.E. from Isle of Man, and (3) In St. George's Channel. None were taken off the Anglesey and Carnarvon coasts—an interesting result to which we refer presently. The fish taken on the Lancashire coast are all small (the extreme lengths are 20 to 26 cms.); those taken off Ramsey Bay are larger (24 to 33 cms.), and those taken in St. George's Channel are also large (25 to 32 cms.). In January to April, that is, during the winter months, the migrations that were described as occurring in December to January still continue: the small fish are returning to the nursery ground and the larger ones are migrating offshore.

If, further, the recaptures reported during the months May to September and then from October to December in the year following that of liberation be considered, we see that the results of the months immediately following those of liberation are repeated. The plaice recaptured are all a year older, and a few cms. longer, of course; but the offshore migration in the summer, the retrograde one in the autumn, and the continued offshore migration to N.W. and S.W. are all to be traced.

Age and the Migration Paths.

Fig. 14 and the following table show how the migration paths depend on the age of the plaice :—

Marked Plaice liberated on the Ribble area and recaptured at the various grounds mentioned in the headings.

Length.	Central Area.	Ribble Area.	More-cambe Bay.	Mersey and Dee.	Beau-maris Bay.	Off Isle of Man.	Else-where.*
18·5	...	...	...	1	...	...	...
19·5	...	1	...	1	...	...	...
20·5	2	4	...	...	...	...	...
21·5	3	12	3	2	1	...	...
22·5	7	12	4	2	3	...	...
23·5	4	13	2	4	4	1	...
24·5	4	5	2	2	7	1	...
25·5	2	5	...	...	4	2	2
26·5	2	6	2	2	2	2	...
27·5	2	3	1	1	2	3	1
28·5	1	1	1	2	...	1	1
29·5	1	2	...	...	1	...	1
30·5	...	...	...	...	...	...	...
31·5	...	...	...	...	...	...	2
32·5	...	...	...	...	1	1	1
33·5	...	...	...	...	...	1	...
34·5	...	...	...	...	1	...	...
35·5	...	...	...	...	...	...	...
36·5	...	...	...	...	...	...	...
37·5	...	...	...	...	...	1	...
	28	64	15	17	26	13	8

* Outside the Irish Sea.

We see from the table that the smaller fish are those that have been recaptured in the central area limited by the August boundary line in Fig. 14, and those taken in the bays and estuaries of the Lancashire coast during the few months immediately following the date of liberation. In these fishes the prevalent size (shortest half-range) is about 22 to 25 cms. Those taken on the grounds off the N.E. Coast of Isle of Man and in the Red Wharf Bay Estuary are a little bigger, 23 to 26 and 25 to 29 respectively. This means that there is a tendency to segregation according to the stage of maturity. The latter is only indicated approximately by the differences in length, for there is a considerable variation in the sizes (or ages) at which plaice become mature. The meaning of these differences in the migration paths taken by the fish is therefore this: the plaice that are approaching the stage of sexual maturity move offshore, into deeper water, and towards the spawning grounds in St. George's Channel and in the Solway, while those which are still in the immature condition migrate back again to the nursery grounds.

(2) *The Red Wharf-Beaumaris Bay Experiments.*

Looking at the results of the marking experiments considered so far we see two rather singular things: (1) Year after year a certain fraction of the plaice that have migrated offshore from the nursery grounds in the summer return there again in the autumn and winter months; (2) Year after year a certain fraction of the plaice that have migrated from the nursery grounds into the Red Wharf-Beaumaris Bays region also return in the winter months. What becomes of the plaice that do not so return? This question was investigated by marking and liberating several lots of fish on the grounds near Red Wharf Bay during the course of the back-end fishery. These experiments were :—

12th Nov., 1904	...	...	42 plaice.
Do.	...	...	49 ,,
24th Oct., 1907	...	...	120 ,,
20th Nov., 1913	...	...	220 ,,
Total	...	...	431 plaice.

First, we take the experiments made in October and November: 431 plaice were liberated, and 106 of these were reported as recaptured on the same grounds as those on which they were liberated—that is, within a line drawn straight from

Point Lynas, in Anglesey, to Great Orme's Head, in Carnarvon. After December no more of the plaice liberated were caught until a year later. The mean length of those taken on the same grounds immediately after liberation was 24·5 cms., and the mean length of those taken on the same grounds a year later was 28·8 cms. The difference represents the mean growth in one year—4·3 cms. Those fish that were caught a year later on the ground where they were liberated had not stayed there during the interval: we know this because there is always some fishing in this area and there were no reports of recaptures during the interval. Further, some of the plaice marked in the Red Wharf-Beaumaris Bays area were actually recaptured on the fishing grounds to the N.E.—five on the nursery grounds, and having a mean length of 24 cms., and three on the central region bounded by the August contour: these had a mean length of 30 cms.

Of the plaice to be found on the grounds off the coasts of Anglesey and Carnarvon in the back-end of the year, some migrate to the nurseries on the coast of Lancashire, and then they move from there out into deeper water in the summer months: these are the smaller fish. The rest of the plaice, that is, the bigger ones, go elsewhere. Where they go is indicated in the following statements, which account for the recaptures during the three years following the date of liberation:—

(1) *Into Carnarvon and Cardigan Bays.*

There were reported:

In Jan. to March,	the year after,	3	fish	of mean length	= 23·1	cms.
,, April to June,	,,	14	,,	,,	= 26·5	,,
,, July to Sept.,	,,	3	,,	,,	= 26·9	,,
,, Oct. to Dec.,	,,	1	,,	,,	= 35·0	,,
,, April to June,	2 years after,	1	,,	,,	= 33·0	,,

(2) *Into Bristol Channel, St. George's Channel, the English Channel.*

There were reported :

In April to June, the year after,	2	fish of mean length	=	29·0	cms.
„ July to Sept.,	„	4	„	„	= 30·7	„
„ Oct. to Dec.,	„	1	„	„	= 29·7	„
„ July to Sept., 2 years after,		1	„	„	= 36·5	„
„ April to June, 3 years after,		1	„	„	= 36·2	„

(3) *To the E. and S.E. Coasts of Ireland.*

There were reported :

In April to June, the year after,	3	fish of mean length	=	28·5	cms.
„ Oct. to Dec.,	„	1	„	„	= 35·0	„
„ July to Sept., 2 years after,		1	„	„	= 41·9	„
„ Oct. to Dec.,	„	1	„	„	= 39·0	„
„ July to Sept., 3 years after,		1	„	„	= 38·6	„

Thus the large (that is, the more nearly mature) of the plaice inhabiting the grounds between N. Anglesey and Carnarvon migrate down channel into the great Welsh Bays, St. George's Channel, the Bristol Channel, the S. and E. Coasts of Ireland, and the English Channel. Of the plaice liberated on the N. Welsh ground and recovered, 28 per cent. had been recaptured on the same grounds or had gone back into the Irish Sea; 5 per cent. were recaptured in Carnarvon and Cardigan Bays, and 4 per cent. were recaptured in St. George's Channel, the Bristol Channel, on the S. and E. Coasts of Ireland, and in the English Channel.

Where do these plaice that are taken on the N. Welsh grounds come from ? The Liverpool Bay marking experiments answer this question. They come from the nursery grounds on the Lancashire coast. Of the plaice that migrate out from those grounds in the summer months, a considerable fraction of the larger ones go down to the Red Wharf-Beaumaris Bays, where they form the material of the fishery that sets in during the back-end.

General Remarks on the Migration Experiments.

The spawning grounds of the plaice are in the water of 15 to 20 fathoms in depth, off St. Bees' Head, in Cumberland, and somewhere in St. George's Channel. The eggs produced in the northern spawning ground drift mostly into the Solway Firth and into the Bays on the S. Coast of Scotland to replenish the nurseries there. The eggs produced in St. George's Channel drift to the N.E., round Holyhead, and are reared on the nurseries just off the Cheshire and Lancashire coasts. The drift of the eggs and larvae is a passive one, due to winds and resultant tidal currents.

The baby plaice live on the nursery grounds until they are about 20 cms. in length and about three years old. Then they begin to migrate.

They move out to deeper water off the coast during the summer months. The more vigorous ones continue to migrate to the grounds off the N.E. Coast of Isle of Man, or to the North Welsh grounds. Most of the others return back again to the nurseries during the months September to December. Next year these latter plaice migrate offshore again and probably succeed in moving away altogether from the nurseries.

The grounds off Ramsey Bay (Shoals, etc.) and those between the N. Coast of Anglesey and Carnarvon are in the nature of " relays " in the plaice migrations. The fish remain there for some time and then reassume their migrations. By the end of January all the plaice have usually left the Red Wharf-Beaumaris Bay region, and they can be traced down into Carnarvon and Cardigan Bays. Later on they go offshore somewhere in order to spawn. During January and February the plaice tend to leave the Shoals region and they probably migrate over to the Cumberland and Lancashire coasts. The larger ones from the Shoals area, and possibly mature fish from the Solway Firth and the South Coast of Scotland, migrate on to the Solway ‘ Slaughter ” area in March in order to spawn.

Temperature changes in the sea are closely associated with the plaice migrations. The long contour lines on the charts (Figs. 8 to 13) were drawn with the idea of elucidating this relationship. They are called “ Isoanomalous lines,” and indicate the rate at which the sea-temperature rises or falls (according to the season) between the coast and the sea offshore. But we have yet far too few data to allow of this subject being pursued. One thing, however, may be noted : in their migrations the small fish of the Irish Sea tend to move *across* the isotherms. Obviously one impulse in the migrations is that of the fish to tend to remain as much as possible in water of the same temperature.

The Growth-rate of Marked Plaice.

First we consider the general growth-rate of plaice as it has been found by the methods indicated on pp. 166-171 and in the data of Table XIV. (See Fig. 7.) These results show that the mean rate of growth of Irish Sea plaice, males and females, taken from all the regions is about 6 cms. (= $2\frac{3}{8}$ inch) per year. That is fish up to five complete years in age. Taking the Age-groups II, III, and IV, the mean increase in length per year is 5·75 cms. (= $2\frac{1}{4}$ inches).

How fast does a *marked* plaice grow ? This is easily found by making measurements of plaice marked and liberated before the beginning of the spring and then recaptured after the end of autumn. Sometimes measurements can be made on plaice that have undergone two or even three complete seasons’ growth. These results are fairly constant and they show a *mean* rate of growth of marked plaice of 3 inches. Sometimes the yearly increase may be much more than this, and it is generally greater in the case of marked plaice *that have made long migrations* from Liverpool Bay into St. George’s Channel.

Why does a marked plaice that has migrated grow faster than those that can be fished on the ground of liberation ? One is apt to say that growth depends mainly on the supply of food, and that is true to some extent. But females grow faster than males, and then, after a certain age, the males seem to die. Therefore there is an intrinsic growth-factor which is different in its " strength " in different individuals. We must assume (in order to attempt to explain the difference in rates of growth of marked and unmarked fishes) that this growth-factor is associated with, or may be the same thing, as the intrinsic factor that urges one plaice to migrate sooner in its lifetime, and to farther distances, than another one. Looking, then, at the general results of the marking experiments we can distinguish between an " ordinary " plaice population, growing sluggishly because of the low intrinsic growth-factor, and another fraction of the general population, growing rapidly and migrating sooner for the opposite reason. *Therefore* a (probably large) fraction of the plaice population off the Lancashire coast *is a residual population, the more vigorous individuals migrating to outside areas.* And so, it would appear, " protection " of this residual population may not be of any practical administrative value.

PART III.

The Pre-War and Post-War Plaice Fisheries.

With the resumption of sea fishing, on the great scale, in 1919, the question arose: had the restrictions that were put in force, as military measures, led to an increase in the productivity of the sea fisheries. The question was directed chiefly to the plaice because this fish had been studied more completely than any other in the dozen, or so, years preceding 1914. It was known that there had been a very marked falling-off in the quantity of plaice landed from the North Sea grounds during the years 1907 to 1913—a falling-off which was particularly evident in the medium-sized and larger fish; this falling-off was to be traced not only in the total quantities landed, but also in the quantities caught per hour's fishing. Naturally the change became associated with the great expansion of steam-trawling since the end of last century, and it was generally believed that the plaice stock in the North Sea was a stock which was being depleted by the intense fishing that had been practised.

Fluctuations in the Plaice Fishery.

When trawling was resumed in the offshore regions of the North Sea in 1919 it was seen that a considerable change had occurred. The landings of plaice rose, as did the quantities taken per hour's fishing. The following graphs show this change very well. Fig. 15A represents the North Sea landings, and it shows that the total quantity taken and brought ashore by British fishing vessels fell from about 650,000 cwts. in 1907 to about 475,000 cwts. in 1913. Then follow several years when war restrictions prevented the full exploitation of the fishing grounds, and when the fishing was resumed the quantity landed was found to have increased—until, in 1920, it exceeded

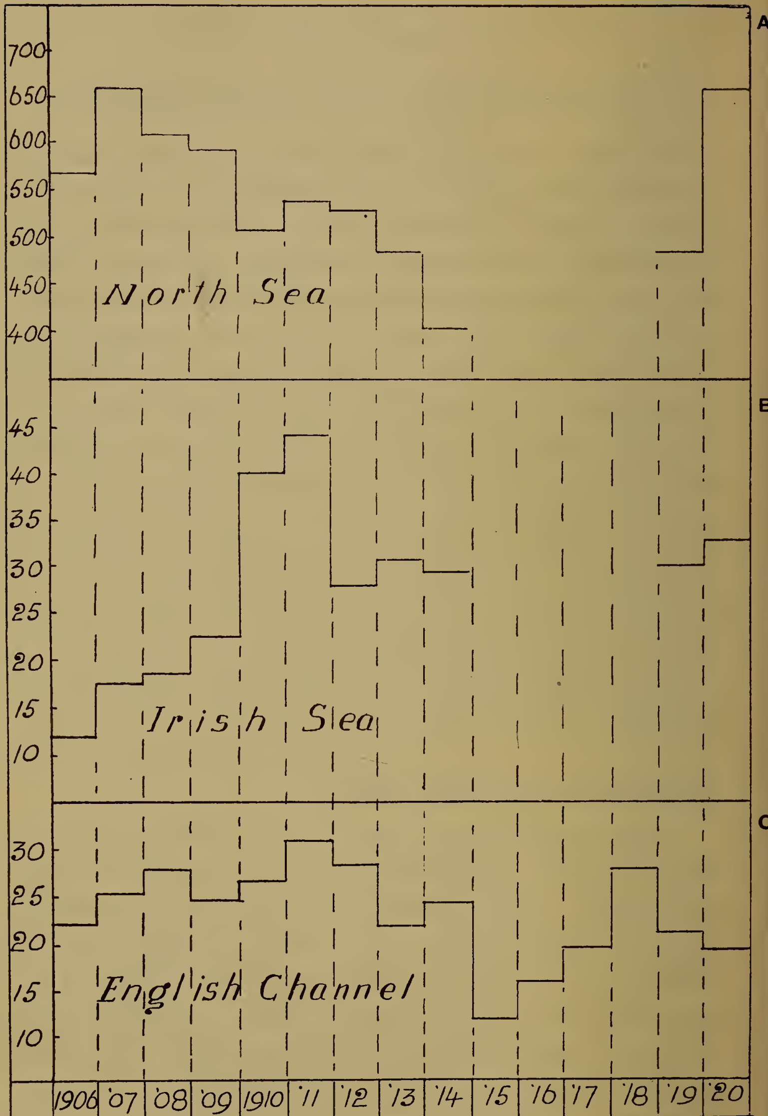


FIG. 15. Graph showing the change in the plaice fisheries in the North Sea, English Channel, and Irish Sea. Based on official statistics.

the quantity landed in 1907. Not only so, but very considerable measurements of the plaice caught aboard trawlers showed that the size of the fish had also increased in a notable manner. So much for the results obtained by the English investigators in the North Sea: similar conclusions were made both by the Danish and German workers.

Fig. 15B represents the total landings on the West Coast, while Fig. 15C is a graph of the same data for the English Channel. Even when we take the quantity of plaice landed per day's fishing the same general result is obtained. There is a marked drop in the catches from the year 1911, in the West Coast and English Channel data, to about 1914-5, and then there is an equally marked rise to about 1918-20. In so far the experience of the southern and western fisheries is similar to that on the East Coast, but there are other features of the graphs representing the latter regions that call for comment. In the case of both the West Coast and Channel there is a *rise* in the quantities landed from 1906 till 1911, and then follows the falling-off. The latter, it has been noted, commenced, in the North Sea, in 1907, but we must remember that we do not know as accurately what were the landings in the years immediately preceding 1907: it may be that they had gradually been rising, just as were those from the West Coast and Channel. Further, the still more important information as to the quantities landed per day's fishing, per vessel, are not known.

So long, then, as we do not know what was the statistical history of the North Sea plaice fisheries prior to 1907, it is not quite certain whether the changes noted were of the nature of those due to a reduction of the stock by over-fishing, or to a natural fluctuation that might have occurred no matter how the intensity of fishing varied (within reasonable limits, of course).

In 1918 everything pointed to the conclusion that greatly increased fishing would deplete a natural stock of fish. So it must, of course, provided the increase is great enough ; but the question we have here to consider is whether the increase of fishing in the North Sea trawling fleet *did* actually lead to the diminution in the catches which was observed in the year following 1907 ? We anticipated, as everyone then did, in 1915-8 that the great decrease in trawling *must* have an effect upon the fisheries, and such statistics as were then available for the North-west of England were examined with that question in mind.

Fluctuations in the abundance of Plaice on the Lancashire Fisheries, 1892-1920.

From the year 1892 onward and till the present time the condition of the inshore ground, or nursery, just off the estuary of the Mersey, has been regularly examined. Experimental hauls, made with a beam trawl-net of 25 to 30 feet in breadth and having meshes of 6 inches, have been made several times every month. Similar hauls with a shrimp trawl-net, of 2-inch mesh, were also made : all these experiments were carried out by Capt. George Eccles, a highly experienced fisherman. Taking them critically one sees that the methods were not always strictly comparable, but this does not affect the broad, general conclusions that are certainly to be drawn from the data. The latter are recorded and are fully discussed by R. J. Daniel,* and the numerical results need not be given here in full. But a graph is necessary in order to see where they lead.

Fig. 16, then, is such a graph. Two series of " averages " have been plotted : first, the average catch per annum (smoothed by taking three-yearly averages yearly, and second, the " half-ranges " calculated as in the following example :—

No. of plaice caught in a haul	0 to 50,	51 to 100,	101 to 150, etc.
No. of times such a catch was made ...	13,	6,	1, etc.
Sums of the above frequencies ...	37,	24,	18, etc.

* *Rept. Lancashire Sea-Fish. Laby.* for 1919.

That is, there were 13 hauls in this year that contained 0 or less than 51 plaice, 6 that contained 51, but less than 100, and so on. The lower line is to be read as follows: there were 37 hauls in the year, and in all of these either no plaice or some plaice were caught; there were 24 hauls in which either 51 or more than 51 were caught; there were 18 hauls in which either 101 or more than 101 were caught, and so on. When we plot the figures of the last line we get a J-shaped curve

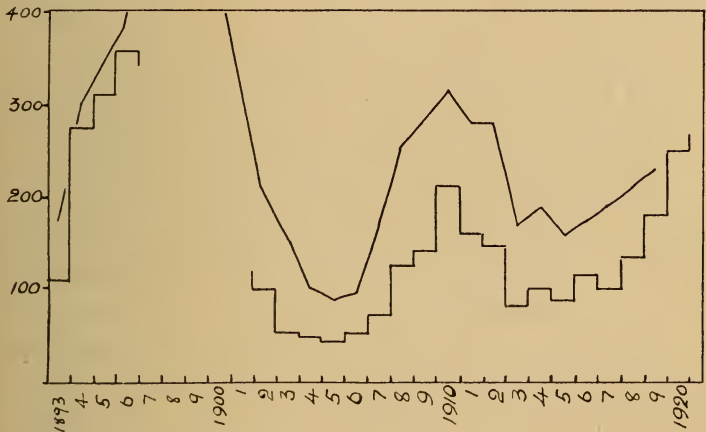


Fig. 16. The continuous, angular line represents the average catch per hour's fishing with a trawl-net of 6-inch mesh. The individual annual averages are "smoothed" by taking three-yearly averages yearly. The catch for the period 1895-7 rises to 895. The series of columns represents the results of the other method described in the text. Several years' records are lost.

(or exponential). Then we take half the area of this curve on the steeper side and note what is the range of frequencies covered by the half area. Such ranges are represented by the columns of Fig. 16.

This kind of average gives us the nearest approximation to the experience of the fishermen. The latter would say "we usually got about 100 fish per haul," or so. This kind of graph is, therefore, the best general expression of the whole experience.

But it does not matter whether we take the results of the trials with the fish trawl-net, or those made with the shrimp trawl-net. Nor does it matter whether we take the average catches per year, or the smoothed average catches per year, or the half-ranges of the summed catches. Whatever way we deal with the data the same result comes out: there is a periodic fluctuation between 1892 and 1920. There are two periods :—

(1) There are *maxima* in 1896-7 and about 1910.

(2) There are *minima* about 1905 and about 1915.

(3) There must have been a *minimum* about 1890.

(4) There appears to be a *maximum* about 1920-22.

(5) When the fish-trawl and the shrimp-trawl data are examined it is seen that the minimum for the former occurs about two years after the minimum for the latter.

Here, then, we have actual observations that point directly to a national, periodic fluctuation in the abundance of plaice on a certain ground—the Mersey nursery area. The evidence is experimental, but the same results also come from examining the variation in the quantities of plaice landed from year to year. Allowing for various sources of confusion this same periodic fluctuation is seen in the quantities of plaice landed at Morecambe—a typical inshore fishing port. It is also to be seen in the total landings from the English Channel and from the West Coast. One cannot doubt that we have here evidence of a natural periodic variation in the abundance of plaice on the West Coast. Every ten or twelve years the fish becomes unusually abundant. There was a minimum of abundance (several lean years) just about the date of commencement of war, but this cannot be more than a coincidence.

Fluctuations in the Size of Plaice taken off the Lancashire Coast: 1908-1920—*Mersey Estuary.*

We now consider the variations from year to year in the sizes of the plaice landed from the Lancashire inshore waters. The data are not so abundant as we might wish and the results are rather inconclusive. But since they may fit in, afterwards, with the results of other investigations it is advisable that they should be recorded. There are measurements of plaice caught on the various grounds and these are summarised in tables. There are, however, no records for the war years 1914-1918 for most of these grounds: only one series of trawlings was maintained all through the period 1908-1920, and that was those taken on the Mersey nursery ground. The two best months here are, on the whole, September and October, and these are, therefore, combined as the series of length-frequency distributions of Table 16. Here we have measurements of the plaice caught in those months by a beam trawl-net of 6-inch mesh used from a sailing boat.

Table XVI. Off Mersey Estuary, Sept.-Oct. Trawl Net, 6-in. mesh.

Mean Length	1908.		1909.		1910.		1911.		1912.	
	f	*f* %	*f*	*f* %	*f*	*f* %	*f*	*f* %	*f*	*f* %
11·5	1	0·02	...	...	...	...	...	...	...	...
12·5	4	0·07	5	0·21	...	...	...	...	...	...
13·5	38	0·68	7	0·36	...	...	...	...	1	0·11
14·5	249	4·47	28	1·22	...	...	...	...	4	0·44
15·5	833	14·97	54	2·36	...	...	2	0·25	12	1·31
16·5	331	23·88	127	5·55	1	0·16	20	2·49	34	3·71
17·5	919	16·51	271	11·86	10	1·62	30	3·74	52	5·66
18·5	600	10·77	327	14·31	22	3·58	29	3·62	77	8·38
19·5	378	6·77	265	11·59	38	6·18	25	3·11	129	14·05
20·5	325	5·83	261	11·37	51	8·29	11	1·34	99	10·78
21·5	253	4·54	221	9·66	69	11·23	13	1·62	121	13·18
22·5	215	3·86	180	7·92	43	6·99	31	3·86	87	9·47
23·5	146	2·62	123	5·38	41	6·66	45	5·66	72	7·84
24·5	81	1·45	109	4·77	61	9·92	57	7·11	57	6·21
25·5	79	1·41	86	3·76	54	8·78	74	9·22	34	3·71
26·5	40	0·73	76	3·32	50	8·13	85	10·61	36	3·92
27·5	31	0·55	50	2·19	48	7·80	98	12·22	24	2·61
28·5	18	0·32	40	1·75	41	6·66	96	11·97	13	1·42
29·5	12	0·21	24	1·05	37	6·02	82	10·22	15	1·63
30·5	3	0·05	11	0·48	17	2·76	36	4·49	15	1·63
31·5	2	0·04	9	0·39	12	1·95	26	3·24	8	0·87
32·5	2	0·04	3	0·13	10	1·62	18	2·24	4	0·44
33·5	2	0·04	2	0·08	6	0·97	9	1·12	9	0·98
34·5	1	0·02	4	0·17	...	...	8	0·98	4	0·44
35·5	...	...	...	...	2	0·33	4	0·49	6	0·65
36·5	...	...	...	...	1	0·16	1	0·12	1	0·11
37·5	2	0·04	1	0·04	1	0·16	1	0·12	2	0·21
38·5	2	0·04	...	...	...	...	...	...	1	0·11
39·5	1	0·02	1	0·04	...	...	1	0·12	1	0·11
40·5	...	...	...	...	...	...	...	...	...	...
	5,568	99·95	2,285	99·96	615	99·97	802	99·96	918	99·98

Table XVI—*Continued.*

Mean Length.	1913.		1914		1915.		1916.	
	f	*f* %	*f*	*f* %	*f*	*f* %	*f*	*f* %
11·5	...	...	...	...	...	...	...	...
12·5	...	...	...	...	1	0·02	...	...
13·5	...	...	2	0·17	4	0·09	...	...
14·5	...	...	9	0·62	33	0·76	3	0·48
15·5	3	0·11	24	2·09	159	3·67	8	1·29
16·5	19	0·67	52	4·53	317	7·32	13	2·10
17·5	89	3·13	115	10·02	540	12·47	13	2·10
18·5	307	10·78	139	12·11	549	12·67	26	4·20
19·5	522	18·34	91	7·94	385	8·89	42	6·79
20·5	533	18·72	94	8·20	365	8·43	57	9·21
21·5	514	18·06	86	7·50	315	7·27	77	12·44
22·5	341	11·98	70	6·10	347	8·01	63	10·17
23·5	216	7·59	59	5·13	307	7·09	78	12·60
24·5	136	4·78	62	5·49	313	7·23	64	10·34
25·5	68	2·39	55	4·80	226	5·22	41	6·62
26·5	35	1·23	59	5·13	185	4·27	32	5·17
27·5	27	0·95	74	6·45	119	2·75	32	5·17
28·5	10	0·35	41	3·58	75	1·73	19	3·07
29·5	8	0·28	44	3·84	31	0·72	15	2·42
30·5	2	0·07	22	1·92	21	0·48	15	2·42
31·5	3	0·11	15	1·31	10	0·23	6	0·97
32·5	3	0·11	11	·96	9	0·21	7	1·13
33·5	1	0·03	10	0·87	3	0·07	2	0·32
34·5	2	0·06	1	0·09	5	0·12	3	0·48
35·5	1	0·03	1	0·09	1	0·02	...	...
36·5	...	...	2	0·17	2	0·05	...	...
37·5	1	0·03	2	0·17	2	0·05	...	...
38·5	...	...	...	...	2	0·05	...	...
39·5	1	0·03	1	0·09	2	0·05	...	...
40·5	1	0·03	3	0·26	...	...	...	...
41·5	1	0·03	...	...	...	...	...	...
42·5	...	...	...	...	...	...	2	0·32
43·5	...	...	1	0·09	1	0·02	1	0·16
44·5	1	0·03	1	0·09	1	0·02	...	...
45·5	1	0·03	...	...	...	...	...	...
46·5	...	...	...	...	...	...	...	...
47·5	...	...	...	...	...	...	...	...
48·5	...	...	...	...	...	...	...	...
49·5	...	...	...	...	...	...	...	...
50·5	...	...	...	...	...	...	...	...
51·5	...	...	1	0·09	...	...	...	...
	2,846	99·95	1,147	99·80	4,330	99·98	619	99·97

Table XVI—*Continued.*

Mean Length.	1917.		1918.		1919.		1920.	
	f	*f* %	*f*	*f* %	*f*	*f* %	*f*	*f* %
11·5	...	...	...	...	...	...	...	...
12·5	...	...	6	0·33	...	...	13	0·53
13·5	2	0·03	18	0·99	4	0·3	7	0·29
14·5	79	2·22	43	2·36	43	3·22	91	3·76
15·5	190	5·34	123	6·75	77	5·75	266	10·99
16·5	297	8·54	195	10·67	109	8·15	307	12·68
17·5	382	10·73	193	10·58	133	9·94	211	8·72
18·5	436	12·24	174	9·54	126	9·92	185	7·64
19·5	446	12·52	169	9·27	144	10·76	190	7·85
20·5	334	9·38	169	9·27	145	10·83	165	6·82
21·5	334	9·38	117	6·42	126	9·42	160	6·61
22·5	299	8·40	156	8·56	111	8·30	166	6·85
23·5	224	6·29	130	7·13	83	6·20	101	4·17
24·5	184	5·17	79	4·33	61	4·56	107	4·42
25·5	100	2·81	60	3·29	45	3·36	93	3·84
26·5	78	2·19	28	1·54	32	2·39	53	2·19
27·5	45	1·26	38	2·08	23	1·72	60	2·48
28·5	27	0·76	34	1·87	22	1·64	59	2·44
29·5	21	0·59	21	1·15	15	1·12	49	2·02
30·5	17	0·48	27	1·48	11	0·82	36	1·49
31·5	14	0·39	11	0·60	3	0·22	23	0·95
32·5	15	0·42	4	0·22	11	0·82	21	0·87
33·5	7	0·20	5	0·27	1	0·07	19	0·78
34·5	6	0·17	2	0·11	2	0·15	16	0·66
35·5	6	0·17	3	0·16	2	0·15	6	0·25
36·5	4	0·11	2	0·11	2	0·15	4	0·17
37·5	3	0·08	5	0·27	3	0·22	4	0·17
38·5	1	0·02	1	0·05	...	...	1	0·04
39·5	2	0·03	3	0·16	1	0·07	3	0·13
40·5	2	0·03	3	0·16	1	0·07	2	0·08
41·5	1	0·02	1	0·05	...	...	...	...
42·5	1	0·02	...	...	1	0·07	1	0·04
43·5	...	...	...	...	...	...	1	0·04
44·5	...	...	1	0·05	1	0·07	...	...
45·5	...	...	1	0·05	...	...	1	0·04
46·5	...	...	...	...	...	...	...	...
47·5	...	...	...	...	...	...	...	...
48·5	...	...	...	...	...	...	...	...
49·5	2	0·03	...	...	...	...	...	...
50·5	1	0·02	...	...	...	...	...	...
51·5	...	...	1	0·05	...	...	...	...
	3,560	100·04	1,823	99·92	1,338	99·96	2,421	100·01

The results of Table 16 are studied by making shortest half-ranges from the various yearly distributions.

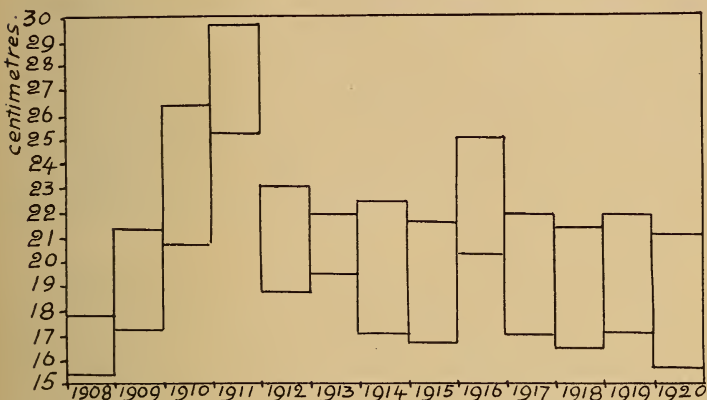


Fig. 17. Variation in length (shortest half-ranges) of plaice caught on the Mersey nursery grounds, during September and October, 1908-1920, by a trawl-net of 6-inch mesh.

The figure represents the prevalent sizes of plaice on the above grounds. The lengths of the columns, read off on the scale on the left-hand side, give these prevalent sizes. Now the latter certainly increased regularly from 1908 to 1911 (which latter year was about the time of a maximum in plaice abundance), but after 1915, when there should be a minimum, the prevalent size of the fish does not increase towards another maximum about 1920, as one might expect. Perhaps, to expect so much would be foolish for we may have to reckon with the fact that the migration periods that we noted above may be variable—and here we have studied two months only. In fact, this question of variation in length is very complex, and we are still without the knowledge that would enable us to deal with it satisfactorily.

Fluctuations in the Size of Plaice—Liverpool Bay.

Next, we take another region, Liverpool Bar to Blackpool (mostly within territorial waters). All experimental fishing was suspended here for the period of the war and we have only the years 1909, 10, 11, 12, 13, and 1920 for comparison with each other. The distributions considered are those for August and September (the best ones), and the data are taken from Tables 5, 23, 24. What we can compare is the pre-war period, 1909-13, with the post-war one, 1920, and it is to be noted that we know nothing of the years 1914-19 : possibly 1919 was a year in which the plaice here ran bigger than they did in 1920. Now which of the pre-war years ought we to set over against 1920 ?

The last pre-war year, 1913, is the one with which we naturally compare the first post-war year, 1919 (or 1920, for we have no data for 1919). But we see, from Fig. 16, that 1913 appears to have been a year of minimum abundance of plaice, while 1910 was situated near a maximum. It is well, then, to see if there are differences between the prevalent sizes of plaice as they occurred on the Liverpool Bay grounds, and so Fig. 18 was prepared.

Evidently, if we compare 1920 with 1913, we find that the post-war plaice ran bigger than did the pre-war ones ; but if we compare 1920 with 1910 we find that there is little (if any) significant difference. If we take the average lengths for the years 1913-1909 we shall find that the plaice of 1920 are, on the whole, bigger than in the years immediately preceding the war ; but it would be wrong to associate the increase so indicated with the restrictions on fishing of the years 1914-18. It is necessary to consider also the *deviations* from the average of 1909-1913, and we see that the good year 1920 is not any better than the best of the pre-war years with which it is contrasted. The fact is that these length-frequency data are very difficult to interpret in some cases : to make the best use of the information that they give requires also a knowledge of the migrations. We should want to know, rather closely, in what months the crises of the migrations occurred, because we are comparing a definite period (August-September) in all the years, and it may be the case that large plaice had left Liverpool Bay, in greater proportion, and in a certain month, in one year than in another.

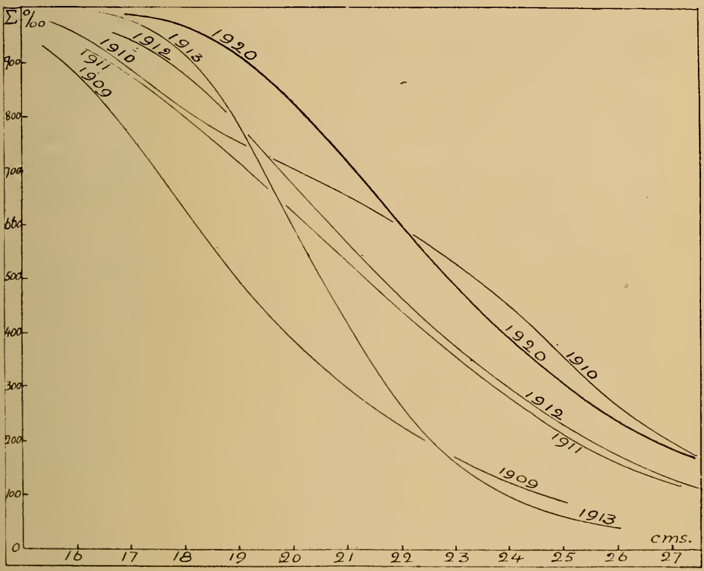


FIG 18. Graph representing the lengths of plaice caught by the 6-inch trawl-net on the Liverpool Bay grounds in the months August-September during the period 1909-13, 1920. Summational curves, from Tables 5, 23, 24.

The Northern Plaice Grounds in 1920 *and* 1921.

There is material for an interesting comparison in the data obtained on the northern grounds in 1920-1921, when investigations into the spawning of the fish were made, and when we were able (by permission of the Fishery Board for Scotland) to trawl in Luce Bay. The Table 17 gives the length-frequencies for the months of January to April, and for the " Shoals " and " Slaughter " grounds (the latter being that on which spawning fish were found). Fig. 19 is a graph of these data, and also the results of the hauls made in Luce Bay in 1920-21.

Table XVII. Northern Grounds, 1920-21. Length Frequencies.

	"Shoals."				"Slaughter."			Solway Spawning Ground.				Luce Bay.	
	I.	II.	III.	IV.	II.	III.	IV.	I.	II.	III.	IV.	1920.	1921.
15·5	...	...	...	2	1	...	6*	...	2	...	8*	...	6
16·5	...	2	...	1	...	3	1	...	2	2	3	2	15
17·5	...	7	3	2	1	4	3	...	10	7	6	3	47
18·5	3	23	2	2	4	5	4	3	31	5	9	2	63
19·5	4	39	5	2	8	8	5	4	51	11	11	6	46
20·5	12	30	6	2	10	6	1	12	45	11	4	5	41
21·5	10	30	10	1	9	8	5	10	44	16	11	6	14
22·5	12	34	11	2	8	10	2	12	48	19	8	5	15
23·5	11	31	16	3	6	18	6	11	48	25	18	3	17
24·5	21	29	17	2	7	8	2	21	48	23	6	4	6
25·5	11	17	16	2	11	14	5	11	34	25	14	3	15
26·5	13	13	13	5	15	20	2	13	36	27	15	5	6
27·5	9	18	12	...	12	13	1	9	36	23	7	1	14
28·5	3	17	7	8	13	18	3	3	35	16	22	3	10
29·5	2	17	10	2	19	21	1	2	49	28	9	3	13
30·5	3	5	6	2	14	18	4	3	25	18	15	6	10
31·5	3	11	8	5	11	18	2	3	30	25	10	4	23
32·5	3	13	5	1	14	16	1	3	36	19	8	5	18
33·5	2	10	2	1	18	12	3	2	38	14	8	7	18
34·5	2	9	7	2	16	21	1	2	27	24	8	5	27
35·5	3	8	2	1	11	23	3	3	23	23	8	10	28
36·5	...	6	6	4	21	9	3	...	30	12	12	11	23
37·5	1	12	3	5	18	13	3	1	34	15	11	10	11
38·5	2	8	1	1	5	10	2	2	20	9	6	8	17
39·5	...	15	...	5	5	13	...	...	21	10	9	10	11
40·5	...	5	4	3	7	6	2	...	13	7	9	12	12
41·5	...	5	...	...	6	7	1	...	13	6	2	12	10
42·5	1	10	3	...	7	8	1	1	20	10	3	7	4
43·5	...	2	1	1	8	5	1	...	14	5	3	11	4
44·5	1	3	1	...	9	8	1	1	14	6	5	6	3
45·5	1	3	...	1	6	8	1	1	12	7	4	3	1
46·5	...	5	1	...	1	1	...	...	7	2	1	3	3
47·5	...	3	4	1	2	8	...	...	6	11	2	2	2
48·5	...	3	...	...	1	...	...	...	5	...	...	3	1
49·5	...	3	...	1	2	1	...	...	5	1	1	3	...
50·5	...	1	1	...	1	1	...	...	2	2	...	...	2
51·5	...	...	1	...	1	1	...	...	1	2	...	...	1
52·5	...	1	...	...	3	1	...	...	5	1	...	...	1
53·5	...	1	1	...	...	1	...	...	3	2	...	1	...
54·5	...	...	...	...	...	...	...	...	...	...	...	1	...
55·5	...	...	...	...	...	1	1	...	1	...	2	...	...
56·5	...	...	...	...	...	...	...	...	1	...	...	...	...
57·5	...	...	...	...	...	...	...	...	...	...	...	2	...
58·5	...	...	...	...	1	...	...	...	1	...	...	...	...
59·5	...	...	...	...	...	...	...	...	...	...	...	...	...
60·5	...	...	...	...	...	...	...	...	...	...	...	1	...
61·5	...	...	...	...	...	...	...	...	...	...	...	...	...
62·5	...	...	...	...	...	...	...	...	...	...	...	...	...
63·5	...	...	...	...	1	...	...	...	1	...	...	...	...
64·5	...	...	...	...	...	...	...	...	...	...	...	...	...
65·5	...	...	...	...	...	1	...	...	...	...	1	...	...
	133	449	185	70	313	367	77	133	927	469	279	194	558

* 10·5 to 15·5.

These results represent the biggest plaice caught anywhere in the Irish Sea area. Here we are concerned only with the Luce Bay figures. The graph shows a fairly well-marked difference between 1920 and 1921 for this region, the plaice taken in 1921 being considerably smaller, on the whole, than those taken in 1920. Now a somewhat similar decrease in size in North Sea plaice, in 1919 and 1920, was held, by the

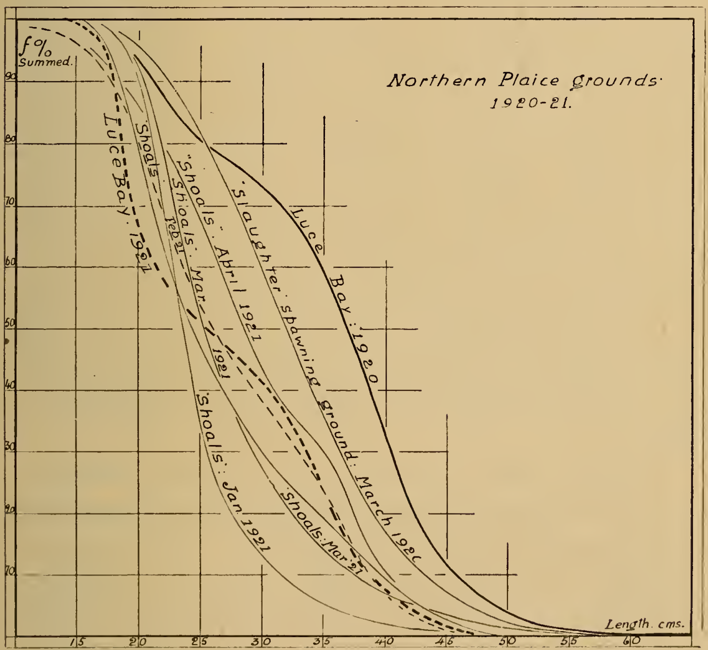


FIG. 19. Graphs of the length-frequencies of plaice caught in a 6-inch mesh trawl-net on the northern grounds in February-April, 1921, and in Luce Bay in September, 1920 and 1921. Summational curves from Table 17.

English workers, to point to the first results of the renewed intense fishing of the North Sea. That explanation is difficult to extend to the Irish Sea area, for there is comparatively little fishing in these northern grounds, and Luce Bay is, of course, a preserved region, where all forms of trawling are prohibited by the Scottish Fishery Board.

Relative Proportions of the Age-groups of Plaice in the various years.

Hitherto it has been rather suggested that plaice are bigger or smaller in one year than in another because they grow more or less rapidly. No doubt there are differences of such a kind in various years, and, no doubt also, these differences depend on a greater or less food supply. Just yet we have very little information about variations in the food supply: the subject is a very important one and it is being investigated, for the North Sea, by the English Ministry of Agriculture and Fisheries. What we have to point out here, however, is that the differences in prevalent length between the plaice of a certain ground from year to year (such differences as are represented by the length-frequency distributions given in this report) *depend principally upon the composition of the shoals of fish as regards the age-groups.* This is the argument, worked out very ingeniously by Dr. Hjort, for the Norwegian cod fisheries.

Consider, first, the lengths of the plaice belonging to Age-group III (over three and under four years old) and taken in Liverpool Bay in the years 1908-15. The sexes are not separated, and the numbers of fish measured in each of the months June to November (the Roman numerals at the heads of the columns) are given separately. The mean lengths of the plaice in each month are given at the bottom of the columns, and we see that this increased from 23·0 cms. in June to 29·5 cms. in November. Thus we have a mean increase in size, during the growing season of the year, of about 7 cms. (for we must suppose that there was some growth in April and May, for which months we have no data).

Table XVIII. Lengths of Plaice of Age-group III, ♂ ♀ : Liverpool Bay, 1908-1915.

Mean Length.	VI	VII	VIII	IX	X	XI
16·5	...	...	...	...	...	...
17·5	3	...	...	1	...	...
18·5	4	4	1	...	...	...
19·5	7	6	...	1	...	...
20·5	16	2	4	1	1	1
21·5	16	5	10	1	1	...
22·5	10	11	7	7	...	...
23·5	18	10	7	11	...	1
24·5	7	9	7	8	...	...
25·5	7	9	8	6	1	...
26·5	5	7	9	10	...	4
27·5	4	6	6	4	3	...
28·5	2	4	4	5	2	1
29·5	2	1	6	3	2	3
30·5	1	...	3	2	...	3
31·5	1	...	4	4	...	1
32·5	...	...	1	1	...	2
33·5	...	...	...	...	...	1
34·5	1	...	...	...	1	...
35·5	...	...	...	1	...	1
36·5	...	...	...	1	...	1
Totals	104	74	77	67	11	19
Means	23·0	23·9	25·4	25·9	27·3	29·5

Relative abundance of Groups II and III—Liverpool Bay.

	II	III	Ratio of II to III
1908-16	3,638	442	100 : 12
1914-16	630	73	100 : 12
1920	928	802	100 : 86

Next, we take the year 1920, for which we have better data. Table 19 gives the results of measurements of plaice caught in Liverpool Bay during the months June to December, distinguishing the sexes and stating the measurements for each month separately. Also Age-groups II (over two and under three years old) and III (over three and under four) are distinguished. Now it is obvious that the data for the months June to August in the case of Age-group II are incomplete, and this is because the trawl-net employed (one of 6-inch mesh) did not sample the fish of lengths 10 to 20 adequately, many of the latter escaping through the meshes. If we had had representative samples of plaice of Age-group II of this range of lengths the mean lengths for June, July, and August would have been reliable : as it is they are not reliable and have not been stated. (This selective action of the nets used is a troublesome source of error far too frequently neglected in discussions such as this.)

Age-group III, male and female, are, however, more adequately sampled and perhaps we can depend on the mean lengths. Allowing, then, for a certain growth in May (not given in the data) we may conclude, from inspection of these tables, that the mean growth-rate for Age-group III was about 7 cms. There is no reason for supposing that there is any trustworthy evidence that plaice of Age-group III grew any faster or slower in 1920 than they did in 1908-1915. If there are distinct differences in the prevalent lengths of plaice inhabiting Liverpool Bay in the period 1908-1915 and in the year 1920 this cannot be said to be due to different rates of growth.

Composition of the Plaice Stock as regards Age-groups.

Now we consider the relative abundance of plaice belonging to Age-groups II and III in all the fish measured, from the Liverpool Bay region, in all the months, during various periods. Sex is not distinguished. We have

	Age-group II	Age-group III	Ratio of II to III
1908-1916	3,638	442	100 to 12
1914-1916	630	73	100 to 12
1920	928	802	100 to 86

All these plaice were taken in the 6-inch mesh trawl-net and so were the following ones, caught during 1909 and 1911 ; Age-group I being also included in this series of measurements :—

	Age-group I	Age-group II	Age-group III
1909	52	46	2 per 100 fish.
1911	11	68	21 „

Table XIX. Lengths of Plaice of different Ages and Sexes : Liverpool Bay, 1920.

Mean Length.	Age-group II, Male.							Age-group II, Female.						
	VI	VII	VIII	IX	X	XI	XII	VI	VII	VIII	IX	X	XI	XII
16·5	4	1	2	...	...	...	...	...	4	...	...	2	...	1
17·5	17	7	3	2	3	3	...	19	9	6	1	3	1	...
18·5	22	10	7	4	5	2	1	10	13	8	6	4	2	1
19·5	15	6	6	10	11	5	2	12	11	7	14	9	5	...
20·5	9	4	14	24	16	10	1	5	5	4	16	8	3	2
21·5	1	4	5	16	18	9	5	2	4	4	19	8	14	3
22·5	1	...	6	22	14	18	6	3	...	6	12	7	11	4
23·5	...	...	1	20	17	15	4	1	1	1	10	16	17	2
24·5	...	...	1	14	11	15	7	...	...	...	5	5	19	2
25·5	...	...	...	4	6	12	3	...	...	...	2	10	7	2
26·5	...	...	...	2	3	5	4	...	...	...	2	1	5	...
27·5	...	...	...	6	1	4	3	...	...	...	5	1	7	...
28·5	...	...	...	...	...	2	...	...	...	...	...	...	3	2
29·5	...	...	...	...	...	...	...	...	...	...	...	...	3	...
Totals ...	69	32	45	124	105	100	36	52	47	36	92	74	97	19
Means ...	...	...	...	22·5	22·1	23·2	23·6	...	...	...	21·8	22·1	23·8	22·9

Mean Length.	Age-group III, Male							Age-group III, Female.						
	VI	VII	VIII	IX	X	XI	XII	VI	VII	VIII	IX	X	XI	XII
16·5	2	...	...	...	...	...	...	...	...	...	...	...	...	...
17·5	1	3	...	...	...	...	...	2	...	...	...	...	...	...
18·5	8	5	...	...	...	...	...	7	4	...	...	1	...	...
19·5	16	4	4	...	...	1	...	7	6	1	1	1	1	...
20·5	18	7	5	...	5	1	...	14	6	1	...	1	1	1
21·1	10	5	2	8	2	...	...	8	4	3	2	1	...	...
22·5	7	7	2	2	5	2	...	13	4	...	9	4	...	...
23·5	2	18	4	4	8	3	3	5	11	3	8	5	3	1
24·5	7	14	5	11	10	4	5	3	19	4	7	3	4	4
25·5	1	8	3	11	3	7	8	...	10	7	7	3	5	2
26·5	...	9	...	19	7	8	1	...	12	1	6	4	3	2
27·5	...	10	2	11	6	11	3	...	9	2	9	8	4	...
28·5	...	8	1	2	8	6	2	...	4	2	3	5	4	5
29·5	...	5	1	1	4	10	1	...	...	1	4	1	9	2
30·5	...	3	...	...	4	5	2	...	...	3	...	5	8	7
31·5	...	...	...	4	1	4	2	...	...	...	4	1	5	2
32·5	...	...	...	4	2	...	...	...	...	...	3	...	2	1
33·5	...	...	...	...	1	...	1	...	...	...	...	...	1	...
34·5	...	...	...	...	1	...	...	...	...	...	1	1	...	...
Totals ...	72	106	29	77	67	62	28	59	89	28	64	44	50	27
Means ...	20·8	24·8	24·0	26·1	26·1	27·3	26·8	21·1	22·8	25·4	26·1	26·1	28·1	28·0

Now Fig. 18 apparently shows that the plaice caught in 1911 were markedly bigger, on the whole, than the plaice caught in 1909, and one might incautiously infer that the rate of growth was greater in 1911 than in 1909. But the comparisons of the composition of the shoals, both in the periods 1908-16, 1914-16, 1920 (Groups II and III), and in the periods 1909, 1911 (Groups I, II, and III) show clearly that the *prevalence of bigger fish in some years is due to the fact that older* (*and therefore bigger*) *fish are more abundant in those years.*

Causes of Fluctuations in Abundance and Size.

Why, then, are plaice bigger, on the whole, and on a certain ground, in one year than they are in another? It is because there are more *older* fish in the shoals in those years when the plaice run bigger, not because there is a greater rate of growth. No doubt the rate of growth varies *to some extent*, but not much —not enough, we think, to account for the differences that are to be observed from year to year.

Why are plaice more abundant on a certain ground in one year than they are in another? It is because more fish have passed successfully through the critical periods of metamorphosis and have managed to settle down on the nursery grounds, there to grow rapidly and safely. If there are more plaice of three years old on the Liverpool Bay grounds in the summer of 1920 than there were in 1919 (say) it is because more little fish came on to the nurseries in the summer of 1916. And so with each age-group.

The abundance of plaice of any particular age-group, on a fishing ground, depends, then, on a number of conditions, all of which have, by some happy chances, been in existence *and have been correlated.*

(1) There must have been, so many years previously, an unusually large production of spawn.

(2) An unusally large proportion of the larvae hatching out from this spawn must have metamorphosed successfully.

(3) The larvae must have found suitable food in the plankton on the sea area where they metamorphosed.

(4) Suitable wind-drifts, tides, etc., must have brought them to a nursery ground and not to some unsuitable part of the coast.

(5) There must have been plenty of food on the nursery, with other suitable conditions.

To test all these conditions is quite possible—and it would be the most fascinating kind of research imaginable. Just yet the resources for such investigation do not, of course, exist and so we cannot offer any data. But even the inadequate material we do have at our disposal may carry us some way and so we have prepared the following Table 20. There are marked differences between the prevalent sizes of plaice taken in the shrimp trawl-net in different years, and these we are considering. We have included all the measurements of plaice caught in hauls with such nets (of 2-inch mesh) in the months October to March of 1908-9, 1909-10, 1910-11, and so on. By October the fish have ceased to grow, and it is April of the following year before growth begins again. Therefore we can, from a study of the relative abundance of very small plaice taken during the winter months, endeavour to obtain a measure of the numbers of plaice spawned, successfully metamorphosed, and transported to the nursery grounds. Thus we have prepared Table 20 in order to make such a measure of the productivity of the various years for which we have data.

Looking at the length-frequencies recorded in Table 20 we see two kinds of distribution: that of the years 1908-9, on the one hand, and that of 1914-15, on the other. Small plaice of less than 8 cms. largely preponderate in winters of which 1908-9 is the type, while in the other kind of winter, such as those of 1915-20, the small plaice are much less frequent in the catches. It is hardly necessary to examine the small fish taken in the shrimp trawl-net in order to find what is their approximate age, for we can be pretty certain that

Table XX. Plaice caught in Shrimp Trawl-Net during Oct.-March, 1908-1920 : Mersey Area.

	1908-9.	1909-10.	1910-1.	1911-2.	1912-3.	1913-4.	1914-5.	1915-6.	1916-7.	1917-8.	1918-9.	1919-20.
4·5	253	68	271	418	17	84	20	18	5	3	...	4
5·5	1,932	695	1,116	4,766	153	588	215	89	7	247	5	24
6·5	2,333	619	956	10,676	219	828	304	85	12	528	30	55
7·5	1,762	618	524	9,423	178	553	290	46	19	545	72	80
8·5	1,365	608	514	4,900	165	264	229	49	33	258	117	95
9·5	706	401	475	1,234	200	106	456	37	6	325	169	72
10·5	294	224	235	235	461	76	480	84	38	264	205	60
11·5	148	163	311	271	603	66	726	101	71	245	207	25
12·5	119	109	220	214	505	78	1,051	83	85	243	187	21
13·5	73	94	205	124	515	41	882	81	129	168	150	23
14·5	90	98	162	52	336	40	445	130	118	133	107	23
15·5	102	79	172	74	226	22	323	135	68	55	74	18
16·5	76	78	113	73	89	26	173	103	17	45	41	2
17·5	46	65	76	40	34	19	70	95	13	6	27	9
18·5	24	34	83	20	8	11	34	61	2	1	17	3
19·5	21	24	46	17	4	8	17	43	...	4	14	7
20·5	18	22	31	7	1	9	12	16	2	1	17	...
21·5	14	15	8	7	4	5	6	28	4	3	13	...
22·5	7	8	7	4	5	1	4	18	...	1	10	...
23·5	8	4	1	7	...	...	1	5	...	1	2	...
24·5	2	9	4	6	2	1	1	5	2	...	...	...
25·5	2	1	5	3	...	1	1	2	...	1	2	...
26·5	2	...	1	...	...	1	1	1	...	...	...	...
27·5	1	...	4	2	...	...	...	...	...	1	...	...
28·5	1	...	2	1	...	...	...	...	...	...	...	...
29·5	...	...	1	1	...	...	1	...	...	...	...	...
30·5	...	...	1	1	...	...	...	...	...	...	...	...
31·5	...	...	2	2	...	...	...	...	...	...	...	...
32·5	...	...	2	...	...	...	...	...	...	...	...	...
	9,399	4,036	5,548	32,578	3,725	2,828	5,742	1,315	631	3,078	1,466	521

about 90 per cent. of all those that are less than 8 cms. in length belong to Age-group O. This arbitrary limit has therefore been taken in Table 20, and the proportions of plaice of less than 8 cms. long have been calculated and regarded as giving us a good idea of the relative abundance of young fish resulting from the spawning of the months March and April immediately before. In this way Fig. 20 has been made.

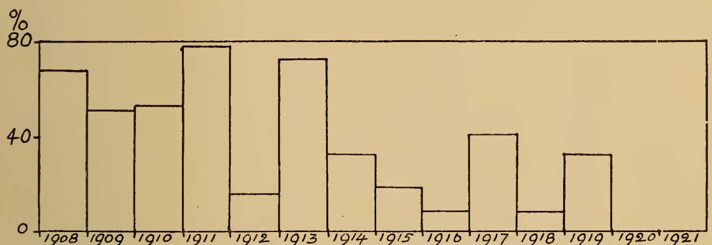


Fig. 20. Graph showing the productivity of the spawning seasons during the years 1908-19. The heights of the rectangles are proportional to the numbers of plaice larvae reaching the nursery grounds.

We see that 1908-11 and 1913 were good years in that large numbers of young plaice came on to the nursery grounds. The years 1912, 1916, and 1918 were bad ones—years in which there was an unusually small production of young plaice.

It would be unprofitable to pursue this matter further, for hardly any data exist, just yet, which would enable us to look for the reasons why some years are better than others.

Tables 21 to 27 now follow: these give the results of measurements of plaice made in the Irish Sea during the year 1920, and they are intended to provide the data for more minute comparisons with the pre-war period than we have now the opportunity to undertake.

Table XXI. June, 1920, Irish Sea: Plaice taken in Fish Trawl.

Mean Length.	Inshore Grounds.								Offshore Grounds.	
	Liverpool Bay.		Mersey Estuary.		North Wales.		Carnarvon Bay.		VIa, VIb.	
	f	f °/oo	f	f °/oo	f	f °/oo	f	f °/oo	f	f °/oo
10·5	...	...	...	...	...	...	...	...	...	...
11·5	...	...	...	...	...	...	...	...	...	...
12·5	...	...	4	3·3	...	...	...	...	...	...
13·5	...	...	19	15·5	...	...	...	...	1	2·4
14·5	...	...	70	57·1	1	4	1	9·8	...	...
15·5	11	12·5	164	134·0	1	4	2	19·6	1	2·4
16·5	24	27·3	189	154·2	3	12	5	49·0	3	7·2
17·5	119	135·4	186	151·7	9	36	1	9·8	3	7·2
18·5	170	193·4	196	159·9	21	84	1	9·8	12	28·8
19·5	166	188·8	128	104·4	18	72	4	39·2	6	14·4
20·5	145	165·0	84	68·5	31	124	5	49·0	6	14·4
21·5	81	92·1	53	43·2	30	120	7	68·6	10	24·0
22·5	48	54·6	46	37·5	19	76	7	68·6	16	38·1
23·5	45	51·2	23	18·8	17	68	12	117·6	15	35·9
24·5	30	34·1	25	20·4	17	68	10	98·0	15	35·9
25·5	16	18·2	15	12·2	17	68	8	78·4	22	52·8
26·5	9	10·2	10	8·1	10	40	12	117·6	28	67·1
27·5	1	1·1	3	2·4	10	40	12	117·6	40	95·9
28·5	3	3·4	6	4·9	10	40	7	68·6	32	76·7
29·5	2	2·3	2	1·6	7	28	1	9·8	37	88·7
30·5	...	...	...	...	6	24	3	29·4	35	83·9
31·5	2	2·3	...	...	4	16	1	9·8	23	55·2
32·5	...	...	...	...	3	12	...	...	30	71·9
33·5	...	...	...	...	4	16	...	...	21	50·4
34·5	...	...	...	...	2	8	...	...	14	33·6
35·5	2	2·3	...	...	1	4	1	9·8	15	35·9
36·5	1	1·1	...	...	1	4	1	9·8	11	26·4
37·5	...	...	...	...	1	4	...	...	5	12·0
38·5	...	...	...	...	1	4	...	...	8	19·2
39·5	2	2·3	...	...	1	4	...	...	4	9·6
40·5	...	...	...	...	1	4	...	...	1	2·4
41·5	1	1·1	1	0·8	...	...	...	...	2	4·8
42·5	1	1·1	1	0·8	1	4	1	9·8	1	2·4
43·5	...	...	...	...	...	...	...	...	...	...
44·5	...	...	...	...	...	...	...	...	...	...
45·5	...	...	...	...	...	...	...	...	...	...
46·5	...	...	...	...	...	...	...	...	...	...
47·5	...	...	...	...	3	12	...	...	...	...
48·5	...	...	...	...	...	...	...	...	...	...
49·5	...	...	...	...	...	...	...	...	...	...
50·5	...	...	...	...	...	...	...	...	...	...
51·5	...	...	...	...	...	...	...	...	...	...
	879	999·8	1,225	999·3	250	1,000	102	999·6	417	999·6

Table XXII. July, 1920, Irish Sea: Plaice taken in Fish Trawl.

Mean Length.	Inshore Grounds.								Offshore Grounds.	
	Liverpool Bay.		Mersey Estuary.		North Wales.		Carnarvon Bay.		VII.	
	f	*f* ‰	*f*	*f* ‰	*f*	*f* ‰	*f*	*f* ‰	*f*	*f* ‰
10·5	...	...	...	...	...	...	...	...	...	...
11·5	...	...	...	...	...	...	...	...	...	...
12·5	...	...	...	...	...	...	...	...	...	...
13·5	...	...	7	5·7	...	...	...	...	...	...
14·5	...	...	35	28·6	4	3·2	...	...	...	...
15·5	...	...	102	83·4	2	1·6	...	...	...	...
16·5	1	1·8	144	117·7	17	13·4	...	...	1	0·8
17·5	8	14·7	187	152·9	51	40·3	1	5·4	6	4·5
18·5	52	95·8	140	114·5	86	67·9	...	...	25	18·8
19·5	67	123·4	83	67·9	123	97·2	1	5·4	49	36·8
20·5	39	71·8	65	53·1	117	92·4	2	10·8	100	75·0
21·5	33	60·8	54	44·1	112	88·5	3	16·2	135	101·2
22·5	20	36·8	51	41·7	95	75·0	9	48·6	145	108·8
23·5	25	46·0	44	36·0	118	93·2	11	59·4	160	120·0
24·5	37	68·1	61	49·9	125	98·7	19	102·7	108	81·0
25·5	44	81·0	39	31·9	110	86·9	16	86·5	126	94·5
26·5	39	71·8	42	34·3	83	65·6	23	124·3	78	58·5
27·5	51	93·9	20	16·3	59	46·6	25	135·1	84	63·0
28·5	38	70·0	25	20·4	41	32·4	16	86·5	67	50·3
29·5	32	58·9	29	23·7	41	32·4	33	178·4	53	39·8
30·5	16	29·5	19	15·5	25	19·7	11	59·4	47	35·3
31·5	14	25·8	8	6·5	10	7·9	8	43·2	32	24·0
32·5	5	9·2	12	9·8	9	7·1	3	16·2	39	29·3
33·5	8	14·7	7	5·7	7	5·5	2	10·8	29	21·8
34·5	7	12·9	5	4·1	12	9·5	2	10·8	17	12·8
35·5	2	3·7	8	6·5	8	6·3	...	...	19	14·3
36·5	2	3·7	9	7·4	6	4·7	...	...	6	4·5
37·5	1	1·8	4	3·3	4	3·2	...	...	1	0·8
38·5	1	1·8	3	2·4	...	...	...	...	1	0·8
39·5	...	...	1	0·8	...	...	...	...	2	1·5
40·5	...	...	7	5·7	...	...	...	...	1	0·8
41·5	...	...	5	4·1	...	...	...	...	1	0·8
42·5	1	1·8	2	1·6	...	...	...	...	...	...
43·5	...	...	1	0·8	1	0·8	...	...	...	...
44·5	...	...	2	1·6	...	...	...	...	...	...
45·5	...	...	...	...	...	...	...	...	...	...
46·5	...	...	...	...	...	...	...	...	...	...
47·5	...	...	1	0·8	...	...	...	...	...	...
48·5	...	...	1	0·8	...	...	...	...	...	...
49·5	...	...	...	...	...	...	...	...	1	0·8
50·5	...	...	...	...	...	...	...	...	...	...
51·5	...	...	...	...	...	...	...	...	...	...
	543	999·7	1,223	998·5	1,266	1000·0	185	999·7	1,333	1000·5

Table XXIII. August, 1920, Irish Sea : Plaice taken in Fish Trawl.

Mean Length.	Inshore Grounds.								Offshore Grounds.			
	Liverpool Bay.		Mersey Estuary.		North Wales.		Carnarvon Bay.		$VIII_{22}$.		$VIII_{54}$.	
	f	f °/oo	f	f °/oo	f	f °/oo	f	f °/oo	f	f °/oo	f	f °/o
10·5	...	...	...	...	...	...	...	...	...	...	...	...
11·5	...	...	...	...	...	...	...	...	...	...	...	...
12·5	...	...	...	...	...	...	...	...	...	...	...	...
13·5	...	...	7	5·4	...	...	...	...	...	...	...	...
14·5	...	...	37	28·8	1	1·2	...	...	...	...	...	...
15·5	1	0·8	147	114·3	...	...	2	100	...	...	...	...
16·5	9	7·3	163	126·7	...	...	2	100	...	...	...	...
17·5	39	31·7	133	103·4	7	8·5	4	200	2	2·8	...	...
18·5	102	83·0	122	94·9	45	54·9	2	100	15	20·5	...	...
19·5	123	100·0	117	91·0	95	115·9	3	150	27	37·7	...	...
20·5	162	131·8	71	55·2	99	120·7	1	50	53	74·1	26	...
21·5	138	112·2	82	63·9	79	96·3	2	100	64	89·5	51	...
22·5	108	87·9	59	45·9	69	84·1	2	100	62	86·7	80	...
23·5	110	89·5	40	31·1	77	94·0	1	50	63	88·1	94	...
24·5	87	70·8	54	42·0	58	70·7	1	50	56	78·3	92	...
25·5	73	59·4	37	28·8	53	64·6	...	...	69	96·5	105	...
26·5	55	44·8	34	26·4	45	54·9	...	...	51	71·3	97	...
27·5	49	39·9	34	26·4	30	36·5	...	...	61	85·3	87	...
28·5	57	46·4	42	32·6	37	45·1	...	...	42	58·7	94	...
29·5	38	30·9	26	20·2	36	43·9	...	...	34	47·6	65	...
30·5	31	25·2	16	12·4	20	24·4	...	...	26	36·4	52	...
31·5	20	16·3	25	19·4	20	24·4	...	...	12	16·8	27	...
32·5	9	7·3	10	7·8	12	14·6	...	...	15	20·5	14	...
33·5	7	5·7	12	9·3	13	15·8	...	...	11	15·4	15	...
34·5	4	3·3	6	4·6	4	4·9	...	...	7	9·8	10	...
35·5	3	2·4	1	0·8	7	8·5	...	...	8	11·2	1	...
36·5	1	0·8	3	2·3	7	8·5	...	...	16	22·4	4	...
37·5	1	0·8	1	0·8	3	3·6	...	...	6	8·4	1	...
38·5	2	1·6	4	3·1	1	1·2	...	...	2	2·8	1	...
39·5	...	...	...	...	1	1·2	...	...	3	4·2	1	...
40·5	...	...	1	0·8	...	...	...	...	3	4·2	...	...
41·5	...	...	1	0·8	1	1·2	...	...	1	1·4	...	...
42·5	...	...	...	...	...	...	...	...	4	5·6	1	...
43·5	...	...	...	...	...	...	...	...	1	1·4	1	...
44·5	...	...	...	...	...	...	...	...	1	1·4	...	...
45·5	...	...	...	...	...	...	...	...	...	...	...	...
46·5	...	...	...	...	...	...	...	...	...	...	...	...
47·5	...	...	1	0·8	...	...	...	...	...	...	...	...
48·5	...	...	...	...	...	...	...	...	...	...	...	...
49·5	...	...	...	...	...	...	...	...	...	...	...	...
50·5	...	...	...	...	...	...	...	...	...	...	...	...
51·5	...	...	...	...	...	...	...	...	...	...	...	...
	1,229	999·8	1,286	999·9	820	999·6	20	1,000	715	999·0	919	...

Table XXIV. September, 1920, Irish Sea : Plaice taken in Fish Trawl.

Mean Length.	Inshore Grounds.									
	Liverpool Bay.		Mersey Estuary.		North Wales.		IXa.		IXb.	
	f	f °/oo	f	f °/oo	f	f °/oo	f	f °/oo	f	f °/oo
10·5	...	...	...	...	...	...	...	...	1	0·6
11·5	...	...	...	...	...	...	1	1·8	3	1·8
12·5	...	...	...	...	...	...	10	18·0	1	0·6
13·5	...	...	...	...	...	...	25	45·1	4	2·5
14·5	2	0·9	5	6·7	...	...	29	52·3	10	6·1
15·5	10	4·7	10	13·3	...	...	31	56·0	18	11·0
16·5	6	2·8	26	34·7	...	...	29	52·3	4	2·5
17·5	37	17·4	46	61·4	...	...	46	82·8	45	27·6
18·5	74	34·7	43	57·4	6	27·0	49	88·4	111	67·5
19·5	139	65·2	58	77·4	11	49·5	59	106·5	178	109·2
20·5	203	95·3	70	93·5	24	108·1	87	157·0	200	122·7
21·5	246	115·4	64	85·5	23	103·6	58	104·6	179	109·8
22·5	274	128·6	77	102·8	21	94·6	26	46·9	151	92·6
23·5	239	112·2	56	74·8	17	76·6	28	50·5	100	61·3
24·5	191	89·6	56	74·8	17	76·6	9	16·2	78	47·9
25·5	154	72·3	48	64·1	15	67·6	18	32·5	63	38·7
26·5	114	53·5	31	41·4	22	99·1	17	30·7	51	31·3
27·5	90	42·2	33	44·1	17	76·6	12	21·7	54	33·1
28·5	96	45·0	34	45·4	12	54·0	7	12·6	40	24·5
29·5	75	35·2	26	34·7	15	67·6	5	9·0	46	28·2
30·5	51	23·9	14	18·7	11	49·5	3	5·4	42	25·8
31·5	37	17·4	7	9·3	4	18·0	3	5·4	49	30·1
32·5	28	13·1	11	14·7	2	9·0	...	...	33	20·2
33·5	37	17·4	9	12·0	2	9·0	...	...	46	28·2
34·5	14	6·6	10	13·3	2	9·0	2	3·6	33	20·2
35·5	5	2·3	3	4·0	...	...	...	...	30	18·4
36·5	5	2·3	1	1·3	1	4·5	...	...	14	8·6
37·5	1	0·5	4	5·3	...	...	...	...	18	11·0
38·5	1	0·5	1	1·3	...	...	...	...	13	8·0
39·5	...	...	2	2·6	...	...	...	...	5	3·1
40·5	...	...	1	1·3	...	...	...	...	2	1·2
41·5	1	0·5	...	...	...	...	...	...	3	1·8
42·5	...	...	1	1·3	...	...	...	...	...	...
43·5	...	...	1	1·3	...	...	...	...	...	...
44·5	...	...	...	...	...	...	...	...	1	0·6
45·5	...	...	1	1·3	...	...	...	...	3	1·8
46·5	...	...	...	...	...	...	...	...	...	...
47·5	1	0·5	...	...	...	...	...	...	...	...
48·5	...	...	...	...	...	...	...	...	...	...
49·5	...	...	...	...	...	...	...	...	...	...
50·5	...	...	...	...	...	...	...	...	1	0·6
51·5	...	...	...	...	...	...	...	...	...	...
	2,131	1000·0	749	999·7	222	999·9	554	999·3	1,630	999·1

Table XXIV—*Continued.*

Mean Length.	Offshore Grounds.									
	IXc.		IXd.		IX_{34}.		IX_{35}.		IX_{13}.	
	f	*f* °/oo	*f*	*f* °/oo	*f*	*f* °/oo	*f*	*f* °/oo	*f*	*f* °/oo
10·5	...	...	...	...	...	...	...	...	...	...
11·5	...	...	...	...	...	...	...	...	...	...
12·5	...	...	...	...	...	...	...	...	...	...
13·5	...	...	...	...	...	...	...	...	...	...
14·5	...	...	...	...	...	...	...	...	...	...
15·5	...	...	...	...	...	...	...	...	...	...
16·5	...	...	...	...	...	...	...	...	...	...
17·5	...	...	8	10·0	2	3·5	...	...	...	...
18·5	...	...	29	36·3	1	1·7	2	5·7	1	1·9
19·5	1	52·6	57	71·3	6	10·4	7	20·4	8	15·5
20·5	3	157·9	59	73·8	18	31·3	21	60·3	21	40·8
21·5	1	52·6	69	86·3	31	53·9	37	106·3	45	87·4
22·5	2	105·3	74	92·5	51	88·7	22	63·2	63	122·3
23·5	2	105·3	59	72·8	41	71·3	20	57·5	81	157·3
24·5	3	157·9	74	92·5	52	90·4	22	63·2	74	143·7
25·5	1	52·6	56	70·0	47	81·7	29	83·3	51	99·0
26·5	...	...	55	68·7	61	106·1	29	83·3	60	116·5
27·5	...	...	63	78·9	58	100·9	32	92·0	46	89·3
28·5	...	...	47	58·8	62	107·8	30	86·2	25	48·5
29·5	3	157·9	43	53·7	45	78·2	16	46·0	16	31·1
30·5	2	105·3	36	45·0	43	74·8	21	60·3	14	27·2
31·5	1	52·6	27	33·7	23	40·0	18	51·7	3	5·8
32·5	...	...	25	31·3	20	34·8	15	43·1	2	3·8
33·5	...	...	9	11·3	6	10·4	7	20·1	3	5·8
34·5	...	...	8	10·0	4	7·0	9	25·9	1	1·9
35·5	...	...	1	1·3	2	3·5	3	8 6	...	...
36·5	...	...	1	1·3	1	1·7	3	8·6	...	...
37·5	...	...	...	...	...	...	2	5·7	...	...
38·5	...	...	...	...	...	...	3	8·6	...	...
39·5	...	...	...	...	...	...	...	...	1	1·9
40·5	...	...	...	...	...	...	...	...	...	...
41·5	...	...	...	...	...	...	...	...	...	...
42·5	...	...	...	...	...	...	...	...	...	...
43·5	...	...	...	...	1	1·7	...	...	...	...
44·5	...	...	...	...	...	...	...	...	...	...
45·5	...	...	...	...	...	...	...	...	...	...
46·5	...	...	...	...	...	...	...	...	...	...
47·5	...	...	...	...	...	...	...	...	...	...
48·5	...	...	...	...	...	...	...	...	...	...
49·5	...	...	...	...	...	...	...	...	...	...
50·5	...	...	...	...	...	...	...	...	...	...
51·5	...	...	...	...	...	...	...	...	...	...
	19	1000·0	800	1000·5	575	999·8	348	999·7	515	999·7

Table XXV. October, 1920, Irish Sea : Plaice measured.

Mean Length.	Liverpool Bay.		Mersey Estuary.		North Wales.	
	f	f °/oo	f	f °/oo	f	f °/oo
10·5	...	...	...	...	...	...
11·5	...	...	...	...	...	...
12·5	...	...	13	7·7	...	...
13·5	...	...	7	4·2	1	1·3
14·5	...	...	86	51·2	...	...
15·5	...	...	256	153·1	1	1·3
16·5	...	...	281	167·9	8	10·5
17·5	3	5·0	165	98·7	19	24·8
18·5	6	9·9	142	84·9	62	81·0
19·5	19	31·4	132	78·9	125	163·4
20·5	29	47·9	95	56·8	74	96·7
21·5	51	84·3	96	57·4	80	104·6
22·5	65	107·4	89	53·2	41	53.6
23·5	67	110·8	45	26·9	49	64·0
24·5	81	133·9	51	30·5	38	49·7
25·5	64	105·7	45	26·9	47	61·4
26·5	47	77·7	22	13·1	53	69·3
27·5	35	57·9	27	16·1	41	53·6
28·5	32	52·9	25	15·0	36	47·0
29·5	22	36·4	23	13·8	33	43·1
30·5	19	31·4	22	13·1	15	19·6
31·5	32	52·9	16	9·6	8	10·5
32·5	9	14·9	10	6·0	11	14·4
33·5	11	18·2	10	6·0	7	9·1
34·5	4	6·6	6	3·6	4	5·2
35·5	3	5·0	3	1·8	8	10·5
36·5	2	3·3	3	1·8	3	3·9
37·5	3	5·0	...	...	1	1·3
38·5	...	...	...	...	...	...
39·5	1	1·7	1	0·6	...	...
40·5	...	...	1	0·6	...	...
41·5	...	...	...	...	...	...
42·5	...	...	...	...	...	...
43·5	...	...	...	...	...	...
44·5	...	...	...	...	...	...
45·5	...	...	...	...	...	...
46·5	...	...	...	...	...	...
47·5	...	...	...	...	...	...
48·5	...	...	...	...	...	...
49·5	...	...	...	...	...	...
50·5	...	...	...	...	...	...
	605	1000·2	1,672	999·4	765	999·8

Table XXVI. November, 1920, Irish Sea : Plaice measured.

Mean Length.	Inshore Grounds.								Offshore Grounds.	
	Liverpool Bay.		Mersey Estuary.		North Wales.		Solway Firth.		XI_{94}.	
	f	f °/oo	f	f °/oo	f	f °/oo	f	f °/oo	f	f °/oo
10·5	...	...	...	...	...	...	...	...	...	...
11·5	...	...	...	...	...	...	...	...	...	...
12·5	...	...	...	...	...	...	1	0·5	4	1·2
13·5	...	...	...	...	...	...	23	12·3	16	4·7
14·5	...	...	...	...	1	1·8	49	26·3	21	6·2
15·5	...	...	...	...	1	1·8	161	86·4	24	7·1
16·5	2	0·9	...	...	1	1·8	282	151·4	31	9·2
17·5	18	7·9	1	15·4	12	21·1	272	146·0	29	8·6
18·5	60	26·4	1	15·4	22	40·1	184	98·7	55	16·3
19·5	111	48·8	4	61·5	44	80·3	202	108·4	82	24·3
20·5	167	73·4	...	...	48	87·6	144	77·3	93	27·5
21·5	222	97·6	6	92·3	49	89·4	145	77·8	149	44·1
22·5	255	112·1	4	61·5	55	100·4	106	56·9	212	62·7
23·5	294	129·2	3	46·1	26	47·4	100	53·7	283	83·8
24·5	290	127·4	3	46·1	35	63·9	71	38·1	327	96·8
25·5	236	103·7	11	169·2	36	65·7	43	23·1	352	104·2
26·5	143	62·9	2	30·7	31	56·6	16	8·6	322	95·3
27·5	100	44·0	3	46·1	31	56·6	14	7·5	280	82·9
28·5	93	40·9	3	46·1	29	53·0	18	9·7	225	66·6
29·5	82	36·0	7	107·7	24	43·8	7	3·8	210	62·1
30·5	59	25·9	4	61·5	19	34·7	4	2·1	181	53·6
31·5	40	17·6	3	46·1	10	18·0	6	3·2	126	37·3
32·5	36	15·8	...	...	15	27·4	1	0·5	92	27·2
33·5	30	13·1	2	30·7	16	29·2	4	2·1	77	22·8
34·5	7	3·1	1	15·4	4	7·3	2	1·1	57	16·9
35·5	19	8·3	1	15·4	7	12·8	2	1·1	50	14·8
36·5	2	0·9	...	...	7	12·8	3	1·6	35	10·3
37·5	2	0·9	1	15·4	5	9·1	...	...	16	4·7
38·5	1	0·4	2	30·7	5	9·1	2	1·1	12	3·6
39·5	...	...	...	...	3	5·5	1	0·5	6	1·8
40·5	...	...	1	15·4	4	7·3	...	...	5	1·5
41·5	1	0·4	1	15·4	1	1·8	...	...	2	0·6
42·5	1	0·4	...	...	4	7·3	...	...	1	0·3
43·5	4	1·8	...	...	1	1·8	...	...	1	0·3
44·5	...	...	...	...	...	...	...	...	1	0·3
45·5	...	...	...	...	2	3·7	...	...	1	0·3
46·5	...	...	...	...	...	...	...	...	...	...
47·5	...	...	1	15·4	...	...	...	...	...	...
48·5	...	...	...	...	...	...	...	...	1	0·3
49·5	...	...	...	...	...	...	...	...	...	...
	2,275	999·8	65	999·5	548	999·1	1,863	999·8	3,379	1000·2

Table XXVII. December, 1920, Irish Sea: Plaice measured.

Mean Length.	Liverpool Bay.		Mersey Estuary.		North Wales.		Solway Firth.	
	f	f °/oo	f	f °/oo	f	f °/oo	f	f °/oo
10·5	...	...	...	...	...	...	2	1·9
11·5	...	...	...	...	...	...	8	7·7
12·5	...	...	...	...	...	...	42	40·2
13·5	...	...	...	...	...	...	76	72·8
14·5	...	...	...	...	2	1·6	128	122·6
15·5	...	...	...	...	...	...	152	145·6
16·5	...	...	...	...	...	...	182	174·3
17·5	1	2·6	1	...	10	8·0	129	123·5
18·5	1	2·6	...	...	27	21·6	87	83·3
19·5	6	15·6	...	...	29	23·1	73	69·9
20·5	8	20·8	...	...	42	33·5	59	56·5
21·5	12	31·3	...	...	40	31·9	40	38·3
22·5	16	41·7	...	...	44	35·1	30	28·7
23·5	32	83·3	...	...	62	49·5	11	10·5
24·5	32	83·3	...	...	58	46·3	15	14·4
25·5	56	145·8	...	...	70	56·0	4	3·8
26·5	61	158·8	...	...	75	59·9	4	3·8
27·5	33	85·9	...	...	113	90·2	...	...
28·5	31	80·7	...	...	108	86·2	1	1·0
29·5	26	67·7	...	...	113	90·2	...	...
30·5	16	41·7	...	...	105	83·9	...	...
31·5	22	57·3	...	...	82	65·5	...	...
32·5	13	33·8	...	...	59	47·1	1	1·0
33·5	6	15·6	...	...	54	43·1	...	...
34·5	5	13·0	...	...	35	27·9	...	...
35·5	3	7·8	...	...	32	25·6	...	...
36·5	1	2·6	...	...	18	14·4	...	...
37·5	2	5·2	...	...	12	9·6	...	...
38·5	...	...	...	...	8	6·4	...	...
39·5	...	...	...	...	9	7·2	...	...
40·5	...	...	...	...	7	5·6	...	...
41·5	1	2·6	...	...	3	2·4	...	...
42·5	...	...	...	...	6	4·8	...	...
43·5	...	...	...	...	7	5·6	...	...
44·5	...	...	...	...	4	3·2	...	...
46·5	...	...	...	...	1	0·8	...	...
47·5	...	...	...	...	2	1·6	...	...
48·5	...	...	...	...	3	2·4	...	...
49·5	...	...	...	...	6	4·8	...	...
50·5	...	...	...	...	3	2·4	...	...
51·5	...	...	...	...	1	0·8	...	...
52·5	...	...	...	...	2	1·6	...	...
	384	999·7	...	...	1,252	999·8	1,044	999·8

The Effect of the War Restrictions on the Fisheries.

It will be seen, then, that the results of the Irish Sea investigations give little evidence that the restrictions that were in operation during the years 1915-18 had any very marked effect. Now we must not assert this conclusion as holding for any other fishing region than that studied here: There is evidence that the war restrictions had an effect in the North Sea—although this evidence is not entirely convincing. So far as it goes, however, it suggests that during those years in which the ordinary intensity of fishing (that characteristic of the pre-war years) was in operation, there was a gradual falling off of the quantities of plaice landed, as well as in the average quantities caught per day's fishing. This decline persisted throughout the years 1908 to about 1914. Then followed about five years during which the existence of mine-fields, and other conditions, greatly reduced the area over which steam trawlers and smacks could fish. When it became possible to resume trawling on a scale comparable with that of the pre-war years it was seen that the quantities of plaice landed per day's fishing had increased. At the same time measurements made at sea aboard the fishing vessels showed that the plaice were, on the average, markedly bigger than they were in, say, the year 1913. The natural conclusion was that the reduced fishing in 1914-1918 had allowed the plaice, that would otherwise have been caught, the opportunity to live and grow. In 1919, therefore, there was an " accumulated stock " on the North Sea grounds, the results of a period of " protection."

Now when the same argument is applied to the Irish Sea grounds the same conclusion follows. There was evidence of a decrease in the abundance of plaice during the pre-war years and there was a marked restriction in the intensity of fishing during the war years. In 1920 the size of plaice had increased, and, on the whole, better catches seem to have been made. *But* the evidence brought forward in this report also shows, we hold, that this variability in the size and abundance of the plaice inhabiting the Irish Sea is something that happens, " of itself," that is, quite apart from the influence of the fishing fleets. Throughout the period 1892-1920 there is good evidence of a natural fluctuation in the abundance of plaice, some series of years being very good, while others are relatively very bad. The evidence we refer to is all experimental, but it is backed up by what we do know about the fluctuations in the quantities of plaice landed by the steam vessels and other trawlers working in the Irish Sea area. Further, the conditions in the English Channel seem to resemble those obtaining in the Irish Sea.

If there had been no war, and no restrictions on fishing in the Irish Sea, the result to have been expected would have been just that which we actually observe—the progress of a natural fluctuation in the abundance of plaice. If only the measurements and other data which we give here, or which are otherwise obtainable, were at our disposal, *and no knowledge that there had been a state of war* during the years 1914-1918, we should have been quite unable to deduce the latter. All we should have known would have been that, for some reason or other, vessels did not go to sea so frequently in 1914-8 as they did in the year previous to 1914.

These results obtained from a study of the West Coast fisheries naturally make us cautious in accepting, without reservation, the conclusion that the effect of the war restrictions was an increase in the stock of plaice inhabiting the North Sea. The natural fluctuation which, we believe, characterised the Irish Sea during the years 1892-1920 may, quite reasonably, be supposed to have characterised the North Sea also : it is to be noted that the statistical information relative to the latter area is very defective for the years before 1908, and between that and 1914 is only a very short period. The conditions, then, that have been observed in the North Sea are consistent with the belief in a natural fluctuation as capable of explaining, *to a certain extent*, the variability, from year to year, in the productivity of the fishery.

"To a certain extent" only, we may add. Probably the Irish Sea is a more productive area, as far as plaice is concerned, than the North Sea. The "productivity" depends on the existence of the shallow-water nurseries. Just because the area of such grounds is greater in the Irish Sea, relative to the total area of sea, so we expect a greater production of plaice. Probably the exploitation of the North Sea, that is, the amount of trawling per square mile, per year, is greater than it is in the Irish Sea. If that is so then the natural fluctuations that we are assuming would be more easily noticeable in the eastern than in the western region, particularly if, as may be assumed, the exploitation in the North Sea is pressing closely on the recuperative power of the nurseries.

It is quite unlikely that the data exist which would enable us to answer the questions suggested above. The fishery statistics are too imperfect prior to 1908; the work of comparison of the productivity of the fishing grounds before and immediately after the cessation of war was not thorough enough, in any British fishing ground; we have no available knowledge of the extent to which military restrictions actually prevented fishing in the various regions; no detailed classification of the "plaice fishing grounds" that is of much use, and, of course, not nearly enough knowledge of the life-history of our species of fish. It is regrettable that the opportunity for studying the very remarkable conditions that the war-restrictions afforded was not taken full advantage of in 1918 and 1919 by any European fishery authority.

PART IV.

Practical Administrative Questions.

One reason why these researches were undertaken was to provide information that would be of use to the administrators. It was assumed, to begin with, that there might be an impoverishment of the Irish Sea plaice fisheries, and that something might have to be done to arrest this. In the past that "something" has generally been a legislative restriction or prohibition—that is, the fishermen have been forbidden to do this or that at one time or another and have been prosecuted when they insisted on doing whatever was forbidden by by-laws or statutes. Lately, the tendency has been towards constructive administration—scientific research, the dissemination of intelligence or the promotion of schemes of development, but so little successful has this kind of work been in England, that it may be regarded as rather alien to the traditions (such as they are) of fishery administration. Here, therefore, we are obliged to suggest in what directions the results of investigation point—those directions being assumed to be restrictions of one kind or other. We assume that such questions as these are being discussed—the prohibition of fishing in certain places or at certain times; size-limits below which plaice may not be legally captured or landed; prohibitions or restrictions of the operations of vessels propelled by steam or internal combustion engines; restrictions on the dimensions and forms of trawl, or other kinds of nets, etc. Now a full discussion of such measures can only be attempted when there are definite proposals, and so we can only indicate, in the most general kind of way, how the data summarised in this respect are to be used. We begin with the question—*Is* there an impoverishment of the Irish Sea plaice grounds?

The Productivity of the Fisheries.

By "productivity" we mean the total quantity of plaice which grow up, in a definite region, to a certain size, in a certain period of time. It is necessary to specify the size because it is only when the fish become so large that they become commercially valuable, and so become commodities. That means that the idea of productivity must necessarily include the idea of commercial profit.

Suppose that plaice only become commercially valuable when they have attained the size of about 20 cms., and the age of about three years. To convert a hundredweight of 13 cm. plaice into 2 cwts. of 20 cm. plaice will require a certain quantity of production in the sea and this will be much the same as the production necessary to convert 1 cwt. of 20 cm. plaice into 2 cwts. of 25 cm. plaice. Yet the latter production will have more commercial significance than the former quantity because 25 cm. plaice have more value, as commodities, than 20 cm. plaice have. Production, in the scientific sense, means the origin in the sea of plaice substance but, in the commercial sense, it means the origin of plaice of the range of size that sells in the markets. What the industry want is plaice of this range of sizes and if such fish decrease in numbers the "productivity" of a fishery region decreases.

The Rate of Exploitation.

The total quantity of plaice that are landed annually depends not only on the productivity of the region in question, but on the degree to which it is fished. If there is an increase in the catching power there will generally be a corresponding increase in the quantity of fish landed. To find whether or not there is any change in a fishing region we require to know whether there has been any change in the catching power employed, and this is always a very difficult question. Plaice are caught by steam vessels, motor boats, smacks and half-decked sailing vessels; by trawl-nets, seine-nets, stake-nets, trammels, etc., and so we must have some idea what all this variety of catching power means when it is reduced to a "common denominator." A steam trawler will catch more fish per day than a smack and a smack will catch more than a half-decked sailing boat. But does the steam trawler catch more fish per unit of man-power, or per £ invested in her maintenance than does a smack? And which rate—the rate of catch per day, or per man, or per £ ought we to adopt?

The ratio of steam vessels to smacks that work on a certain fishing ground is not always the same and we cannot, usually, neglect the fishing by half-decked sailing vessels and motor-boats. What, then, is to be the "common denominator"? We may calculate how many small trawlers are equal in catching power to one smack, and then how many smacks equal one steam trawler. Thus we can express the catching power in ideal vessels, or "fishing units," or we might try to calculate the number of hauls made per week or day and then, knowing the average size of the trawl-nets used, calculate the number of square miles of sea bottom swept per day. Any sort of calculation made in these ways would be a rough one since we have not much exact knowledge of the conditions. In practice, what is done is generally to calculate the average quantities of plaice caught, per day's absence from port, of an average steam trawler or smack. If this decreases we say that the productivity of the fishing grounds worked also decreases—noting all the while that our quantity of fish caught is fish of a certain, chosen range of sizes. Obviously the results are rough ones in any case and too much strain must not be put on them. Whatever changes in the results of fishing we observe must be big enough to be much the same (that is, to show much the same tendencies) in whatever way we estimate the change in catching power. Thus the quantity of plaice annually landed in England, from the North Sea grounds, diminished from 1908 to 1913, and so did the average quantity of plaice caught per day's absence from port of the average steam trawler.

Of course the whole question is a rather academic one: what the owner of a steam trawler has to consider is the average cost of catching the average cwt. of fish and then the average price obtained when it is sold.

The Impoverishment of a Fishery Region.

For the moment we deal with plaice of a definite range of size—say, 20 to 25 cms. (small plaice). Suppose that the productivity of a certain fishing region is "indefinitely great," no matter how many plaice are caught there would still be plenty left—that would be what we mean by "indefinitely great." So many small plaice are produced that a certain fraction must die from want of food: now if, say, 1/10th are caught by the fishermen that would mean that about the same number would not die, but would survive to take the place of those that had been caught. Probably some localised fishing regions are like this—they are "overcrowded" grounds. On the whole, however, such an area as the Irish Sea is not an overcrowded one, where the productivity is indefinitely great, for the fact that the abundance of plaice undergoes periodic changes shows *either* that the quantity of plaice food changes, *or* that the quantity of baby plaice spawned, hatched, and transformed changes. Probably the latter is the case.

Has there been an Impoverishment of the Irish Sea Plaice Grounds?

To answer this question we have to consider both the commercial statistics and the results of experimental trawlings. The quantity of plaice landed from year to year depends on the catching power *and* the natural productivity of the grounds. The statistics of catching power are not very accessible (if they exist), but it is probably the case that it has not decreased of late (except during the war years). The number of steam vessels working from Fleetwood has increased, and though most of these vessels fish outside the Irish Sea region it is likely that much about the same fraction of all of them trawl on these grounds each year. The number of smacks working from Fleetwood and Hoylake has steadily decreased since about 1890, and there are no indications that the number of half-decked sailing boats has increased. But the increase in number of the steamers probably makes up for the decrease in the smacks and the decrease ("if any") in the small boats. Probably, then, the catching power is approximately uniform or has increased.

So far as the commercial statistics go they show that there are marked ups and downs in the quantities of plaice landed from the Irish Sea. There was a maximum in 1911, a minimum about 1915, and another maximum about 1920. Thus there is no definite tendency one way or the other, so far as these data enable us to discuss the question.

So far as the experimental trawlings go the same conclusion is to be made. There are ups and downs, and these are nearly the same as the changes revealed by the commercial statistics. In fact these two series of data support each other to a certain extent and indicate that there have been actual changes in the natural productivity of the Irish Sea grounds during the period 1908-1920.

When we deal with the measurements of lengths of plaice caught on the fishing vessels (steamers and smacks) and caught experimentally there is rather more trouble, because there are so many ways of going wrong in our deductions. "Lumping" of the various grounds in even such a small region as the Irish Sea is fatal. In the winter of 1920, for instance, a fairly large number of plaice were measured on the Solway grounds and these were all rather small fish (see Tables 26, 27). Also 2,275 plaice were measured on board a steam trawler working just outside the territorial limits in Liverpool Bay (Col. 1 of Table 26), and these fish also were unusually small. Now these grounds were not worked in the corresponding months of any of the previous years, and so (just because of this difference in the sampling methods) the size of plaice on the " North-west Coast region " would have appeared to have diminished in 1920 as compared with previous years. Therefore we must distinguish, to a rather fine degree, between the various grounds, and we must compare, with each other, only rather small areas. Even then there are " accidental " variations that might mislead us. Thus a good breeze of wind may make a perceptible difference in the kind of plaice found on a ground in the course of a few days. We have seen, however, that it is not the difference in the rate of growth that makes the fish on a ground appear to be bigger in some years than in others, but rather the varying proportions of older and younger plaice. That means, then, that more fish are spawned, transformed, and reared (one or all) in some years than in others, which means, again, that some years are more productive than others. So there is a good deal to be made out of the length measurements—if we are critical. If only we had had good series of plaice measurements in 1889 (when the regulation began in Lancashire) the questions propounded now would have been more easily answered. Perhaps this is the most convincing argument for the future utility of the series of measurements recorded in this report.

Is there an " Accumulated Stock " ? Does Increased Fishing tend to make the Fish run smaller ?

An " accumulated stock " of plaice means that the fish grow old more rapidly than they are caught. There is no accumulated stock in Liverpool Bay because the plaice migrate out from this region as they grow old. But even if the natural conditions were such that plaice of five or more years of age preferred to remain in Liverpool Bay they would probably not be any more numerous than they are at present. There are fewer fish of six years old than there are of five, fewer of five than there are of four, and so on, and therefore trawling affects the abundance of larger fish more than it affects that of the smaller ones. There is so much trawling in Liverpool Bay that the abundance of these larger fish would be kept down, even if the grounds were natural ones for such plaice.

On the other hand we do seem to have an accumulated stock of plaice in Luce Bay. We have reasons for believing that fish that have spawned on the northern grounds migrate into the Bay when they become spent. They are protected there because trawling is effectively prohibited by the Fishery Board for Scotland, and the other methods of fishing that are practised are probably quite insufficient to bring down the numbers of the big plaice (up to 65 cms.) that are found there.

Did a Stock of Large Plaice accumulate in the Irish Sea during the War Years?

We have discussed this question in the preceding pages and find that there is no very good evidence that such an accumulation took place.

Our conclusion is, therefore, that there is no reliable evidence in favour of the conclusion that there is an impoverishment of the plaice grounds of the Irish Sea due to over-fishing. But it may be said that the plaice there " run rather small " and that they might get bigger and so become commercially more valuable if there were size-limits, or restrictions of other kinds. This further question must briefly be considered. If we could, by any means, raise the prevalent size of plaice from (say) 23 to 30 cms. the same total weight of fish landed would be more valuable. If, further, we could so legislate that *the same numbers* of plaice would continue to be caught, but that the prevalent size of these fish would be 30 instead of 23 cms., the fisheries would become still more valuable. Apparently it is some such ideas that are at the bottom of any suggestions for size-limits, etc.

The Possible Effects of Legislative Restrictions.

The only kinds of restrictions or prohibitions that seem to be "practical politics" are (1) the closure of spawning, or nursery grounds, and (2) the imposition of size-limits. One may ask, first of all, whether it is practicable to enforce such restrictions or prohibitions. Of course this is no business of a scientific investigator any more than it is the business of the Central Authority (which has, of course, no power of actual fishery regulation, but is only responsible for the approving, or initiation, of policies). Still the whole affair, that is, the initiation, approval, and enforcement of legislative proposals, ought to be one, and any person that recommends a policy ought to be prepared to consider whether or not it is practicable. He ought also to consider in what way it is going to affect the existing fishery customs and populations. It must be said that a fair amount of actual contact with the fishermen of this coast, and some experience of the difficulty and enforcing highly unpopular restrictions does not encourage us to regard anything of the kind with much favour.

The Protection of the Spawning Grounds.

Should we add significantly to the number of marketably valuable plaice in the Irish Sea by preventing the capture of spawning fish on the Solway grounds ? Any measure of this nature would mean the closure of a fairly well-defined area, and the employment, therefore, of an efficient police. It is, further, an "international" question since the area is mostly outside territorial waters. We are not certain, in any case, that it is the eggs and larvæ of the plaice, in the Irish Sea, that ought to be protected *should* we have to admit that there is progressive improvement of the grounds. Evidently, then, *this* question need not be further discussed in the meantime.

The Question of Size-limits.

First of all one asks how any specified size-limit would affect the various classes of fishermen on this coast, and what is to be the size-limit? Those that have generally been discussed are 20 and 22 cms. (8 and $8\frac{3}{4}$ inches). Such a restriction would mean that a certain fraction of all the plaice caught by the inshore trawlers (the few smacks, the half-decked sailing vessels and the stake-net fishermen) would have to be returned to the sea. The length-frequency distributions tabulated in this report for the various areas and seasons enable us to state approximately what this fraction of rejected plaice would be. If the limit were 20 cms.—and still more if it were 22 cms.—the fraction would be so great that the restriction would interfere, in a most serious degree, with inshore fishing on the North-western Coasts. It would be most strongly resisted by a class of fishermen who are, by no means, inarticulate. The question, however, may be deferred until definite proposals have been made.

How would it affect the Smacks and Steam Vessels?

There are now so few smacks left that the question has little significance (except for the few smacksmen, of course). At any rate the Irish Sea smacks fish in the summer mostly for soles, and small plaice on the sole grounds are not very numerous. A size-limit of 20 cms. (or even one of 22 cms.) would make little difference.

How would it affect the Steam Trawlers?

Col. 1 of Table 26 represents the catches made by a steam trawler working on a small fish-ground. Even a size-limit of 22 cms. would obviously mean that a large proportion of the total catch made would have to be rejected. But a useful answer to our question hinges upon information as to the extent to which such small plaice grounds *are* generally worked by local steam trawlers, and we do not know whether or not that information is obtainable.

Also, we must consider whether small plaice caught in the large trawls—and long drags—of smacks and steam trawlers can be returned to the sea alive. Undoubtedly the business of trawling could be so conducted as to allow most of the small plaice to be put back alive into the sea. Without doubt the nets could be so made as to allow small plaice to escape through the meshes (when valuable soles would also escape, in the case of the smacks). But all this depends on the willingness of skippers to work regulations which could hardly be enforced upon them—as things are. For one must never forget that it is of little use to discuss such proposals as these without also considering their obvious consequences—which are a much more elaborate (and expensive) system of fishery police than exists at the present time.

The Possible Effect on the Fisheries of a Size-limit.

Merely to prevent the trawlers from catching—or selling—plaice of less than 20 or 22 cms. in length means nothing but a restriction: we have to investigate what would be the effect on the Irish Sea Fisheries as a whole. The restriction might be expected to deter the steam trawlers from fishing on the small plaice grounds (always supposing that they do fish there to an appreciable extent); if they do go to these grounds they go to make money by getting marketable plaice, and if they are prevented from getting them there they will have to go further and so spend more money in catching the same value of fish, for otherwise they would not go to the small fish areas in preference to going to the more distant grounds. We are expected to convince them, therefore, that it will be more profitable to refrain from catching small plaice near the territorial limits because these small fish will become big ones a year or so later, and then the big fish can be caught on the more distant grounds. The argument runs thus: Small plaice of about 25 cms. migrate out from the shallow-water grounds, and they grow more quickly when they so migrate. Thus an hundredweight of plaice of 25 cms. in length will become about 1½ cwts. of plaice of 30 cms. long as the result of a year's growth. Better then not to catch the fish until they are 30 cms. long, for then they are worth much more in the markets.

And certainly the data given in the foregoing pages do seem to lend some support to the kind of argument indicated above. Out of every 100 plaice marked and liberated on the Nelson Buoy grounds in the summer months about 2 migrate into the Red Wharf-Beaumaris Bay region in the latter months of the year. These are the bigger fish and their mean size is about 25 cms., whereas the mean size of all the fish when marked on the Nelson Buoy grounds is about 21 cms. Next we mark and liberate plaice caught on the Red Wharf-Beaumaris Bay grounds, and we find that out of every 100, 9 are caught on the southern grounds—in Carnarvon and Cardigan Bays, in St. George's Channel, in the Bristol Channel, and on the S.E. Coast of Ireland. These also are bigger plaice than those that were marked: their mean length is 30 cms. as against 24 cms. Therefore about $\frac{1}{10}$th % of the percentage of the small fish that inhabit the nursery grounds in Liverpool Bay can be shown to migrate and grow up during the two to three years following the date of liberation into medium and large fish. Protect a large quantity of the small plaice from being caught on the nurseries and we therefore get a small, additional quantity on the offshore grounds, where the fish run much bigger in size. This, we take it, is the argument for the imposition of size limits.

The very Theory of this Argument implies Differential Legislation.

Obviously one robs the fisherman, Peter, in order to benefit the other fisherman, Paul! In order to increase the quantity of medium and large plaice on the grounds frequented by the smack and steam trawlers we deliberately restrict fishing on the grounds frequented by the small sailing vessels. We must contemplate, if our policy is to be effectively carried out, curtailing the earnings of the poorer class of fishermen in order to increase those of the owners of the smacks and the industrially organised steam trawling fleets. Now this may be "quite all right." It may be expedient that the small, unorganised, individualistic, inshore industry should be sacrificed in order that the highly industrialised and capitalised industry should continue to make progress, and that all the world and his wife should have abundant (if rather stale) plaice. It may (and we like to think that it will) be the case that an organised steam fishing industry should assimilate itself to the "State" in some way not yet specified very clearly—for obviously differential legislation that boosts the big industry, employing State services for this purpose, ought to expect a *quid pro quo.* Now the scientific calm of this discussion would evidently be broken up as the result of a further development of this line of thought, and so we drop it. It is sufficient to have pointed out that some policy or other must be clearly stated and adopted before the question of size-limits can be resolved.

Finally we can look at the matter from a rather sordid (and, therefore, thoroughly practical) point of view. Some steam-trawlers fished just outside Liverpool Bar, and up towards Nelson Buoy, in November of 1920 and caught considerable quantities of quite small plaice. It is also said that they made a lot of money.* If they had not trawled there, and so avoided catching the small plaice, they would

* See *Quarterly Rept. of the Superintendent, Lancashire and Western Sea-Fisheries Joint Committee*, December, 1920, p. 5.

have had to go further afield, spent more money, and caught less fish. (For that, we may take it, is why they fished where they did.) But the year after, or the year after that again, they might have caught the small fish (which they had refrained from catching in Liverpool Bay in 1920) when these fish had grown to be much bigger. Now, knowing all this, would the skippers have voluntarily consented not to exploit the small fish grounds? Would the legislator who suggests the restrictions on sizes have done so had he not been a legislator, but the owner of the steam trawlers? If not, then, it is certainly very unfair to advocate restrictions on the inshore fishermen that have the same objects and are enforceable only by making them penal offences.

Cultivation.

It is because of the difficulties suggested in this section of the report that cultivation seems to be a much more promising field for research and application than are legislative restrictions and prohibitions. We do not refer here to the artificial hatching and rearing of plaice because that is still a matter of polemics. But the now well-known suggestions of Captain Douglas and the experimental proof of these by the transplantations carried out by the Marine Biological Association on the Dogger Bank certainly open out a broad track along which cultivation methods may develop. This does seem to be the line which scientific and practical fishery work will follow if and when it becomes clear that the productivity of the fishing grounds is diminishing under the reign of *laissez-faire*, as established by the strictly modern steam-fishing industry.

BIOMETRIC INVESTIGATIONS ON THE HERRING.

By W. Birtwistle and H. Mabel Lewis.

When this work was originally planned the intention was to accumulate three series of data, on (1) the Manx summer spawning herrings, (2) the Welsh winter spawning herrings, and (3) trawled herrings. It was only possible to deal with rather small samples, and it was intended to add together all samples belonging to each of these three groups and so make three large distributions. But it was found that samples of 50 fish taken from the same place but at different times, appeared to be more different from each other than was expected on the assumption that they were samples of the same race. When these small sub-samples were added together the frequency distributions of a single character became rather irregular, suggesting that the material was heterogeneous in respect of the character studied. This was not always the case, but it was so often enough to cast doubts on the propriety of adding together small sub-samples taken from the same locality but in different months (to say nothing of different years) to form one big sample.

Scale readings suggested also that the herrings invading Manx waters in (say) June differed from those in (say) August. This, too, is what the local fishermen appear to think. The idea suggested itself that we have not to deal with a single "Manx summer race" of herrings, but really with a small number of sub-races or "genotypes." In some weeks the shoal may consist predominantly of fish of one genotype, but at other times predominantly of fish of another genotype, or perhaps of a mixture of several. It is possible that seasonal conditions may favour now one genotype and at another time another.

Therefore it would appear that it might be necessary to measure big samples taken at the same time. But even then, such would be expected to differ from big samples from the same locality at another time—if the physical conditions had changed. At all events it was necessary to test this.

First of all we have taken all the herrings measured so far and have (as a rule) taken them sample by sample and not lumped them. The characters *D*, *V*, *A*, *l.cp.l.*, and K_2 only are dealt with. A separate frequency distribution was made in each case. In each case the independent variable is *D*, etc., expressed as a percentage of *T.cd.* The classes of *D*, etc., change by 0·25 %. In the tables " 50·25," " 50·50," " 50·75," etc., must be read as " 50·25 to 50·49," " 50·50 to 50·74," " 50·75 to 50·99," etc. The dependent variable is, of course, the numbers of cases of *D*, etc., falling within the classes 50·25 to 50·49, etc.

The conventional signs indicating the various characters are as follows :—

T. = Total length from tip of snout to the tip of the dorsal lobe of the caudal fin.

T.cd. = Total length to base of tail.

D. = Length from tip of snout to beginning of dorsal fin.

V. = Length from tip of snout to beginning of pelvic fins.

A. = Length from tip of snout to anus.

l.cp.l. = Lateral length of head.

K_2 = Number of keeled scales between anus and pelvic fins.

In order to investigate the matter further we have assumed that all Manx herrings belong to the same " race." Thus the samples of June and September, 1920 (Table XII), for instance, although they are rather different in respect of the distribution of frequencies of values of *D*, are assumed to represent the same " population " or " race." To what are the differences due ?

We assume they are due (1) to errors of measurement and (2) to errors of random sampling. Errors of measurement are then reduced somewhat by grouping the classes. Thus we take, say, 50·00 to 50·49, 50·50 to 50·99, etc., instead of 50·00 to 50·24, 50·25 to 50·49, 50·50 to 50·74, 50·75 to 50·99, etc. The range of the classes is now doubled, and so the risk of mis-measurement is minimised.

There may also be errors due to distortion (as the results of bad condition, icing, freezing, etc.), but we do not consider that this source of error is considerable.

The error of random sampling is the greatest, and it cannot be avoided except by making very large series of measurements and on big samples taken from the same locality at the same time. This is, in general, impracticable. The method used is based, therefore, on the study of small samples (50 or thereabouts). These are subject to errors of measurement, distortion and sampling. All this has to be considered in making conclusions as to the existence of "races."

In the following pages use has been made of Pearson's method of "goodness of fit" (see *Biometrika*, Vol. VIII, pp. 250-254). We make the hypothesis :

All Manx fish belong to the same race and the differences between sample and sample are due to errors of random sampling.

This hypothesis is now to be tested.

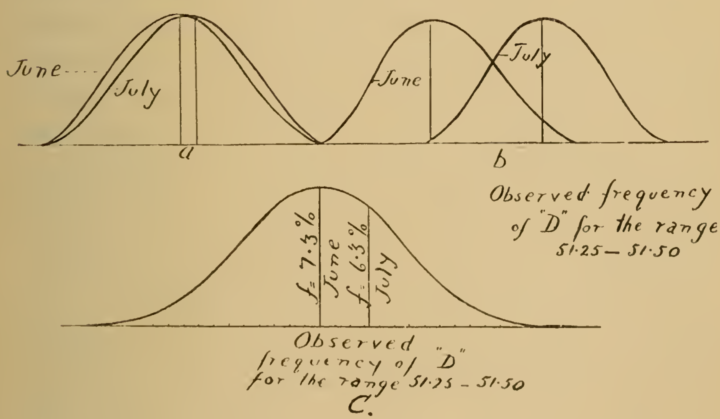
Let there be two samples taken at the same place, but at times a month apart. For instance (Table XII, D) :—

$D =$	51·00—51·25,	51·25—51·50,	51·50—51·75,	etc.
$f =$	23,	24,	36,	etc. (June).
$f_2 =$	14,	12,	21,	etc. (July).

Consider only the frequency, 24, corresponding to the class-range, 51·25—51·50.

Suppose that, instead of only *one* sample for June, we had had five samples : then, instead of the one frequency, 24, we might have had (say) 19, 23, 24, 26, 28, or some such numbers—in general, we should have had about as many different frequencies as there were samples. This is because the range of $D =$ 51·25—51·50 is only one part of the whole range, which is about 46 to 59, and our methods of collecting are such that we cannot, in general, always take the same proportion of fish from this range in every sample. We assume that the divergence of any one frequency from the mean in our series of samples conforms to the normal law of error (given by the Gaussian curve). We might get 19, 23, 24, 26 or 28 in any one sample, but there would be a tendency for the majority of these frequencies to cluster round the mean (say round 24).

Next take the series for July, when the frequency for $D = 51{\cdot}25$—$51{\cdot}50$ is 12. If we had had a number of samples instead of the single one we would have found $f = 9, 10, 12, 14, 15$ (or some such numbers) and these latter frequencies would also have tended to cluster round their mean (say round 12). If we reduce the two series of frequencies to percentages of the totals and then replace them by theoretical ones and draw curves we should get some such figure as Fig. *a*. Here there



is very little doubt that the two series represent the same conditions but, again, in such a case as that of the Manx summer herrings of 1914 compared with those of 1920, the superposed curve would be more like Fig. *b*. Here we have little doubt that the two samples represent different conditions or populations (with regard to the character *D*).

If, then, we always had a series of samples for each place and time of sampling, we might be fairly certain whether or not the population had changed in its character. But we have, as a rule, only one sample for each place and time of sampling, and that is generally all that is practicable in routine work.

Thus, considering only the frequency of occurrence of character *D* for the range of values 51·25 to 51·50, we find that it is 24, or 7·3 % of the whole, for June, and 12, or 6·3 % of the whole, for July. The problem is this : does the difference between 7·3 % and 6·3 % represent a " real " difference in the populations of June and July, or is it only a difference due to random sampling ? No answer, admitting of no doubt whatever, can be given to this question, but we can say yes or no, and assign a rough degree of probability to the answer.

Fig. *c* represents the curve that might be calculated giving a large number of samples taken at the same time in June and at the same place. The central ordinate gives the observed frequency of our single sample, that is 7·3 %, and we assume that this is the mean of the theoretical series that would be given by our hypothetical series of samples. Ordinates drawn on either side of this central one give the divergences of the frequencies from the mean one that are due to errors of random sampling. We now take the observed frequency for the July sample : it is 6·3 %, or 1 % *less* than the mean of June, and there will be another ordinate 8·3 %, which is 1 % *greater* than the mean and which we must regard as equally probable of occurrence. We draw these two ordinates in the curve, one on either side of the mean. There is a block of frequencies greater than 8·3, and another block less than 6·3, and we calculate their combined area. Then we divide this by the *whole* area of the curve and the quotient represents the probability that divergences from the mean greater and less than 1 % on either side of the mean will occur as the result of the error of random sampling.

But that is only for one class-range of D, 51·25 to 51·50, and we must do the same for every range. This will give some idea of the mathematical reasoning involved. It is not the observed frequencies that we must deal with, but the relative ones, and so each is divided by the total frequency, thus f/n is taken instead of f. Obviously the samples are of different size, and this is necessary. Also the negative divergences (less than the mean) must be added to the positive ones (greater than the mean) and so we have to square the relative frequencies, so that all of them will be positive. Finally, we calculate the sum :—

$$\text{Sum}\left[\frac{\left(\frac{f}{n}-\frac{f^1}{n^1}\right)^2}{f+f^1}\right]=s.$$

f and f^1 are the two series of frequencies and n and n^1 the two total frequencies. Having obtained s we calculate $\chi^2 = s \times n \times n^1$. We look up χ^2 and also the number of classes in our distributions in Pearson's *Tables for Statisticians* and so get a value, P. This gives us the probability that the two distributions that we compare are both representative of the same population and that the differences between them are only due to errors of random sampling. When $P = 0·1$ the chances are 1 in 10 that differences as great or greater than those observed are due to random sampling; if P is 0·01 the chances are 1 in 100, and so on. Let, for instance $P = 0·1$, then once in every ten times, or samples, random sampling would give differences as great as, or greater than, those we observe.

Elderton, in *Frequency-Curves and Correlation*, p. 144, paragraph 7, says :—" The only other point to which reference is necessary is the actual value of P at which a good fit ends and a bad one begins. It is impossible to fix such a value. We have merely a measure of probability for the whole table, and if the odds against the graduation are twenty or thirty to one the result is unsatisfactory; if they are ten to one the graduation is not unreasonable, but the exact value when a result must be discarded cannot be given. As, however, it is clearly impossible to imagine any test which can fix an absolutely definite standard, there is no reason for objecting to the particular method because it fails to do so."

The results of these calculations of P are tabulated below :—

TABLE I.—Calculation of P on sub-samples of Manx herrings taken during 1914, on characters D and *l.cp.l.*

1914.	Character *D*.						
	June 13.	June 25.	July 9.	July 31.	Aug. 21.	Sept. 4.	Oct. 2.
June 3	0·003	0·116	...	...	...	...	...
June 13.........	...	0·052	...	...	...	...	...
June 25.........	...	...	0·44	...	...	...	...
July 9	...	...	...	0·215	...	...	...
July 31	...	...	...	...	0·66	...	...
Aug. 21.........	...	...	...	...	...	0·573	...
Sept. 4	...	...	...	...	...	...	0·684

1914.	Character *l.cp.l.*						
	June 13.	June 25.	July 9.	July 31.	Aug. 21.	Sept. 4.	Oct. 2.
June 3	0·001	0·044	...	...	...	...	...
June 13.........	...	...	...	...	...	...	...
June 25.........	...	...	0·072	...	...	...	...
July 9	...	...	...	0·008	...	...	...
July 31	...	...	...	...	...	...	...
Aug 21.........	...	...	...	...	...	...	...
Sept. 4	...	...	...	...	...	...	...

Table II.—Calculation of *P* on bulk samples of Manx herrings.

	Character *D.*			Character *V.*			Character *l.cp.l.*		
	July, 1914.	Aug., Sept., Oct., 1914.	Summer Season, 1920.	July, 1914.	Aug., Sept., Oct., 1914.	Summer Season, 1920.	July, 1914.	Aug., Sept., Oct., 1914.	Summer Season, 1920.
June, 1914 ...	0·095	0·199	...	0·34	0·98	...	0·027	0·067	...
July, 1914......	...	0·785	...	...	0·57	...	...	0·000	...
Summer Season, 1914	...	...	0·000	...	...	0·000	...	...	0·000

Table III.—Calculation of *P* on bulk samples of Welsh herrings.

	Character *D.*		Character *V.*		Character *l.cp.l.*	
	Winter, 1914.	Winter, 1921.	Winter, 1914.	Winter, 1921.	Winter, 1914.	Winter, 1921.
Winter, 1913	0·000	0·000	0·000	0·9	0·000	0·05
Winter, 1914	...	0·000	...	0·000	...	0·000

Table IV.—Calculation of *P* on bulk samples of trawled herrings from the Smalls.

	Character *D.*	Character *V.*	Character *l.cp.l.*
	October, 1914.	October, 1914.	October, 1914.
October, 1913...............	0·00008	0·0008	0·099

Dealing first with the small sub-samples of Manx herrings taken during 1914 (Table I), the general result based on character *D* supports the view that the differences are most likely due to errors of random sampling, except in the two cases where June 3rd is compared with June 13th, and June 13th with June 25th. In these two cases the odds *against* the differences being due to random sampling are 333 to 1 and 19 to 1. In all the other cases they are less than 10 to 1.

Comparing these results calculated on *D* with results calculated on *l.cp.l.*, we find confusing discrepancies. The lowest odds *against* the differences being due to random sampling are about 14 to 1, in the case of June 25th compared with July 9th. This is becoming unsatisfactory; and they even become as high as 1,000 to 1 when June 3rd is compared with June 13th. So that, with the exception of June 3rd and June 13th, the result based on character *D* is negatived by that calculated on *l.cp.l.*

The lumped samples are next compared (Table II) and the three characters, *D*, *V*, and *l.cp.l.* taken. Only in one case out of four, the summer season of 1914 compared with the summer season of 1920, do we get agreement on all three characters, the odds against the differences being due to random sampling being more than 1,000 to 1, as computed on each of the three characters.

In the other three examples *D* and *V* show odds of 10 to 1 or less *against* the differences being due to random sampling, yet *l.cp.l.* shows these odds to be so increased that they are either in the region of doubt or improbability.

The examination of the Welsh herrings (Table III) reveals a high probability that the differences are due to reasons other than random sampling. But one confusing result occurs which is unexplained. Winter 1913 compared with Winter 1921—character *V* gives odds of 1·1 to 1 against the differences being due to random sampling. On *l.cp.l.* for these same samples the odds against are 20 to 1, and on *D* over 1,000 to 1. The samples of Winter 1914 compared with those of 1921 agree on all three characters, with odds of more than 1,000 to 1 against the differences being due to random sampling.

The trawled herrings from the Smalls (Table IV)—October 1913 compared with October 1914—show somewhat conflicting results. *D* and *V* suggest that the differences are due to causes other than random sampling, but *l.cp.l.* shows much lower odds against—about 10 to 1—whereas in the other two cases the odds are over 1,000 to 1 against.

It is difficult to explain these anomalies. We consider the most reliable character to be *l.cp.l.* from the measurer's point of view and would regard it with more confidence perhaps than any other character. It is clearly defined and does not suffer from the effects of distortion due to bad condition, freezing or softening, as might *D*, *V*, or *A*, and in nearly all cases *P*, when calculated on this character is low. In the one case only—that of the Smalls, October 1913 and October 1914, does this character give any value of *P* which indicates any approach to a "good fit." So that the bulk of the evidence inclines to the theory that there is no racial homogeneity in the samples compared.

It seems pretty clear that the herrings inhabiting the Irish Sea are a mixture of sub-races, or genotypes, and that one of these predominates at one time, and another at another time. For the chances that the differences observed are due solely to errors of random sampling are, very often, far too small to allow of any other conclusion. Further complications are the choice of the diagnostic character, *or* whether we should not, preferably, choose a combination of characters, *or* whether some other character than those studied must be sought? Evidently the question of races is not so simple a one as has been thought and some further investigations, as to what characters are truly germinal ones and what are environmental only, must obviously be undertaken. Meanwhile we hope that the records given in the frequency distributions may serve for comparison with other sea-areas.

The possibilities of a shifting with growth of any one of the characters investigated should also be considered. That this actually happens in the case at any rate of young herrings of from 30 mm. to 60 mm. is very clearly shown in Table V. This is a series of measurements of young herrings from North Wales made by Mr. Andrew Scott and examined by Professor Johnstone. The distance *D* is expressed as a percentage of *T* (total length) and correlated with *T* as tabulated, giving a coefficient of correlation of —0·9696. This is almost absolute correlation. The form of the table shows at a glance how the dorsal fin is gradually moving forward as the young herring is growing.

This investigation of the shifting of characters was extended to the sprat. Measurements were made by Mr. Scott and tabulated by Professor Johnstone. Tables VI and VII show the results. Table VI is a correlation between the position of the dorsal fin and the total length. The result shows that this character does not vary in any regular way with increasing length. Table VII is a correlation between the position of the ventral fins and total length. This shows a somewhat irregular tendency to move forward as the fish grows, but not so definite as in the case of the dorsal fin of the young herring.

Unfortunately, in the case of the samples of larger herrings examined by us, time did not permit of more than four correlations being made. Three of these were based on character *A*, and one on character *D*. The results were inconclusive, as Tables VIII to XI show. There is little or no evidence of correlation in any case investigated.

Table V.—Correlation between length and position of the dorsal fin in the Herring.

Total length.	Distance of dorsal fin from snout: %						Totals.
	43-44	45-46	47-48	49-50	51-52	53-54	
31-33	...	...	...	...	1	1	2
34-36	...	...	...	1	2	21	24
37-39	...	...	...	9	42	8	59
40-42	...	...	1	23	33	1	58
43-45	...	3	5	22	1	...	31
46-48	1	7	19	1	...	...	28
49-51	4	22	2	...	...	...	28
52-54	1	4	1	...	...	...	6
55-57	4	6	...	...	...	...	10
Totals	10	42	28	56	79	31	246

r = Coefficient of Correlation = $-0{\cdot}9696 \pm 0{\cdot}0005$

Table VI.—Correlation between length and position of the dorsal fin in the Sprat.

Total Length.	Distance of dorsal fin from snout: %					Totals.
	41-42	43-44	45-46	47-48	49-50	
30- 49	4	37	106	45	12	204
50- 69	...	17	100	77	18	212
70- 89	...	14	90	83	12	199
90-109	...	12	154	99	4	269
110-129	3	7	73	7	...	90
130-149	...	...	9	5	...	14
Totals	7	87	532	316	46	988

r = Coefficient of Correlation = $-0{\cdot}0945 \pm 0{\cdot}0205$.

Table VII.—Correlation between length and position of the pelvic fins in the Sprat.

Total Length.	Distance of pelvic fins from snout: %.					Totals.
	40-41	42-43	44-45	46-47	48-49	
30- 49	1	8	107	62	19	197
50- 69	3	46	97	46	9	201
70- 89	10	79	84	24	6	203
90-109	2	109	148	8	...	267
110-129	1	47	40	2	...	90
130-149	4	5	4	...	...	13
Totals	21	294	480	142	34	971

r = Coefficient of Correlation = $-0{\cdot}5005 \pm 0{\cdot}015$.

TABLE VIII.—Manx Herrings, 1914. Character *D*.

Correlation between *T.cd.* and *D* expressed as a % of *T.cd.*

T.cd.—the actual measurements in millimetres.	48–48·9	49–49·9	50–50·9	51–51·9	52–52·9	53–53·9	54–54·9	Totals.	Means.
180-189	...	...	1	4	7	5	...	17	52·44
190-199	...	...	4	25	25	10	3	67	52·25
200-209	...	3	27	58	51	17	3	159	51·88
210-219	...	2	38	96	72	17	3	228	51·82
220-229	1	1	19	45	44	27	3	140	52·09
230-239	...	...	6	15	17	9	2	49	52·21
240-249	...	...	...	...	3	...	...	3	52·50
Totals	1	6	95	243	219	85	14	663	
Means	225	211·6	214·26	213·15	213·40	214·18	213·57		

r = Coefficient of Correlation = 0·000499.

TABLE IX.—Welsh Herrings, 1914. Character *A*.

Correlation between *T.cd.* and *A* expressed as a % of *T.cd.*

Actual measurement of *T.cd.*	73–73·9	74–74·9	75–75·9	76–76·9	77–77·9	78–78·9	79–79·9	Totals.	Means.
180-189	...	6	16	10	3	...	...	35	75·78
190-199	4	12	16	8	3	2	...	45	75·50
200-209	1	4	5	11	7	1	...	29	76·26
210-219	...	7	14	12	12	1	1	47	76·27
220-229	1	4	24	36	15	5	...	85	76·38
230-239	...	3	5	11	6	2	...	27	76·45
240-249	...	...	2	2	...	...	...	4	76·00
Totals	6	36	82	90	46	11	1	272	
Means	201·6	205·1	209·5	215·7	216·7	218	215		

r = Coefficient of Correlation = 0·267 ($\pm$ 0·047).

TABLE X.—Welsh Herrings, Winter, 1921.

Correlation between *T.cd.* and *A* expressed as a % of *T.cd.*

Actual measurement of *T.cd.*	73–73·9	74–74·9	75–75·9	76–76·9	77–77·9	78–78·9	79–79·9	80–80·9	Totals.	Means.
180-189	...	1	1	5	13	4	3	...	27	77·50
190-199	1	1	2	17	19	14	2	1	57	77·37
200-209	1	1	3	8	25	13	4	...	55	77·50
210-219	...	1	5	11	15	6	4	...	42	77·26
220-229	...	...	...	3	10	4	2	...	19	77·76
230-239	...	...	2	4	10	12	1	...	29	77·71
240-249	...	...	...	2	5	7	2	...	16	78·06
250-259	...	1	...	...	1	...	...	...	2	76·00
260-269	...	...	...	...	1	...	...	...	1	75·50
Totals	2	5	13	50	99	60	18	1	248	
Means	200	211	210·38	207	210·15	214·3	211·11	195		

r = Coefficient of Correlation = 0·094.

TABLE XI.—Manx Herrings, June, July, August, 1914/20.

Correlation between *T.cd.* and *A* expressed as a % of *T.cd.*

Actual measurement of *T.cd.*	73–73·9	74–74·9	75–75·9	76–76·9	77–77·9	78–78·9	79–79·9	80–80·9	Totals.	Means.
170-179	...	...	1	...	1	1	...	...	3	77·17
180-189	...	6	3	6	6	3	...	1	25	76·54
190-199	2	12	28	37	36	14	2	2	133	76·65
200-209	3	19	46	68	46	30	6	2	220	76·59
210-219	2	13	33	55	46	14	7	...	170	76·68
220-229	...	1	10	14	29	15	4	1	74	77·35
230-239	1	...	...	3	7	3	2	1	17	77·68
Totals	8	51	121	183	171	80	21	7	642	
Means	208·75	203·24	206·32	207·35	209·33	208·75	214·05	206·43		

r = Coefficient of Correlation = 0·152.

Remarks.

The mathematical investigation of these data can scarcely be regarded as giving very satisfactory results ; many of them are conflicting and in some cases one result completely annuls another. The reasons may be sought in many directions, some of which under present circumstances would be difficult to follow. We might get more trustworthy results from weekly samples of herrings and by dealing with them immediately. This, however, would necessitate the abandonment of some other equally important work during a very critical time in a marine laboratory programme. Methods of measurement might be improved and additional characters investigated, including the counting of the vertebrae.

The grouping of the data according to scale markings has been considered. That is, instead of giving a range of percentages of *T.cd.* of any one character and lumping together all the fish of a sample irrespective of their ages, as we have done in the present report, the fish would be selected according to the scale markings and each age group treated separately. This, however, has the great disadvantage of reducing the present data to many groups with much smaller frequencies and would consequently necessitate much larger samples. The samples would at least be homogeneous as far as age was concerned, and any peculiarities due to a possible shifting of any character might reasonably be expected to be confined to the particular age group under consideration and to be evenly distributed among the varying length frequencies.

Our examination of scale markings of the various samples considered reveals great heterogeneity as regards age. A sample generally contains fish with from two to six scale rings. In some cases one special ring group will predominate, in another perhaps three groups will be equally represented and form the bulk of the sample.

We do not consider the keeled scales (K_2) to have any particular significance and they seem to show very little variation. For this reason we have not investigated them mathematically.

Our indebtedness to Professor Johnstone is acknowledged. He drew up this scheme of investigation and supervised its carrying out. Thanks are also due to Mr. Smith and Mr. Fleming, who have helped in the measuring and examination of all the samples. It should not be overlooked that the measuring and examination alone of a sample of 50 fish is a full day's work for two operators, and the greatest care must be exercised. Scale reading takes up a great deal of time and becomes very trying. The results of scale readings of the samples will be the subject of another report.

The analysis of all samples received from the commencement of these biometric investigations in 1913 to the present time are appended. See Tables XII to XX.

" Range " of a character in the Tables means the percentage of the measurement *T.cd.* occupied by the measurement of the character under consideration. The material is divided into sub-samples, which appear under the heading of locality, month and year. The final column for each year is the total of these sub-samples and forms the " lumped " samples data.

Table XX. Character K_2. The " range " of these data are not percentages of *T.cd.* but absolute numbers of the keeled scales as counted.

Table XII.—*D*.

Range of *D*.	Manx, 6, 1914,	Manx, 7, 1914.	Manx, 9, 10, 1914.	Manx, 1914.	Manx, 6, 1920.	Manx, 6, 1920.	Manx, 9, 1920.	Manx, 9, 1920.	Manx, 1920.	Manx, 3, 1921.	Manx, 5, 1921.	Manx, 8, 1921.	Manx, 1921.
46·00	...	...	...	...	1	...	...	...	1	...	...	...	...
46·25	...	...	...	...	...	...	...	...	...	...	...	...	...
46·50	...	...	...	...	2	...	...	...	2	...	...	...	...
46·75	...	...	...	...	1	...	...	...	1	...	...	...	...
47·00	...	...	...	...	...	...	...	...	...	...	...	...	...
47·25	...	...	...	...	...	...	...	...	...	...	...	...	...
47·50	...	...	...	...	...	...	...	...	...	...	...	...	...
47·75	...	...	...	...	1	1	...	...	2	...	...	...	...
48·00	...	...	...	...	...	1	...	...	1	...	...	...	...
48·25	...	...	...	...	...	...	...	1	1	...	...	...	...
48·50	...	...	...	...	...	...	...	...	...	...	...	...	...
48·75	...	1	...	1	...	...	...	...	...	...	...	...	...
49·00	1	1	...	2	...	...	...	...	...	...	...	...	...
49·25	2	...	...	2	...	...	...	...	...	...	...	...	...
49·50	...	1	...	1	...	...	...	...	...	...	...	...	...
49·75	...	1	...	1	...	...	...	...	...	...	...	...	...
50·00	9	7	7	23	2	5	...	1	8	...	...	...	...
50·25	7	3	1	11	...	4	1	...	5	...	1	...	1
50·50	16	2	5	23	2	...	...	2	4	...	1	...	1
50·75	20	12	4	36	2	5	...	...	7	...	2	1	3
51·00	23	14	15	52	7	3	...	4	14	1	1	1	3
51·25	24	12	10	46	3	2	6	1	12	1	...	...	1
51·50	36	21	14	51	6	13	4	4	27	3	4	...	7
51·75	40	21	13	74	5	4	4	10	23	6	4	2	12
52·00	38	15	17	70	2	15	7	7	31	3	5	...	8
52·25	30	16	14	60	3	12	7	14	36	10	3	4	17
52·50	22	14	14	50	2	15	6	16	39	5	5	2	12
52·75	21	13	9	43	4	15	5	15	39	4	4	4	12
53·00	17	14	9	40	5	11	7	21	44	6	7	3	16
53·25	10	7	4	21	5	16	4	16	41	3	4	3	10
53·50	6	6	6	18	1	11	2	16	30	3	4	1	8
53·75	1	2	3	6	1	8	3	13	25	1	1	1	3
54·00	1	3	4	8	1	4	2	15	22	1	2	1	4
54·25	2	...	...	2	...	2	1	6	9	...	...	...	...
54·50	...	2	...	2	1	2	...	6	9	...	...	1	1
54·75	...	...	...	...	...	2	1	7	10	...	1	...	1
55·00	1	2	...	3	...	...	...	1	1	...	...	...	...
55·25	...	...	...	...	...	...	...	...	...	...	...	...	...
55·50	1	...	...	1	...	...	...	2	2	...	...	...	...
55·75	...	...	...	...	...	...	...	1	1	...	...	...	...
56·00	...	...	...	...	2	...	...	...	2	...	...	...	...
56·25	...	...	...	...	...	1	...	1	2	...	...	...	...
57·50	...	...	...	...	1	...	...	...	1	...	...	...	...
57·75	...	...	...	...	...	1	...	...	1	...	...	...	...
59·50	...	...	...	...	...	...	...	1	1	...	...	...	...
	328	190	149	667	60	153	60	181	454	47	49	24	120

TABLE XIII.—*D*.

Range of *D*	Welsh, 1913.	Welsh, 1914.	Welsh, 10, 1921.	Welsh, 12, 1921.	Welsh, 1, 1922.	Welsh, 1921-2.	Smalls, 1913.	Smalls, 1914.
48·00	...	...	...	...	...	...	...	...
48·25	...	...	...	...	...	...	...	...
48·50	...	...	...	...	...	...	...	...
48·75	...	...	1	...	...	1	...	...
49·00	...	...	...	...	...	...	...	1
49·25	1	3	...	1	...	1	...	...
49·50	2	4	1	...	...	1	...	1
49·75	1	5	...	...	...	...	...	2
50·00	4	26	2	...	1	3	...	4
50·25	7	26	1	1	...	2	1	...
50·50	9	20	4	1	...	5	2	...
50·75	7	31	4	2	...	6	2	4
51·00	10	27	13	1	2	16	5	5
51·25	21	33	13	6	1	20	5	9
51·50	15	34	19	4	...	23	7	13
51·75	10	12	17	7	1	25	5	9
52·00	10	19	17	2	...	19	11	12
52·25	15	20	17	7	1	25	12	18
52·50	10	11	21	9	5	35	11	11
52·75	3	4	10	4	1	15	17	5
53·00	2	3	15	6	2	23	19	8
53·25	5	...	6	5	4	15	12	11
53·50	1	...	7	5	2	14	14	2
53·75	4	...	5	...	4	9	7	2
54·00	3	1	4	...	9	13	12	1
54·25	...	...	4	...	2	6	2	1
54·50	...	1	2	...	5	7	2	1
54·75	...	...	...	...	2	2	2	...
55·00	...	...	1	...	1	2	...	...
55·25	...	...	...	...	3	3	2	...
55·50	...	...	...	...	1	1	...	...
55·75	1	...	1	...	1	2	...	...
56·00	...	...	...	...	...	...	...	...
56·25	...	...	...	...	...	...	...	...
56·50	...	...	...	...	...	...	...	...
56·75	...	...	...	...	...	...	...	...
57·00	...	...	...	...	...	...	...	...
	141	280	185	61	48	294	150	120

TABLE XIV.—*V*.

Range of *V*.	Manx, 6, 1914.	Manx, 7, 8, 1914.	Manx, 9, 10, 1914.	Manx, 1914.	Manx, 6, 1920	Manx, 6, 1920.	Manx, 9, 1920.	Manx, 9, 1920.	Manx, 1920.	Manx, 3, 1921.	Manx, 5, 1921.	Manx, 8, 1921.	Manx, 1921.
48·00	...	...	...	...	1	...	...	...	1	...	...	...	...
48·25	...	...	...	...	...	...	...	...	...	...	...	...	...
48·50	...	...	...	...	1	...	...	...	1	...	...	...	...
48·75	...	...	...	...	1	1	...	...	2	...	...	...	...
49·00	...	...	...	...	...	1	...	...	1	...	...	...	...
49·25	...	...	...	...	1	...	...	...	1	...	...	...	...
49·50	...	...	...	...	...	...	...	...	...	...	...	...	...
49·75	...	...	...	...	1	...	...	...	1	...	...	...	...
50·00	...	...	...	...	...	...	...	...	...	...	...	...	...
50·25	...	...	...	...	...	...	...	...	...	...	...	...	...
50·50	...	...	...	...	...	...	...	...	...	...	...	...	...
50·75	...	...	...	...	...	...	...	...	...	...	...	...	...
51·00	...	...	...	...	...	...	...	...	...	...	...	...	...
51·25	1	...	...	1	...	3	...	...	3	...	...	...	...
51·50	...	1	...	1	1	...	...	...	1	...	1	...	1
51·75	1	...	...	1	1	...	...	...	1	...	...	...	...
52·00	...	3	...	3	...	...	...	...	...	...	...	...	...
52·25	1	1	...	2	1	1	1	...	3	...	...	...	...
52·50	4	2	2	8	2	4	...	...	6	...	...	...	...
52·75	5	1	2	8	1	8	2	1	12	...	...	...	...
53·00	6	4	4	14	...	4	2	...	6	...	1	...	1
53·25	12	6	5	23	1	7	1	1	10	1	1	...	2
53·50	18	8	8	34	3	10	2	...	15	...	1	1	2
53·75	28	12	14	54	3	10	5	...	18	1	1	4	6
54·00	22	20	12	54	...	13	7	1	21	...	...	1	1
54·25	28	10	8	46	6	10	4	3	23	...	...	2	2
54·50	29	13	11	53	7	19	3	7	26	1	2	2	5
54·75	22	17	12	51	4	13	4	5	26	3	2	1	6
55·00	41	22	18	81	6	12	7	8	36	5	6	4	15
55·25	22	12	11	45	5	4	2	10	21	3	5	4	12
55·50	27	16	11	54	4	6	12	15	37	2	4	1	7
55·75	16	12	7	35	4	8	1	11	20	5	8	1	14
56·00	17	4	8	29	1	6	1	10	18	8	1	2	11
56·25	13	8	7	28	...	3	2	20	25	4	6	1	11
56·50	7	6	4	17	1	2	5	16	24	4	3	...	7
56·75	3	2	2	7	1	3	...	19	23	5	4	...	9
57·00	1	3	1	5	...	2	...	13	15	2	...	...	2
57·25	2	3	2	7	...	1	...	14	15	...	2	...	2
57·50	3	...	...	3	1	...	...	16	17	...	1	...	1
57·75	...	2	...	2	...	...	...	5	5	1	...	...	1
58·00	...	1	...	1	1	...	...	4	5	1	...	...	1
58·25	...	1	...	1	...	...	...	1	1	1	...	...	1
58·50	...	...	...	...	...	...	...	2	2	...	...	...	...
58·75	...	...	...	...	...	...	...	5	5	...	...	...	...
59·00	...	...	...	...	1	...	...	2	3	...	...	...	...
60·00	...	...	...	...	1	...	...	1	2	...	...	...	...
61·00	...	...	...	...	1	...	...	...	1	...	...	...	...
	329	190	149	668	60	152	61	181	454	47	49	24	120

Table XV.—*V*.

Range of *V*.	Welsh, 1913.	Welsh, 1914.	Welsh, 10, 1921.	Welsh, 12, 1921.	Welsh, 1, 1922.	Welsh, 1921-2.	Smalls, 1913.	Smalls, 1914.
48·00	...	...	...	...	...	...	...	...
48·25	...	...	...	...	...	...	...	...
48·50	...	...	...	...	...	...	...	...
48·75	...	...	...	...	...	...	...	...
49·00	...	...	...	...	...	...	...	...
49·25	...	...	...	...	...	...	...	...
49·50	...	...	...	...	...	...	...	...
49·75	...	...	...	...	...	...	...	...
50·00	...	...	...	...	...	...	...	...
50·25	...	...	...	...	...	...	...	...
50·50	...	...	...	...	1	1	...	...
50·75	...	...	...	...	...	...	...	...
51·00	...	1	...	...	...	...	...	...
51·25	...	1	...	...	...	...	...	...
51·50	...	...	1	...	...	1	...	...
51·75	...	...	...	...	...	...	...	...
52·00	...	...	...	...	...	...	...	...
52·25	...	9	...	...	...	...	...	1
52·50	1	4	...	1	1	2	...	...
52·75	3	7	1	3	...	4	1	3
53·00	2	19	4	5	...	9	...	2
53·25	4	16	4	1	...	5	1	5
53·50	6	18	8	1	2	11	...	4
53·75	2	28	9	2	...	11	1	5
54·00	5	25	8	4	...	12	3	8
54·25	9	29	10	11	2	23	8	5
54·50	11	28	15	6	...	21	10	12
54·75	16	29	19	4	1	24	17	12
55·00	13	19	15	8	1	24	11	13
55·25	15	28	28	6	2	36	10	8
55·50	11	7	11	2	2	15	19	11
55·75	11	11	13	3	2	18	19	4
56·00	9	3	10	...	6	16	10	15
56·25	7	2	15	3	4	22	6	7
56·50	9	...	1	1	3	5	10	2
56·75	2	...	5	...	4	9	9	1
57·00	1	...	...	...	9	9	3	1
57·25	2	...	2	...	6	8	5	1
57·50	2	...	1	...	...	1	3	...
57·75	...	...	2	...	...	2	1	...
58·00	1	...	...	...	1	1	2	...
58·25	...	1	1	...	2	3	...	...
	142	285	183	61	49	293	149	120

Table XVI.—*A*.

Range of *A*.	Manx, 6, 1914.	Manx, 7, 1914.	Manx, 8, 1914.	Manx, 9, 1914.	Manx, 10, 1914.	Manx, 1914.	Manx, 6, 1920.	Manx, 6, 1920.	Manx. 9, 1920.	Manx, 9, 1920.	Manx, 1920.	Manx, 3, 1921.	Manx, 5, 1921.	Manx, 8, 1921.	Manx, 1921.
73·00	...	...	...	...	...	...	1	...	...	...	1	...	...	...	...
73·25	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
73·50	1	...	...	...	...	1	1	1	...	...	2	...	...	...	...
73·75	...	...	...	...	...	...	1	2	...	...	3	...	...	...	...
74·00	3	1	...	...	...	4	2	4	...	...	6	...	...	...	...
74·25	2	...	...	...	...	2	1	7	...	...	8	...	...	1	1
74·50	4	1	...	...	...	5	3	6	...	...	9	...	...	...	...
74·75	...	6	1	...	...	7	3	8	...	...	11	...	...	...	...
75·00	7	4	...	...	2	13	7	9	...	...	16	...	...	...	...
75·25	8	5	...	...	2	15	1	15	...	...	16	...	1	...	1
75·50	9	8	1	1	2	21	1	12	2	1	16	1	1	1	3
75·75	15	7	3	3	1	29	3	6	1	...	10	2	2	...	4
76·00	8	10	5	1	3	27	3	14	4	...	21	4	4	...	8
76·25	16	9	4	2	4	35	5	9	4	2	20	2	2	4	8
76·50	17	14	...	3	1	35	6	16	5	...	27	2	4	4	10
76·75	21	10	5	1	1	38	5	6	5	1	17	4	3	2	9
77·00	12	12	2	5	7	38	4	7	5	5	21	3	5	1	9
77·25	21	20	8	4	5	58	...	5	2	9	16	7	7	3	17
77·50	18	16	4	10	4	52	3	8	8	9	28	1	5	1	7
77·75	12	12	1	4	2	31	1	4	7	11	23	2	3	1	6
78·00	9	11	2	2	2	26	1	4	7	18	30	4	4	1	9
78·25	6	12	3	5	9	35	...	2	5	24	31	3	...	2	5
78·50	6	6	5	3	2	22	1	2	2	12	17	2	...	2	4
78·75	3	5	1	1	...	10	2	...	3	21	26	3	4	...	7
79·00	2	8	2	1	2	15	...	...	...	18	18	1	1	...	2
79·25	...	5	2	1	1	9	...	1	1	19	21	2	1	...	3
79·50	...	...	...	2	...	2	[67·0	0...1	...	7	7	2	2	...	4
79·75	...	2	...	...	...	2	69·5	0...1	...	6	6	...	...	...	...
80·00	...	4	...	...	...	4	72·7	5...2	...	17	17	...	...	1	1
80·25	...	...	...	...	...	...	...	...	...	3	3	...	...	...	...
80·50	...	1	...	...	...	1	...	...	...	2	2	1	...	...	1
80·75	...	...	1	...	...	1	...	1	...	3	4	...	...	...	...
81·00	...	1	...	...	...	1	...	1	...	...	1	...	...	...	...
81·25	...	...	...	...	[6	7·75	... 1	...	...	[8	3·00	...1	...	...	1
81·50	...	...	...	...	6	8·00	... 2	...	...	2	2	...	...	...	...
81·75	...	...	...	...	6	8·25	... 1	...	...	...	...	...	...	...	...
82·00	...	...	...	...	7	1·50	... 1	...	...	1	1	...	...	...	...
	...	...	...	...	...	...	...	...	[<7	3·00	...9	...	...	...	...
	200	190	50	49	50	539	60	154	61	181	466	47	49	24	120

TABLE XVII.—*A*.

Range of *A*.	Welsh, 10, 1914.	Welsh, 11, 1914.	Welsh, 12, 1914.	Welsh, 1914.	Welsh, 10, 1921.	Welsh, 12, 1921.	Welsh, 1, 1922.	Welsh, 1921-2.
73·00	...	1	...	1	...	[70·50	... 1	... 1
73·25	...	...	...	...	...	...	...	...
73·50	1	1	...	2	...	...	...	...
73·75	1	2	...	3	2	...	...	2
74·00	...	2	1	3	...	...	...	...
74·25	3	2	2	7	3	...	1	4
74·50	2	10	4	16	1	...	...	1
74·75	2	8	1	11	1	...	...	1
75·00	2	18	6	26	1	1	...	2
75·25	2	12	10	24	1	...	...	1
75·50	...	12	6	18	3	1	...	4
75·75	3	5	9	17	5	1	...	6
76·00	1	12	13	26	5	1	2	8
76·25	4	10	11	25	9	3	...	12
76·50	2	10	8	20	12	5	2	19
76·75	2	11	8	21	9	5	...	14
77·00	1	6	8	15	17	9	...	26
77·25	...	10	11	21	17	2	...	19
77·50	1	2	6	9	30	8	...	38
77·75	...	4	...	4	10	5	1	16
78·00	...	...	1	1	11	7	2	20
78·25	2	...	3	5	14	4	2	20
78·50	1	...	2	3	11	...	3	14
78·75	1	...	1	2	10	3	2	15
79·00	...	...	1	1	4	1	5	10
79·25	...	...	...	...	3	2	2	7
79·50	...	...	...	...	3	2	5	10
79·75	...	...	...	...	2	...	3	5
80·00	...	...	...	...	1	...	6	7
80·25	...	...	...	...	...	...	3	3
80·50	...	...	...	...	...	...	1	1
80·75	...	...	...	...	...	...	1	1
81·00	...	...	...	...	...	...	3	3
81·25	...	...	...	...	...	...	1	1
81·50	...	...	...	...	...	...	...	...
81·75	...	...	...	...	...	...	2	2
82·00	...	...	...	...	...	[83·25	... 1	... 1
	31	138	112	281	185	60	49	294

TABLE XVIII.—*l.cp.l.*

Range of *l.cp.l.*	Manx, 6, 1914.	Manx, 7, 1914.	Manx, 8, 1914.	Manx, 9, 1914.	Manx, 10, 1914.	Manx, 1914.	Manx, 6, 1920.	Manx, 6, 1920.	Manx, 9, 1920.	Manx, 9, 1920.	Manx, 1920.	Manx, 3, 1921.	Manx, 5, 1921.	Manx, 8, 1921.	Manx, 1921.
19·00	...	...	...	...	...	...	...	...	...	4	4	...	...	...	...
19·25	...	...	...	...	...	...	...	...	1	3	4	...	...	...	...
19·50	...	1	...	...	...	1	...	1	1	5	7	...	...	2	2
19·75	3	...	...	...	...	3	1	...	1	2	4	...	...	1	1
20·00	...	8	4	...	1	13	2	1	8	6	17	1	1	4	6
20·25	9	6	4	2	1	22	...	1	5	8	14	...	...	1	1
20·50	6	11	7	2	1	27	2	5	10	11	28	...	1	7	8
20·75	19	13	5	6	1	44	2	9	8	13	32	1	1	3	5
21·00	24	11	7	2	2	46	6	9	10	9	34	4	1	1	6
21·25	44	12	6	8	4	74	4	11	4	14	33	7	1	1	9
21·50	44	30	4	5	4	87	4	17	5	24	50	7	4	2	13
21·75	41	23	5	6	5	80	5	17	1	16	39	4	2	2	8
22·00	46	13	5	3	11	78	6	12	2	12	32	3	6	...	9
22·25	27	19	...	6	9	61	6	18	2	17	43	6	5	...	11
22·50	24	13	1	4	5	47	6	16	2	9	33	6	5	...	11
22·75	16	9	...	3	3	31	6	14	...	8	28	4	4	...	8
23·00	11	12	1	2	2	28	5	15	1	7	28	2	7	...	9
23·25	7	3	1	...	...	11	3	3	...	5	11	2	9	...	11
23·50	5	2	...	...	1	8	1	3	...	7	11	...	2	...	2
23·75	1	3	...	...	...	4	1	1	...	1	3	...	...	...	...
24·00	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
24·25	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
24·50	1	...	...	...	...	1	...	...	...	...	...	...	...	...	...
	328	189	50	49	50	666	60	153	61	181	455	47	49	24	120

Table XIX.—*l.cp.l.*

Range of *l.cp.l.*	Welsh, 1913.	Welsh, 1914.	Welsh, 10, 1921.	Welsh, 12, 1921.	Welsh, 1, 1922.	Welsh, 1921-2.	Smalls, 1913.	Smalls, 1914.
19·00	...	[18·75	... 1	...	[18·75	... 1	...	...
19·25	...	...	3	...	...	3	...	...
19·50	...	...	1	2	...	3	1	...
19·75	6	1	6	...	...	6	...	...
20·00	3	6	5	3	...	8	...	...
20·25	8	13	5	5	...	10	1	...
20·50	14	9	6	7	...	13	1	4
20·75	14	23	14	6	3	23	4	9
21·00	14	30	17	10	2	29	6	9
21·25	19	31	18	6	1	25	18	12
21·50	13	37	29	6	1	36	5	20
21·75	7	45	21	3	5	29	17	19
22·00	9	26	12	5	4	21	24	18
22·25	8	24	8	4	3	15	16	16
22·50	6	19	12	...	10	22	17	8
22·75	4	12	11	1	7	19	15	3
23·00	4	6	10	1	5	16	9	...
23·25	3	...	...	1	3	4	10	...
23·50	5	...	4	...	4	8	4	1
23·75	...	...	1	...	1	2	2	...
24·00	...	...	1	...	...	1	...	...
24·25	...	...	...	...	...	...	...	...
24·50	...	...	...	...	...	...	...	...
	137	282	185	60	49	294	150	119

TABLE XX.—K_2.

Range of K_2.	Manx, 6, 1914.	Manx, 7, 1914.	Manx, 8, 1914.	Manx, 9, 1914.	Manx, 10, 1914.	Manx, 6, 1920.	Manx, 6, 1920.	Manx, 9, 1920.	Manx, 9, 1920.	Manx, 3, 1921.	Manx, 5, 1921.	Manx, 8, 1921.
12	1	...	...	...	...	...	1	...	...	...	1	1
13	17	29	4	4	2	10	9	5	25	32	25	10
14	147	88	28	24	30	23	83	26	96	14	21	9
15	115	50	14	16	16	19	56	24	53	1	2	4
16	39	16	4	4	2	3	4	6	5	...	...	...
17	5	2	...	...	...	3	...	...	1	...	...	...
	324	185	50	48	50	58	153	61	180	47	49	24

Range of K_2.	Welsh, 1913.	Welsh, 1914.	Welsh, 10, 1921.	Welsh, 12, 1921.	Welsh, 1, 1922.	Smalls, 1913.	Smalls, 1914.	Maryport, 1, 1922.	Morecambe, 1, 1922.
12	5	4	8	[11...	... 1	3	1	...	7
13	30	33	55	16	11	33	16	2	32
14	66	149	99	30	28	88	62	4	23
15	37	76	19	12	2	26	39	2	2
16	4	18	3	3	...	...	3	...	...
17	...	...	...	...	...	...	...	...	...
	142	280	184	61	49	150	121	8	64

SEASONAL CHANGES IN THE CHEMICAL COMPOSITION OF THE MUSSEL (*MYTILUS EDULIS*). (*Continued*).

By R. J. Daniel, B.Sc.

The investigation into the seasonal variations in the flesh of *Mytilus edulis*, which was referred to in last year's Report on the Lancashire Sea Fisheries Laboratory, has now been concluded, and covers a period of two years. Observations show a marked annual reproductive cycle which, on the whole, repeats itself in each of the two years. The discrepancies are probably due, in the main, to the unavoidable errors of sampling.

The data obtained from examination of the samples, tabulated in various ways, is shown in the attached tables. It is not possible just yet to publish the results obtained from microscopic sections, stained to show the distribution of fat and glycogen in the tissue, but since the information obtained from these latter investigations is closely bound up with the fluctuations in chemical composition, it will be necessary to refer to it in passing.

The samples sent from Morecambe are to some extent "selected" mussels. They have been gathered in the same manner as the fishermen pick them for food, only those greater than two inches (5·1 cms.) being taken. This is not altogether a disadvantage; it lessened the irregularities with regard to the size of the mussels, and allows of results which are comparable with the shellfish that are actually put on to the market. Most of the mussel samples showed an average length of 6·0—6·5 cms., and only five of them averaged so low as 5·5—6·0 cms. There were one or two samples which were obviously not in the "general" run. For example, the mussels received on August 16th, 1921, were small, and with very dark shells; they were procured from a bed near to Morecambe, and not from the usual Skears. On the other hand, the sample for December 17th, 1920, was composed of mussels so large and well-nourished that they must have enjoyed the most favourable conditions on the Skear, from which they were obtained. Although such samples cause irregularities in the tables showing weights and percentages, they do not obscure the general trend of the figures.

The methods of dealing with the shellfish in the laboratory have already been described.* The selection of six mussels at random from the whole sample, for the drying and subsequent analyses, has been successful, within limits, as may be seen by examination of Table I. The figures for the average weights of shell and of flesh for the six mussels, and the corresponding ones for the rest of the sample, do not show differences which alter the main conclusions. For instance, a graph plotted for the average weights of wet flesh for the rest of the sample shows fluctuations, but the curve does not differ fundamentally from a corresponding curve for the six mussels.

Differences in Weight.

The weight of wet flesh in both years rises from May, with variations, to December, and then maintains a relatively high value until there is a rapid fall to almost half the maximal value in the April oı May of the following year.

The series of weights given by the dried flesh show the same sequence in a more marked manner. It will be seen that, during one part of the year, it is possible for the mussel beds to yield two-fold the amount of foodstuff that they offer at another time.

The proportion of water to dry flesh is least from August to October, and shows an increase before and after spawning in the Spring. There is no doubt that all these differences of condition are connected directly with the reproductive cycle of *Mytilus*. In May the mussels were in a spent condition. The

* *Report on the Lancashire Sea Fisheries Laboratory*, 1920, pp. 74-84.

reproductive products, which invade and cause to swell enormously the mantle, and also every part of the body which is not occupied by organs or muscle, had been extruded, leaving behind a thin, watery, and semi-transparent animal, so emaciated in appearance in the case of the older mussels that one is almost led to wonder how they survive. The "fat" condition of the mollusc which forms such a contrast to this state of emaciation, is dependent upon the amount and conditions of the sexual products ; this is "common" knowledge to the fisherman, and a closer examination of the reproductive phases during the two years under consideration bears it out.

The spawning time of the mussels in the Morecambe Bay area has received some attention in the past. Herdman and Scott* record that in 1894, mussels matured about the middle of May and that spawning continued until the middle of July. Scott† confirms, two years later, that the mussel reaches maturity about the middle of May. So far as the Morecambe Skears themselves are concerned, Mr. Edward Gardner, Honorary Bailiff to the Lancashire and Western Sea Fisheries, has kindly given information drawn from his long experience, and which may be summarised as follows :—The main spawning time is about the middle of April, but the actual date varies slightly according to the weather. Some beds seem to ripen before others, and there may be a spawning at the back end of the year which never comes to very much and seems to be due to the younger mussels which recovery more rapidly than the older ones.

Certainly there is other evidence for this spawning later in the year,‡ but so far as the evidence of the two years under

* Herdman and Scott. *Lancashire Sea Fisheries Laboratory Report*, 1894, p. 40.

† Scott. *ibid.*, 1896, p. 5.

‡ Johnstone, *Lancashire Sea Fisheries Lab. Report*, 1898, p. 36; Ascroft, *ibid.*, p. 81.

consideration goes, it was centred round the month of Apiil. The fall in weight in the October and November of both years might suggest sporadic spawning during these months, especially as in one or two cases the mantles showed little difference in thickness from those of a spent " fish " (0·7—0·8 mm.). This thinness, however, was due to poor condition; the mantle consisted of connective tissue, and a few immature eggs or sperm sacs, and did not show the typical collapsed condition containing but a few residual ripe reproductive elements, which one associates with a spawned mussel.

The differences in the weight and condition of the samples for April and May in 1921 show that a short and thorough spawning had taken place between these two months. The spring of 1922 exhibits a less well-defined spawning period. One or two mussels of the March sample ran with spawn when being handled. Millions of fry had settled on the Morecambe Skears in mid-April, which (if the estimation that it takes about a month for the larvae to settle down* is reliable) suggests spawning in March and possibly in February.

The April sample also showed a condition where some mussels were full and others not, and it was only after examination of some shellfish sent in May that one felt sure the spawning period had come to an end.

Proteid.

The amounts of proteid have been obtained by multiplying the Kjeldhal nitrogen values by the usually accepted factor 6·25. This assumes molluscan proteid to be the same in empirical composition as that of the higher animals, and must therefore be adopted with some reservation. Factors obtained from the amount of nitrogen in fat-glycogen-ash-free substance give somewhat higher values, but they vary, and the experiments cannot be regarded as definitive. Whatever factor is

* Johnstone, *ibid.*, p. 38.

used will not alter the relative values of the proteid throughout the year, but is certain to affect the amounts of carbo-hydrates obtained by difference, and may explain, in part, the higher percentages of carbohydrates so obtained, and the corresponding glycogen estimations, in those samples where the latter were taken. Undoubtedly the percentage of nitrogen in mussel proteid is not constant.

The amount of proteid rises throughout the season from the spawning time in early spring, until the eve of the next spawning. There is a slight depression about February in both years, which seems to occur, however, in conjunction with a fall in general body weight. There seems little doubt that, on the whole, there is an increase up to the time of spawning.

From May the proteid percentage in the dry-ash-free substance slowly falls until September and October, and then rises again to a maximum in the following March. Since the actual amount of proteid is increasing when the percentage depression shows itself, this increase is obviously not proportional to the rest of the tissue during September and October, when there is a rapid formation of carbohydrate material.

Carbohydrates.

The carbohydrates differ materially from the proteid and fat as regards their variation throughout the year. There is a slow but steady rise up to the months of September and October, a tendency to form a second maximum in December of both years, and then a rapid decrease until March. The percentages of carbohydrate in the dry-ash-free substance shows essentially the same variations, and in the first year the percentage value rises again up to the spawning in April. The relative abundance and stability of glycogen in the mussel have been referred to in the previous paper, and the conclusions have been borne out by subsequent observations. Water extractions carried out in a Soxhlet apparatus upon mussels which had performed the railway journey from Morecambe, and subjected to the Mohr-Bertrand method of volumetric estimation for glucose, after precipitation of the proteids in the solution with basic lead acetate, gave no reaction. Yet the water extraction is fairly effective, as is shown by the fact that in the sample for April 1922, the solution, after inversion, gave a glycogen return of 0·862 % on the wet substance, whereas a glycogen estimation by Pflüger's short method gave a value of 0·992 % which is not much higher. In this connection it is interesting to compare the results of glycogen estimations made from the wet flesh, and then from the dried powder of the same sample: the following results are expressed as percentages on the wet substance, and were obtained by Pflüger's method except where otherwise stated.

The percentage of Glycogen in the wet substance—

	Calculated from wet flesh.	Calculated from dry powder.
June 23, 1921	4·095	2·733
Nov. 17, 1921	3·844	0·704 (water extraction)
Dec. 16, 1921	2·699	1·965 1·252 (water extraction)

Extractions from the dry material of these samples were also carried out by stirring with 0·4 % hydrochloric acid and repeated decanting through filter paper. The solution obtained failed to reduce Bertrand's solution. This suggests that the glycogen may be broken down into other material than glucose.

The question of variation in the quantity of glycogen seemed of such importance that, in spite of the labour entailed, estimations were performed for the later samples. Pflüger's method was adopted, and after inversion the glycogen was estimated as glucose, by the Mohr-Bertrand, or Benedict's method. Both of these give results which are strictly comparable, but the former was found to be the shorter, and easier of manipulation. The results obtained are given as percentages in Tables III and IV, and in all cases but one fall below the corresponding figures for the carbohydrates calculated by difference. These differences cannot be due entirely to the wrong use of a constant (such as the proteid 6·25, or that of 0·927 used for calculating glycogen from glucose) because they vary in amount.

As seen above, there is no sign of the discrepancy being due to inversion into glucose, before the samples were tested for glycogen, and this is borne out by sections, which show great quantities of glycogen, even when the tissue is not fixed until it arrives at the laboratory. It may be that there is some non-nitrogenous, organic matter present which exists in other forms than glycogen and its inverts. This is at once the most interesting, but, so far, the least conclusive part of the whole investigation. One fact which is of importance, however, emerges from the data, and that is that both the relative amounts of glycogen and carbohydrates by difference are at a maximum, on the whole, about October, and then decrease rapidly to immediately before the spawning time. This decrease in glycogen before the time of spawning is of additional interest when one studies its distribution in the tissues of the animal. MacMunn* was unable to discover glycogen in sections of the digestive gland of several invertebrates, including *Mytilus edulis*, and the study of sections of one or two mussels, fixed in absolute alcohol on the mussel beds, as well as that of many sections made from mussels after having been received at the laboratory, has led to the same conclusion. In all sections, whether from mussels fixed directly or after they have been on a railway journey, it has been possible to detect glycogen by staining with iodine and Best's Carmine after several fixatives, in changing quantities throughout the year, in the connective

* *Phil. Trans.*, 1887, part I, p. 257.

tissue of the body and mantle, in the muscle, and even the labial palps and gills, yet it has not been possible to get the same staining reactions in the "liver" itself. This means that if there is glycogen present in the organ, it is either there in such a form or in such minute quantities that methods which are successful for the demonstration of it in other parts of the body are unable to detect it in the liver.

In this concentration of glycogen in the connective tissue, as well as in the slowness of inversion in the body, *Mytilus* seems, to contrast markedly with the oyster. Mitchell* states that in the latter mollusc, glycogen is found mainly in the liver region. In the Report of the Government Chemist for the year ended 31st March, 1921, page 24, it is stated that determination of the glycogen in oysters was "carried out with difficulty owing to its rapid change to other carbohydrate matter immediately after opening the oyster."

In the light of this evidence it is interesting to compare the seasonal variations in carbohydrates of the mussel described above, with the quantity of glycogen present in samples of oysters examined throughout the year by J. A. Milroy.† Speaking of the percentages of dry glycogen in the moist animal, Milroy says: "As regards seasonal variations there is a gradual rise in the percentage from the beginning of August until the middle or end of October. This is succeeded by a fall which reaches its minimum about the middle of December. From that period onwards the percentage rises until it reaches its maximum some time between the beginning of April and early in May. The percentage then falls until it reaches its second minimum early in August."

According to Bulstrode,‡ oysters in British waters spawn

* Mitchell, *Bull. Bureau of Fisheries, U.S.A.*, XXXV., 1915-16, p. 483.

† Milroy, "Seasonal variations in the quantity of Glycogen present in samples of Oysters." *Dept. of Agriculture and Technical Instruction for Ireland Fisheries Branch Scient. Investigation*, 1907, No. IV.

‡ Bulstrode, 24th *Annual Report of Local Govt. Board*, 1894-95. Supplement, "On Oyster Culture in relation to Disease," p. 8.

between May and August, so that from Milroy's results, the percentage of glycogen rises from December to within a month or two of spawning. Mitchell* obtained glycogen in American oysters in quantities which he states to be similar to those of Milroy, and he also gives the spawning time as July and August. The rise in glycogen in late summer is similar in the oyster and mussel, but from December the variations in the two animals do not show agreement. For several months before the oyster spawns, the glycogen content of the animal is steadily rising and, although a decrease sets in before the spawning takes place, the minimum is not reached until this season is over. With *Mytilus* there is a rapid fall of glycogen from December to March, and then a tendency on the whole to a rise until the time of spawning in April. It is of the greatest interest to examine the sections stained for glycogen during this period. In September, although the mantle may be comparatively thick (2·4 mm.), there is no sign of reproductive products in the connective tissue; mantle thickness is not necessarily an index of increasing sexual maturity. The glycogen is seen as solid lumps lying in the connective tissue cells. From October onwards, the egg and sperm sacs ramify through the tissue, increasing apparently at its expense, and grow until they almost impinge one upon the other. The glycogen, along with fat globules, is seen to be wedged into the surrounding tissue. Apparently one reason why there is less glycogen now is because the sperms and eggs take up the space occupied by the former. It is to be expected that such rapidly-growing tissue requires nutriment, and there is little doubt that they obtain the latter at the expense of the fat and glycogen; but whereas the former becomes incorporated into the reproductive products, so far as micro-chemical methods are to be relied upon, there is no conclusive evidence that this is the case with the glycogen, *as such*; it is apparently converted into some other substance.

* Mitchell, *loc. cit.*, p. 481.

The eggs are quite as large a month or two before spawning as when they are extruded, and during this time when they are maturing it may be that nutrition is no longer necessary, and would explain the rise in glycogen just before the spawning period. This, along with the apparent absence or slowness of a diastatic enzyme suggests that the glycogen stored up by the sea mussel is made direct use of in the extraordinary reproductive activity of this animal.

Fat.

The amount of fat, as we have already seen, is small, and shows a steady increase up to the time of spawning. The accumulation of fats throughout the year is well shown both in frozen sections stained with Sudan III, and in tissue fixed in Fleming without acetic acid. Sections in October show fat only in certain liver tubules, and intestinal epithelium. This increases in amount, and by November the fat is beginning to show in the growing reproductive products in the body and mantle. From December onwards there is an accumulation of fat about the sperm sacs of the males, and in the eggs of the females, and this condition obtains until the spawn is extruded, after which time the fat again seems restricted mainly to the liver.

Enterochlorophyll.

The greenish yellow pigment extracted from the digestive gland of several molluscs by MacMunn*, and named by him Enterochlorophyll, is very evident in frozen sections, and also attracted attention during the extraction of fats in the Soxhlet apparatus, by giving to the carbon tetrachloride a deep green or brown colour, until the apparatus had siphoned over several times. It was noticed too that after a Pflüger glycogen estimation the pigment showed itself in the filtered liquid, and had therefore apparently resisted digesting on the water

* MacMunn, *loc. cit.*, p. 235.

bath with 60 % caustic potash. The frozen sections show that the colour and intensity differ from month to month, although the years do not repeat entirely the same conditions. The liver is a lighter green about September, and it is certain that a dark brown colour, much more intense than at other periods of the year, appears in March and April, the months which cover the reproductive period.

MacMunn concluded that the colour was secondary in nature and derived from the diatoms taken in food. List* and Dastre and Floresco† have shown that the liver can be colour-fed. This organ of *Mytilus* certainly shows most colour during the period of the plankton maximum and when the spores of algae are abundant. It is interesting to note that the amount of ash steadily increases up to the two months in question; since the amount of ingested sand and mud must affect considerably the ash estimation, this also suggests a vigorous feeding in the early spring. There is evidence that the time of most active feeding is from January to April.‡

Composition of the Mussel Shell.

Estimations for calcium carbonate and iron were carried out on shells ground to a powder in a mortar, from various samples. The water percentage was estimated from the difference in the weights of a sample of powder before and after drying to constant weight in an electric oven at 100° C.; this was carried out immediately after the grinding down of the shells. To obtain the amount of calcium carbonate present, a sample of approximately 0·5 grammes of shell powder was taken, and dissolved in dilute hydrochloric acid, after the organic matter had been removed by ignition in a crucible. The solution was made alkaline with ammonia, and then acetic acid

* List, "Die Mytiliden," *Fauna und Flora des Golfes von Neapel*, XXVII, 1902.

† Dastre and Floresco, *C. R. Ac. Sc. Paris*, T. 128.

‡ Herdman and Scott, *loc. cit.*, p. 41.

added until there was a slight excess. After heating, a boiling solution of ammonia oxalate was added, and the precipitated calcium oxalate allowed to stand overnight. It was then washed carefully with boiling water to remove any excess of ammon. oxalate and received on to a filter paper. The paper was pierced and the precipitate washed into a measuring flask with boiling water and warm dilute hydrochloric acid; sulphuric acid was then added to dissolve the precipitate completely, and to get the oxalic acid into solution. After making up to 250 cc., the solution was titrated against $n/10$ potassium permanganate, and from this titration the amount of $CaCo_3$ found.

From several estimations which were made in duplicate it would seem that the method of sampling was not to be trusted. The chitinous covering of the shell, and also its organic matrix, probably did not allow of a homogeneous mixing. It has been thought as well to give the results in Table V, with the results of a second estimation, when these were taken, in brackets.

The same error of sampling would of course apply to the iron estimations. Here 0·5 grammes of the powder was ignited, dissolved in HCl, and then the iron present was converted into the ferric state by careful addition of potassium permanganate to the solution.

The estimation was carried out colorimetrically with the aid of potassium thiocyanate, against a standard solution of ferric iron.*

* See Sutton, *Volumetric Analysis.*

Table I.

Date.	Average Weight of Shell and Flesh.		Average Weight of Shell.		Average Weight of Wet Flesh.	
	6 mussels.	Rest of sample.	6 mussels.	Rest of sample.	6 mussels.	Rest of sample.
1920						
May 21	13·1	13·0	6·9	6·9	6·1	6·1
June 10	15·8	16·4	10·0	11·2	5·8	5·6
July 7	12·0	12·5	6·2	7·4	5·9	5·1
July 26	15·8	14·2	9·9	...	5·9	...
Aug. 20	18·3	18·3	10·8	10·4	7·5	7·8
Sept. 13	18·0	17·4	10·4	9·6	7·6	7·8
Oct. 8	17·0	15·0	7·9	6·9	9·1	8·1
Oct. 29	17·6	18·9	9·4	9·6	8·2	9·3
Nov. 25	16·0	17·3	8·0	8·2	8·0	9·1
Dec. 17	20·8	20·4	8·4	8·6	12·3	11·8
1921—						
Jan. 13	19·7	17·7	9·2	7·9	10·6	9·8
Feb. 5	19·0	20·6	8·3	9·2	10·7	11·4
Mar. 2	18·7	15·8	9·5	8·2	9·2	7·6
Mar. 24	22·4	20·5	11·1	10·6	11·3	9·9
April 22	18·9	18·6	9·5	9·6	9·5	9·0
May 20	14·8	15·5	8·7	8·7	6·1	6·9
June 23	19·8	19·5	11·2	11·3	8·6	8·2
July —	...	...	...	...	...	...
Aug. 16	14·4	16·5	8·1	9·6	6·3	7·0
Sept. 15	21·4	17·1	10·9	8·9	10·4	8·2
Oct. 18	14·7	14·3	6·2	6·4	8·4	7·9
Nov. 17	15·3	16·1	6·3	5·5	9·0	10·6
Dec. 16	17·7	18·5	7·7	7·9	10·0	10·6
1922—						
Jan. 17	19·9	15·9	10·2	8·1	9·7	7·7
Feb. 17	17·0	15·1	7·3	6·5	9·6	8·6
Mar. 15	20·0	23·9	10·0	11·3	10·0	12·6
April 20	14·3	13·1	6·8	6·2	7·5	6·9

TABLE II.

Weights of six mussels from each sample.

Date.	Weight of shell and flesh.	Weight of shell.	Weight of wet flesh.	Weight of dried flesh.	Weight of water.
1920—					
May 21	75·5	41·7	36·8	5·2	31·6
June 10	94·8	60·2	34·7	5·1	29·6
July 7	72·1	37·0	35·2	5·7	29·5
July 26	94·9	59·4	35·4	7·1	28·3
Aug. 20	109·7	64·6	45·1	9·9	35·2
Sept. 13	107·9	62·5	45·4	10·7	34·7
Oct. 8	101·6	47·1	54·5	10·9	43·6
Oct. 29	105·7	56·6	49·1	10·3	38·8
Nov. 25	96·0	48·1	47·9	9·4	38·5
Dec. 17	124·6	50·5	74·1	13·0	61·1
1921—					
Jan. 13	118·4	54·9	63·5	12·0	51·5
Feb. 5	114·0	49·8	64·2	11·2	53·0
Mar. 2	112·2	57·2	55·0	10·0	45·0
Mar. 24	134·5	66·8	67·6	11·3	56·3
April 22	113·6	56·9	56·7	11·4	45·3
May 20	88·6	51·9	36·7	5·4	31·3
June 23	118·7	67·0	51·7	8·8	42·9
July —	...	...	...	...	...
Aug. 16	86·4	48·7	37·7	7·5	30·2
Sept. 15	128·1	65·7	62·4	12·5	49·9
Oct. 18	88·0	37·5	50·5	10·0	40·5
Nov. 17	91·9	37·8	54·1	10·2	43·9
Dec. 16	106·5	46·3	60·1	11·2	48·9
1922—					
Jan. 17	119·4	61·1	58·3	9·2	49·1
Feb. 17	101·7	43·9	57·8	8·9	48·9
Mar. 15	120·0	60·0	60·0	11·4	48·6
April 20	85·8	40·7	45·1	7·6	37·5
May 13	82·9	42·3	40·6	...	...

TABLE III.

Percentage composition of the wet substance.

Date.	Water.	Dried flesh.	Proteid (N 6·25).	Oil (Carb. tetrach. extract).	Ash.	Carbo-hydrate (by difference).	Glycogen (Pflüger).
1920—							
May 21	85·9	14·1	8·2	0·6	0·9	4·4	...
June 10	85·4	14·6	8·5	0·5	1·2	4·4	...
July 7	83·9	16·1	8·6	0·7	2·3	4·5	...
July 26	80·1	19·9	10·8	1·2	1·5	6·4	...
Aug. 20	78·0	22·0	11·8	1·5	1·6	7·1	...
Sept. 13	76·5	23·5	12·5	1·5	1·7	7·8	...
Oct. 8	80·1	19·9	9·7	1·3	2·1	6·8	...
Oct. 29	79·0	21·0	11·0	1·4	1·9	6·7	...
Nov. 25	80·3	19·7	10·8	1·6	1·9	5·4	...
Dec. 17	82·4	17·6	9·1	1·1	1·8	5·6	...
1921—							
Jan. 13	81·1	18·9	11·7	1·5	0·2	5·5	...
Feb. 5	82·6	17·4	10·7	1·3	1·8	3·6	...
Mar. 2	81·8	18·2	11·7	1·5	2·4	2·6	...
Mar. 24	83·3	16·7	10·9	1·6	2·1	2·1	...
April 22	80·0	20·0	12·0	2·1	2·4	3·5	...
May 20	85·4	14·6	8·6	0·7	2·2	3·1	...
June 23	83·0	17·0	8·6	1·1	2·7	4·6	4·1
July —	...	...	...	...	...	...	...
Aug. 16	80·1	19·9	10·6	1·6	1·9	5·8	...
Sept. 15	80·1	19·9	9·8	1·3	1·7	7·1	2·5
Oct. 18	80·3	19·7	10·1	1·0	2·5	6·1	6·6
Nov. 17	81·2	18·8	9·7	1·2	2·4	5·5	3·8
Dec. 16	81·4	18·6	10·2	1·5	1·9	5·0	2·7
1922—							
Jan. 17	84·2	15·8	9·6	1·0	1·8	3·4	1·3
Feb. 17	84·6	15·4	9·6	1·2	2·2	2·4	0·5
Mar. 15	81·1	18·9	11·9	1·2	3·5	2·3	0·2
April 20	83·2	16·8	9·8	1·3	3·8	1·9	1·0

Table IV.

Percentage composition of the dry, ash-free substance.

Date.	Proteid. (6 × 25)	Oil. (Carb. tetrach. extract).	Carbohydrates (by difference).	Glycogen (Pflüger).
1920—				
May 21	62·3	4·7	33·0	...
June 10	64·1	3·9	32·0	...
July 7	62·4	5·2	32·4	...
July 26	58·7	6·8	34·5	...
Aug. 20	57·8	7·2	35·0	...
Sept. 13	57·3	6·9	35·8	...
Oct. 8	54·6	7·0	38·4	...
Oct. 29	57·7	7·5	34·8	...
Nov. 25	60·5	9·3	30·2	...
Dec. 17	57·6	7·2	35·2	...
1921—				
Jan. 13	62·3	7·8	29·9	...
Feb. 5	68·7	8·1	23·2	...
Mar. 2	74·1	9·7	16·2	...
Mar. 24	74·2	10·7	15·1	...
April 22	68·1	12·1	19·8	...
May 20	69·3	5·4	25·3	...
June 23	59·7	7·4	32·9	28·5
July —	...	...	...	...
Aug. 16	58·7	9·0	32·3	...
Sept. 15	54·0	6·9	39·1	13·8
Oct. 18	58·5	6·0	35·5	38·6
Nov. 17	58·7	7·5	33·8	23·4
Dec. 16	61·2	9·0	29·8	16·1
1922—				
Jan. 17	68·8	7·4	23·8	9·2
Feb. 17	73·0	8·9	18·1	4·3
Mar. 15	77·0	7·6	15·4	1·4
April 20	75·7	10·2	14·1	7·6

Table V.

Percentage composition of the shell.

	Undried Shell.	Dried Shell.		
	Water.	$CaCO_3$.	Fe.	Organic matter, etc.
1920—				
Oct. 29	1·07	96·90	0·05	3·05
Nov. 25	0·95	95·27	0·10 (0·08)	4·63
Dec. 17	0·67	95·75	0·18 (0·13)	4·07
1921—				
Jan. 13	0·74	95·31	0·08 (0·06)	4·61
Feb. 5	0·90	95·35 (98·39)	0·07 (0·07)	4·58
Mar. 2	0·93	95·31 (96·69)	0·08	4·61
Mar. 24	0·74	94·90	0·04	5·06
April 22	0·77	95·31	0·02	4·67
May 20	0·66	95·74	0·05	4·21
June 23	0·73	96·90	0·04 (0·05)	3·06
Aug. 16	0·84	98·06 (95·43)	0·007	1·93
Sept. 15	3·34	95·79	0·002	4·21
Oct. 18	1·20	99·38	0·007	0·61
Nov. 17	0·79	98·05 (96·29)	0·007	1·94
Dec. 16	1·01	98·22	0·01	1·77
1922—				
Jan. 17	0·92	97·31	0·02	2·67
Feb. 17	0·87	99·26	0·008	0·73
Mar. 15	1·29	98·25	0·007	1·74
April 20	0·82	97·27	0·003	2·73

DISEASES AND PARASITES OF FISHES.

By JAS. JOHNSTONE, D.Sc.

CONTENTS.

Septic Ulcers in Cod and other Marine Fish : Malnutrition of North Sea Fishes in 1921.

Between September, 1921, and March, 1922, a number of specimens of diseased cod and other marine fishes were received : all of them were taken in the S.W. part of the North Sea. The sendings were : 27th Sept., 1921, codling ; 24th Oct., cod ; 27th Oct., cod ; 4th Nov., cod ; 7th Nov., cod, 2 plaice ; 17th Nov., 2 plaice, codling, haddock ; 24th Nov., cod ; 28th Nov., plaice, sole ; 20th Jan., 1922, cod ; 14th Jan., cod. All these fish were taken inshore, or at a greatest distance from the land of about 60 miles.

The same general affection was displayed by all these fishes. There were large, shallow ulcers on the surface of the body, destroying the skin and eating down into the flesh to a depth of about one quarter of an inch. In most cases there were several ulcers, or sores, and usually on both sides of the fish. In several cases there was healing—this I refer to later on. Sometimes there were red, highly-inflamed patches on the skin, without erosion of the latter. In other cases there were places where there was no ulceration, but where the scales were apparently raised up and swollen, and with swellings in the skin below the scales.

Usually the fish were in " poor " condition, or were "slinks," and in several cases there was extreme emaciation. This was especially characteristic of one of the plaice—where, however, there was healing of the ulcerated sores. In some of the cod the emaciation, particularly on the head and shoulders, was very great. In two cod there were other malformations, a shortening of the length of the fish relative to its girth. This was due to a twisting of the backbone, the latter having a slightly spiral shape.

The general appearance of the ulcers is, of course, highly variable. Sometimes they are little more than inflamed spots on the skin, but as a rule there is complete destruction of the latter over a greater or less area. When this occurs there is a typical "sore," the boundary of the ulcer being rather sharply marked and its floor being formed by the underlying body muscles, the skin being completely destroyed. Thus there is a shallow cavity of irregular shape, partially filled with pus and products of necrosis, including much blood. The ulcer is never very deep, though occasionally there are small pits going down into the muscles. Generally the edges are highly inflamed, and the inflammation often extends over the whole floor of the shallow cavity, though sometimes the colour of the latter may be yellow-white. Beneath and round the eroded area there is always a margin of inflamed skin or muscular tissue.

In the plaice examples all stages of healing were observed. One fish was very greatly emaciated, the skin, in some places, "clinging to the bones." There was an ulcer of about 3 inches in diameter on the coloured side, but the greater part of this had healed over and there had been regeneration of tissue. Near the centre were the remains of the ulcer, as a cavity about an inch in diameter, at the bottom of which several vertebræ, with their hæmal species, only very lightly covered with colourless connective tissue. The whole area was thus skinned over, and the greater part of this new skin was pigmented quite normally. In another plaice the process had gone still further and, though the ulcerated cavity had not completely filled up, the edges had smoothed down and the pigmentation had, except for two small white spots, been completely restored. This was on the coloured side of the fish: on the colourless side was a patch of skin about an inch and a half in diameter where there had been an ulcer. This was level with the rest of the skin and of the same colour. In all these cases of healing it is notable that there was no regeneration of the scales. It would appear that, once destroyed in a fish, these structures are not formed again.

Often the first indications of the lesion are the apparent swellings of the scales. Underneath a small patch of the latter there is an obvious thickening, and the margins of the scales become loosened so that their outlines are the more easily seen. Each scale lies in a sort of dermal pocket and is covered over with epidermis, and all these structures share in the general disintegration of tissue which is the result of the inflammatory process.

On the whole, then, the sores are very obvious, very familiar, in a kind of way, and are so repulsive that they are, of course, sufficient to ensure the instant rejection of the fish as an article of food.

Sections were made of various parts of the ulcers, including the edge, and other lesions where the surface was unbroken, but where there was a region of inflammation beneath the skin. Smears from the pus on the open sore were made and stained, and these showed numerous bacteria, which had, of course, infected the sore after the latter had been formed. Staining of the sections so as to demonstrate the presence of bacteria had very variable results: in some cases the latter could not be detected. What was seen were only abundant leucocytes, blood corpuscles, and broken-down tissue in general. Round the margin of the ulcer there is a kind of ring of connective tissue crowded with small, round leucocytes and containing an abundant blood supply. That is all that can sometimes be found. In other sections, however, even when the surface of the skin is not eroded, but where there is only inflammation, the presence of micro-organisms can be seen. There are apparent spaces in the sub-dermal or dermal tissues filled with small bacilli, very evident when the section has been stained only with carbol fuchsin. Except for these, and a richer blood supply than ordinary, there may be no evidence of a pathogenic condition. In other cases there are plenty of bacilli lying among the leucocytes in the marginal parts of the sores, even although none may be found in the pus in the central parts. Evidently, then, we have to deal with infections —the ulcers may be regarded as generally septic ones in spite of the condition that, in some cases, the micro-organisms are difficult to detect. There was no opportunity for making cultures, or for studying the living fish. This kind of investigation demands an amount of time and special training which we are, as yet, unable to give to the work. The only special tests that were made were those for acid-fast bacilli, and in no case were such successful.

The interest of these specimens of ulcerated cod and other fishes was increased because of various circumstances. The number of diseased fish occurring in the North Sea arrested attention during the last winter. Thus : " The skippers report that they have never known such a year as the present one for poorness in the quality of fish and the number of fish seen with sores. They report that the sea is extremely dirty at all places. It may be of interest to you to know that the herrings landed this season at Yarmouth are all of very poor quality, having the appearance of being starved." Again, " The general condition of the cod caught in the deep water has been extremely poor. The majority of the fish are poorly furnished and are termed ' slinks '."

The North Sea herrings were also abnormal in quality in 1921. Thus a packer of tinned herrings of high grade says: "This year's pack has something the matter with it. The flesh of the fish is grey to brown instead of light, like a chicken. The liquor in the tin is watery and dark and bitter instead of light, thickish, and pleasing to smell and taste." These defects, it must be understood, were comparative ones, for even this 1921 pack of herrings were, to the ordinary person, of very high quality. Nevertheless, to the trained eye and palate the result of the packing operations was inferior to that of 1920. Why?

What one heard about was, on many sides, the "still and dirty" water (which meant unusually large quantities of plankton organisms). The abundance of oil was also blamed, and the mines and dumped explosives which were "exuding their filthy, deleterious chemical compounds to the detriment of the plant life upon which the little animals forming the herring's food, feed."

It is, of course, quite impossible to say, with the information that we have, whether the general poverty of nutrition characterising many fish, at certain times of the year, was due to any one, or several of the suggested causes. The ulcerated cod which are described here *may* have been such because of some form of poisoning due to the presence of products of decomposition of explosives. Not all these sores were septic, and in some there was little indication of organisms in the pus. It is possible to produce a septic pus by the local action of various chemicals, such as mercury and copper and their salts, and so some of the ulcerated fish may have become so by such means. Still other sores were certainly septic, so that, on the whole, it is not possible to state definitely what were the causes of the lesions.

Various Fish Tumours.

(1) A Benign Tumour in the Plaice.

A plaice of 16½ inches long, a female in very fair condition, was sent to us by Mr. King, the Collector of Statistics at Yarmouth. The fish has a very typical tumour on the dorsal fin, on the coloured side. The growth is about 3½ cms. in diameter, and is raised up from the general surface of the fin about 3 cms. It is nearly spherical, except that it is a little flattened in the same plane as that of the fish. It is pigmented very much in the same way as the fin and there are several very noticeable blood vessels running just beneath its surface. It is firm, but elastic. It has all the appearance of a human "wen," such as one sees sometimes on a man's neck, except that the fish tumour has a rather narrow attachment to the part on which it is situated.

Sections show the structure to be that of a typical fibroma. At the periphery there is no proper skin, resembling that of the fish: whatever cuticle there is is rather transparent. Beneath the surface there is a layer of strong elastic tissue and on the surface itself this merely becomes rather more compact than it is in the deeper layers. There is a very definite "capsule" made up of this dense elastic tissue, and below this, and occupying the central part of the tumour, there is a loose connective tissue, the fibres of which are wavy, but run, on the whole, in laminæ concentric with the surface. Here and there are a few small blood vessels and capillaries, and sometimes a few rounded, connective tissue cells, but otherwise the histology presents no remarkable features.

(2) Sarcoma in a Haddock.

The specimen described here was sent to me by Mr. F. Stokes, Port Sanitary Inspector at Grimsby. It was a haddock of large size caught by a Grimsby codman and landed at that port. It is of some interest because very much the same kind of affection has been seen in several cod, and it is important to ascertain whether or not such conditions are of exceptional occurrence.

The fish was much emaciated, so that, as might be expected, the presence of a large, malignant tumour has a considerable influence on the conditions of health. In such cases as this we may expect some diffusion, through the body, of the products of the growth. This, I take it, is the justification for the condemnation, as articles of human food, of fish suffering from malignant, " cancerous " growths.

The growth in question is situated on the top of the head, above and behind the eyes. It is represented, about half natural size, in Fig. 1. There are two principal tumours, or

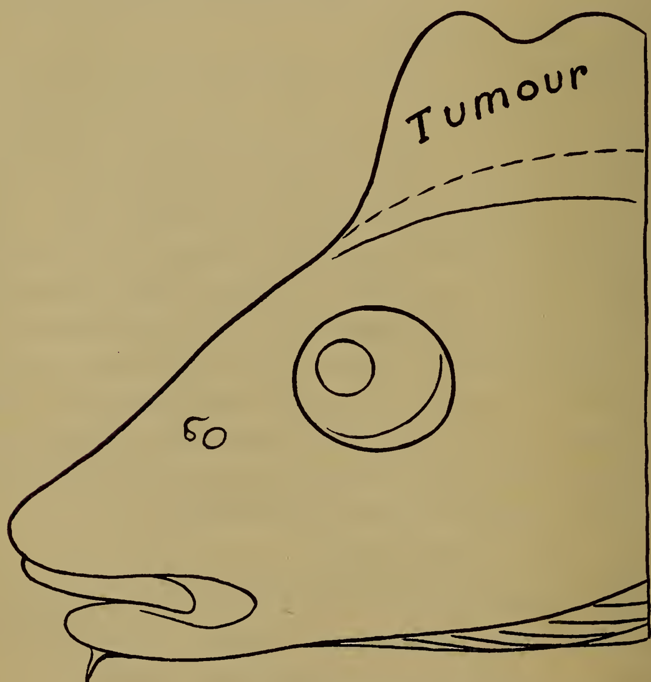


FIG. 1.

centres of growth, and these have run together. Cutting down into them we find a general softening, or necrosis, and this has gone so far as to lead to a breaking through the surface at the top of the foremost growth. There is a peripheral zone of firm tissue, but internal to this the tumour is semi-liquid in consistency.

The histology is represented, under a magnification of about 10 diameters, in Fig. 2. The figure represents a section taken

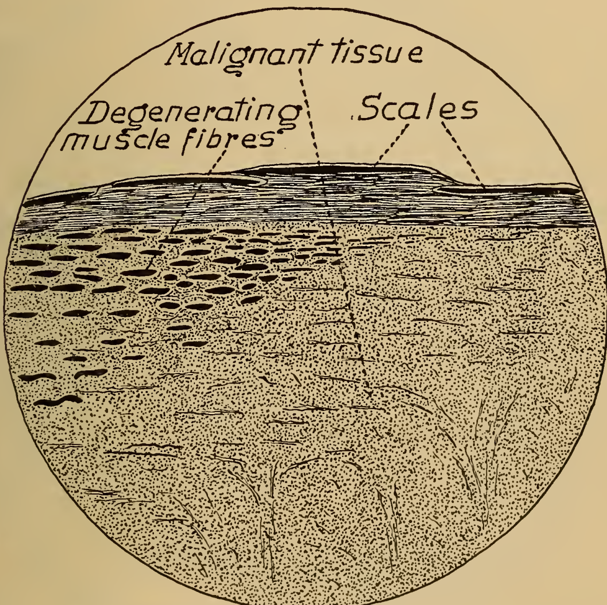


Fig. 2.

at the margin of the tumour, that is, at the growing part. The skin is shown diagrammatically, with several scales in position, each in its epithelial pocket. Below these is the dermis, here a rather thick, fibrous layer. To the right of the part represented in the figure this dermal layer thins out and the scales disappear, though the ordinary pigmentation of the skin remains. At the central part of the tumour the integument, so altered, becomes very thin and finally breaks through at the region where the internal part of the tumour is undergoing necrosis.

Cutting down into the latter, along its middle line, we find this general liquefaction, and the necrosed contents rest directly on the bones of the skull. In the firmer parts we have the fibroid type of structure—fine fibres running in various directions and, here and there, a few round cells. The latter, however, do not characterise the histology, which is of the nature of that seen in fibromata rather than in sarcomatous growths. The malignancy is evident, however, when one looks at the growing margin. On the left-hand side in Fig. 2 are a number of isolated muscle fibres, here cut obliquely: in a section of this region in a normal fish there would be a thick layer of muscle bundles running in various directions. Here, however, these are degenerate and are represented only by detached fibres, becoming fewer as the tumour is approached. The malignant tissue is represented by fine stippling in the figure, and this is seen infiltrating the muscle tissue, intruding between the fibres. It is, as in all other fish sarcomata that I have seen, this intermuscular connective tissue that takes on the conditions of malignancy and gives rise to the sarcomatous tumours.

Cestode Degeneration Cysts in Trout.

The viscera of a 10-lb. yellow trout were sent to me by Mr. J. Ritchie, of the Perth Natural History Museum. These structures contain a number of cysts which are so very remarkable that a description may be interesting even although the parasites responsible cannot now be identified.

The peritoneum over the liver and pyloric cæca bear a number of little oat-shaped bodies which look almost like seeds. They are about 4 or 5 by 8 to 10 mm. in their lesser and greater diameters. They have a kind of papery lustre and are hard. Some of them appear to be embedded in the liver, but they can generally be separated, when it is seen that they are attached to the peritoneum by slender pedicels.

They are easily cut. Fig. 3 represents a transverse section through one of them. At first sight the appearance is very

FIG 3.

puzzling, but on dissecting a cyst one finds that a firm nucleus can easily be "shelled out." Then the nucleus can easily be dissociated into two or four collapsed thin-walled cysts that were evidently spherical when they were in their original condition. So Fig. 3 shows four of these cysts, crumpled together by mutual pressure and fitting into each other, so to speak, in the way shown in the section.

The outer wall of the whole cyst is fibrous in structure with a thin, external serous layer, and among the fibrous layers there are a few blood vessels. This part, therefore, belongs to the host. The fibrous layers send inwards a few trabeculæ between the secondary cysts, but apart from this there are no other tissues. The internal, secondary cysts have walls of quite a different nature, these consisting of an apparently homogeneous substance (it is represented by the thick black bands in Fig. 3. It may be called "elastic tissue," though it is not exactly like this. It is yellow in colour. Within these secondary cysts there is nothing but an unrecognisable cell debris containing much oil, which tends to coalesce in droplets when the cyst is opened and scraped out. No remains that can be ascribed to known parasites can be identified—no hooks, spines, or calcareous corpuscles. This is rather a difficulty in assuming that we have to deal with a degenerate cestode larvæ, for the hooks and spines are very persistent. Still, the parasite may not have had any skeletal structures and the calcareous corpuscles may have been dissolved for the specimen had been kept for nearly two years in spirit and part of it was fixed in an acid preservative.

A taxidermist who had the fish supposed that the cysts were ova that had been eaten by the fish, but this is obviously not the case. Nor are they ova that have not been extruded for there is no trace of egg structure. It is exceedingly likely that they are really small groups of Plerocercoid larvæ which have degenerated. In many fishes there are collateral life-histories for the contained Cestode and Trematode parasites: that is, there is an infection arising by the fish eating some animal which contains the larvæ of the Cestode. Now the latter has usually "definitive" hosts, one which contains the larvæ and which is eaten by the definitive final host, where the

Cestode comes to sexual maturity. If, however, other fishes than the definitive final host become infected the life-history of the Cestode cannot be completed, and the larvæ develop no further than the Plerocercoid stage, which finally dies and degenerates. But in so doing there is some reaction on the part of the collateral host. That is, there is often some kind of covering laid down by the tissues of the host and this may take extraordinary forms, as for instance, when typical pearl-like bodies are formed round the unrecognisable remains of a parasite of some kind. This is what has, no doubt, happened in the specimens we have. Plerocercoid larvæ of tetrarhynchid tapeworms are very common in many teleost fishes, where they appear as little cyst-like bodies attached to the peritoneum. In teleosts the development of a Plerocercoid larva ends the life-history of the *Tetrarhynchus*, which then dies and degenerates; but in rays and dogfishes the larva completes its metamorphosis, gets into the intestine and becomes a sexually mature Cestode. Here, then, we doubtless have some Cestode (but evidently not a *Tetrarhynchus*) which has so entered a *cul-de-sac* in its life-history, has died, become invested in a cyst wall which shields the host from its further reaction, and so gives rise to these peculiar bodies.

The "Oyster Parasite," *Gasterostomum gracilescens*.

This is the well-known *Bucephalus haimeanus*, Lacaze-Duthiers.* We have found it already in this district, but never in such a heavy infection as in this case. It occurred in cockles that were being dissected in a vacation Biology course, held at the Piel Laboratory in August, 1921. The infected molluscs were bright yellow in the upper part of the visceral mass, and out of 55 specimens examined 3 were infected. The

* See Miss Lebour, "A Review of the British Marine Cercariæ," *Parasitology*, Vol. IV, No. 4, 1912, p. 424.

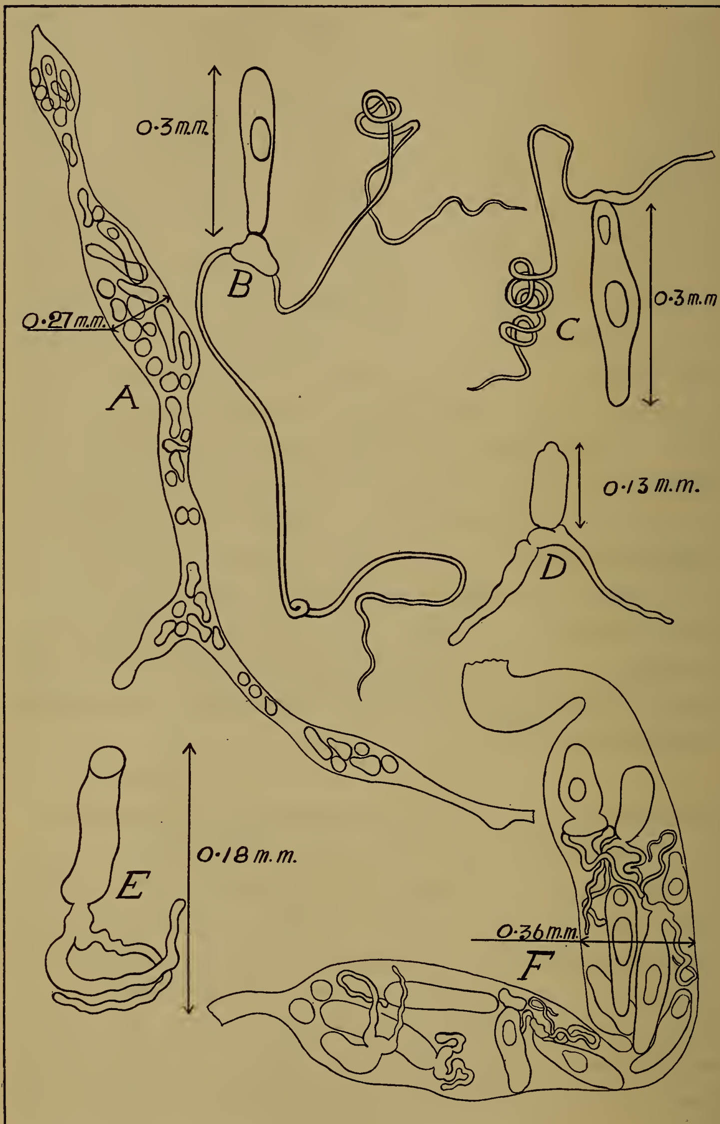


FIG. 4.

parasites occur in long, greatly-tangled, tubular and branching sporocysts. These are represented in A and F, Fig. 4. They are full of larvæ in various stages of development, but these are rather more numerous than are shown in the figures. The fully-developed Cercariæ are represented in Fig. 4, B and C, and less mature ones are shown by D and E. The body of the worm is covered by very closely set spines, arranged in transverse rows. The tails are extremely long and highly mobile, retaining this mobility for some time even after they have been accidentally detached from the body. The living sporocysts and larvæ make most interesting objects, but apart from their occurrence there is nothing remarkable to record about them. Except for the very long tails their characters are just such as have been described by Miss Lebour.

A Myxosporidian from the Hake.

In February of this year, Dr. Hanna, Port Medical Officer for Liverpool, sent me the head of a large hake which exhibited several tumours. There were three of the latter: one situated just in front of each orbit and the third exactly between the other two and on the roof of the skull. Each was about an inch in diameter and was raised above the general surface by about half to three-quarter inch. As usual the skin was much broken over these tumours. Cutting down into them it was found that they were cartilaginous and that each was full of little opaque specks, about one-half a millimetre in average diameter. This, of course, at once suggested the nature of the tumours—hypertrophy of the cartilage of the head due to an extensive infection by a Myxosporidian parasite. In the Twelfth Annual Report of this Laboratory (for 1903, pp. 46-62), Dr. H. M. Woodcock described various Myxosporidian parasites from local fishes, including one from the cartilage of the auditory

Capsule of a plaice: this he called *Sphærospora platessæ.* In a later report (No. 15, for 1906, pp. 207-208) Dr. Woodcock describes another Myxosporidian which occurred in the sclerotic of the Norway Pout, *Gadus esmarkii*, and this he called *Myxobolus esmarkii.* Since then we have found that similar Myxosporidia are not at all uncommon in the cartilage of the auditory capsule of whiting and cod, and these parasites are probably identical with the latter one characterised by Dr. Woodcock.

In the hake described here the sclerotic of one eye is heavily infected with the Myxosporidian cysts in a way that is quite similar to that seen in the specimen of *Gadus esmarkii* referred to above. Not only so, but almost everywhere in the skull; wherever there is cartilage the same condition exists. There are blunted projections into the mouth, and on cutting into these they are seen to be cartilaginous and to contain numerous Myxosporidian cysts. Evidently we have to deal with a very heavy infection.

Rough sections were made of the tumours on the head and these were found to consist of a fibrous cartilage. Round each cyst there appeared to be a thin limiting membrane, but there was no fibrous capsule. However, the fixation had been a simple, weak formalin one, and so the preservation was too imperfect to admit of close study of the histology.

Fig. 5 shows two of the spores. A is stained with Mann's methyl-blue-eosin and B with carbol fuchsin. The spores are lenticular in shape, but very nearly spherical (10 by 9 μ) when seen on the flat. There are two oval polar capsules, each measuring about 4 μ in longest diameter. There is a large iodinophilous vacuole. The fixation was so imperfect that none of the stains (Mallory and also hæmalum were used) were able to demonstrate the nuclei. No polar filaments could be seen.

So it is perhaps risky to attempt to identify the organism, but it may be safe to place it in the genus *Myxobolus*; and it resembles the form called *M. esmarkii*, by Woodcock, so closely that it is not improbable that such is its species.

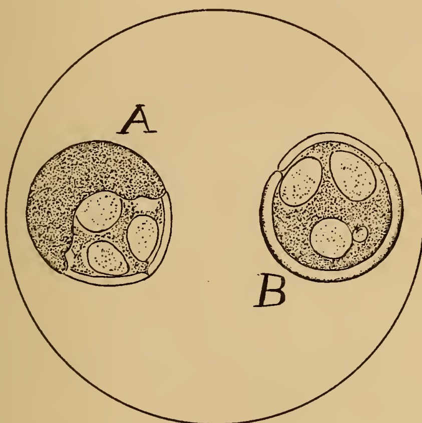


FIG. 5.