No. IX.

REPORT FOR 1900

ON THE

LANCASHIRE SEA-FISHERIES LABORATORY

AT

UNIVERSITY COLLEGE, LIVERPOOL,

AND THE

SEA-FISH HATCHERY, AT PIEL.

DRAWN UP BY

Professor W. A. HERDMAN, D.Sc., F.R.S.,

Hon. Director of the Scientific Work:

Assisted by Mr. ANDREW SCOTT and Mr. JAMES JOHNSTONE.

WITH NINE PLATES, AND OTHER ILLUSTRATIONS.

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1901.

Report on the Investigations carried on during 1900 in connection with the Lancashire Sea-Fisheries Laboratory at University College, Liverpool, and the Sea-Fish Hatchery at Piel, near Barrow.

Drawn up by Professor W. A. Herdman, F.R.S., Honorary Director of the Scientific Work; assisted by Mr. Andrew Scott, Resident Fisheries Assistant at Piel, and Mr. James Johnstone, B.Sc., Fisheries Assistant at Liverpool.

With Nine Plates, and other Illustrations.

Contents.

Introduction and General Account of the Work.

In the main the work of the past year has been similar in its nature to that of the previous one, and has consisted in:—

(1) The hatching operations and other work carried out at Piel by Mr. Andrew Scott;

(2) Laboratory investigations by Mr. Johnstone at Liverpool;

(3) Certain observations at sea taken from the steamer, at Piel, at the Isle-of-Man, and at various other points in the district, by Mr. Dawson, Mr. Ascroft, and others—all discussed and reduced to order at the Liverpool Laboratory;

(4) The work of the circulating Fisheries Exhibit;

(5) Practical laboratory classes at University College, Liverpool, for fishermen; and

(6) Various memoranda and reports that I have had occasion to address to the Chairman and Committee during the year.

I shall remark upon some of these matters here, and the others will be treated more fully in the separate sections which follow. Last year I commenced the plan, which I hope to be able to adhere to, of having in each annual report a detailed account of some animal of local economic importance. It was then a memoir on the common Cockle, by Mr. Johnstone; this time it is a full account of two closely allied and very important Fish-Parasites, *Lernæa* and *Lepeophtheirus*, by Mr. Scott; while next year it will be the memoir on the Plaice by Mr. Cole and Mr. Johnstone, for which the plates are already drawn. Mr. Scott's remarks upon the effect which the fish-parasites have on their hosts, and upon their nutrition and mode of life, will be found of interest. The preparation of this account of the fish-parasites has occupied a large portion of Mr. Scott's time during that period of the year when hatching operations were not in progress.

An account of the hatching work will be found at p. 31. The plan of storing up spawning fish* in the tanks in place of trusting to the steamer for supplies has been most successful, and the increase from the three and a half millions of the previous year to fourteen millions of young fish set free this year is most satisfactory. For the rest, Mr. Scott's time has been filled up by collecting and observing, by giving demonstrations to parties of fishermen, by experiments with shellfish, and by various other pieces of useful work. The determination of the spawn-

* We had over 100 adult flounders in the tanks. I see from the Report of the Scottish Sea Fishery Board that in their first year's work at their new hatchery at Aberdeen they had 400 spawning plaice, from which over 16 millions of fry were hatched. The female flounder, however, produces about three times as many eggs as the plaice.

ing times and the habits of the mussel at Piel will be found on p. 36.

Mr. Johnstone's time—in addition to helping me with general work, correspondence, the examination of any specimens that arrive, the preparation of "memoranda" throughout the year, and of this Report—has been largely taken up with arranging and superintending the removal of the travelling Fisheries Exhibit from place to place. The packing and unpacking of specimens, the renewal of labels, &c., takes up a good deal of the time of both Mr. Johnstone and of the fisheries laboratory boy, W. Raw.

The Exhibit, it will be remembered, after being at Liverpool, Salford, Preston and Bolton, was at University College in the winter of 1899-1900. In March it was removed to St. Helens, where it remained at the Public Museum till November. The Curator, Mr. Alfred Lancaster, has sent me a letter on behalf of his Museum Committee, tendering their thanks to the Lancashire Sea-Fisheries Committee for the loan of "the very interesting and instructive collection of Sea-Fisheries Exhibits." He states further that "the exhibition was visited by upwards of 16,000 persons," and he refers to the use which school teachers made of the exhibition as the subject of object lessons.

It will be remembered that a couple of years ago some desire was expressed to have the exhibit at Barrow, but negotiations eventually broke down. Mr. Scott has since suggested that if the cases were exhibited for a time in the large laboratory at Piel, that might serve for visitors from Barrow and from the neighbouring fishing villages. Accordingly in November the collection was transferred to Piel, and is now on exhibition there.*

* Any other Museums or public Institutions desiring to have the Fisheries Exhibit on loan should apply for a copy of the conditions and regulations.

During the past year the following have occupied work places in the laboratory at Piel for the purpose of carrying on Zoological investigations:—

Dr. F. W. Gamble, Owens College, Manchester.
Working at Crustacea.

Dr. J. T. Jenkins, University College, Liverpool.
Working at digestive glands of Oyster.

Mr. F. H. Smith, B.Sc., Barrow-in-Furness.
Working at Algæ and Diatoms.

Mr. J. E. Turner, B.A., Barrow-in-Furness.
Working at Marine Zoology and Fisheries.

Mr. John Graham, B.Sc., Barrow-in-Furness.
Working at Marine Biology and Physics.

These gentlemen have sent me short reports upon their work, in which they express their thanks to the Committee and their appreciation of the facilities given by the institution and the help rendered by Mr. Scott.

Parties of fishermen from Bardsea and Baicliff have been brought on various occasions by Rev. R. B. Billinge and Rev. Dr. Hayman, when explanations and demonstrations were given by Mr. Scott and Mr. Johnstone. Many other visitors, more or less connected with fisheries and scientific work, including Mr. A. Milman, C.B., Mr. J. B. Feilding, Mr. J. Fell and other members of the Sea-Fisheries Committee, and the members of the Barrow Field Naturalists' Club, have been shown over the establishment, and have had the operations explained to them.

I regret that the applications for the two £60 Scholarships for higher education in Fisheries Science, each tenable for two years at University College, Liverpool, which had been offered by the Lancashire County Council, were most unsatisfactory. Only one candidate applied, and from his defective preliminary education he was evidently quite unsuitable. This unfortunate result was apparently due to want of information among the higher schools in the county of the advantages to be derived from these scholarships. Several suitable candidates were heard of when it was too late. Considering the increase of work and of interest in Marine Biology and its application to Fishery questions of late years, it will be very unfortunate if this important experiment is allowed to lapse merely because of the absence of candidates in the first year, before the scheme was sufficiently known.

In addition to these scholarships, the County Council granted last year a sum of £100 for studentships to enable fishermen to undertake a short course of practical instruction in the Zoological Department at University College, Liverpool. It was, after careful consideration by a Committee, decided to send 20 elected fishermen representative of different centres and branches of industry, to University College; each to have a fortnight's instruction, and the sum of £5 to be paid to each man to cover his travelling expenses and board and lodging, and to reimburse him to some extent for what he might have lost by not following his ordinary vocation during the two weeks. These laboratory classes were held in February and March, 1900; and the main part of the work was carried on by Mr. Johnstone under my personal direction and supervision. The course was divided up into ten days, the work upon which was as shown in the following sections:—

1. The Common Mussel.—Structure (especially in regard to feeding, breathing, reproducing and habits), spawning and life-history.
2. Haddock.—Structure, feeding, breathing, spawning, and life-history.
3. Crab, Prawn, Shrimp and Lobster.—Habits, food, eggs, reproduction and life-history.

4. Surface Life of Sea.—Townet gatherings, fish eggs, diatoms, copepoda.
5. Fisheries Museum.—An examination of the cases in the museum at University College.
6. Edible Mollusca.—Oyster, cockle and mussel.
7. Fish Parasites.—External and internal, and their hosts.
8. Fish Structure.—Cod—Also stages of growth and changes in reproductive organs.
9. Food of Fishes.—How to examine fishes' stomachs and determine principal food matters.
10. Eggs and Larval Stages of Fish.—How to distinguish them and where they are found. Also eggs of Shell-Fish and Crustacea.

The whole course was made entirely practical in character. Each man examined everything for himself. The course was preceded by an introductory address by myself, and I finished it with a short concluding lecture.

The Committee may like to have recorded here the list of those who attended this first laboratory class for fishermen. It is as follows: —

In February—

John Wright, Southport.
William Wright, Southport.
George Alexander, Morecambe.
Luke Woodhouse, Morecambe.

In March—

Walter Baxter, Morecambe.
Robert Gardner, Morecambe.
James Allan, Morecambe.
Thomas Wilson, Morecambe.
Edward Woodhouse, Morecambe.
John Wright, Southport.
Albert Robinson, Southport.

John Rigby, Southport.
R. Rimmer, Marshside.
R. Ball, Marshside.
W. Houldsworth, Marshside.
John Hardman, Lytham.
Thomas Clarkson, Jun., Lytham.
John Parkinson, Lytham.
Robert Wright, St. Annes.

Mr. Dawson has already reported as to the way in which the men appreciated these practical classes, and he has now written to me of the benefit which, in his opinion, the studentships were to the fishermen. He says: "From Morecambe, Lytham, St. Annes, and Southport and the district I have heard the work spoken of with praise, and how satisfied the men were. I have also had several enquiries as to when more classes would be held, as the men wanted to go to them." And again, "On all sides I am informed that the fishermen were most interested in the work, and that if any more studentships are offered the difficulty will be not to get men to go, but to choose from amongst the number of applicants."

In October some questions arose in regard to the condition of the Oysters on the bed at the mouth of the Ogwen River, near Bangor, so I arranged that Mr. Andrew Scott, from Piel, should visit the locality, take certain observations, and bring back samples of oysters, of deposits, of water and of microscopic food materials in the neighbourhood of the bed, for examination in the Liverpool Laboratory. Mr. Scott carried out his inspection on October 9th, along with Mr. Jones, the Head Bailiff of that division, and brought back material which I examined with him. The oysters are *Ostrea edulis* in various stages of growth (from one to three inches in diameter), and are evidently living and reproducing between tide-marks. Many were attached to stones. It is consequently a *natural* oyster-bed, but it is evident from the condition of the specimens examined that there is not sufficient food on the ground or in the water to constitute the locality a good fattening area. The bodies of the oysters were found to be very thin and in poor condition generally.

The bed is entirely covered at each tide, and only ebbs completely dry at low water of an eighteen-foot tide with favourable weather. The bottom is hard, being composed of gravel and shells, with some fine mud between. Samples from the ground and from the water showed that diatoms and other minute forms of life which are so necessary in the case of a flourishing oyster fishery were so few as to be almost absent. It is quite possible that during summer, at the breeding season, more microscopic food may be present—perhaps due in part to the river, and it is probable that the bed in favourable seasons forms a good enough spatting ground; but all the evidence before us shows that it is not a favourable locality for the rearing and fattening of oysters. Probably the best plan would be to use it as a place for the production of spat, from which a certain proportion of the young oysters should be transferred to other localities where they can be more satisfactorily nourished. I think it worth while to try whether it would not be possible by the judicious placing of tiles and other collectors, and by certain obstructions in the water channels over the bed, to largely increase the deposit of spat; and I should recommend that some of the half-grown oysters be removed to certain grounds in the neighbourhood of Piel, on the south and south-east sides of Foulney Island, which we know to be richly supplied with diatoms and the othe necessary food, in order that their growth may be watched and compared with that of similar oysters left on the bed at Bangor.

I think it is a question whether the spat on the Ogwen bed is derived wholly from the old oysters in sight, or whether its source may not be individuals in deeper water somewhere in the neighbourhood. I propose to visit the bed myself during next spawning season in order to try to settle this and several other questions in connection with the reproduction and spatting of the oyster.

The further point has been raised that the Ogwen River oyster-bed may be liable to sewage contamination from the drains of Bangor. The observations made by Mr. Scott and the samples brought back by him, although not absolutely conclusive on this point, certainly suggest material of sewage origin, and it is difficult to believe that under certain conditions of wind and tide the bed can escape from pollution by the town drainage. However, this is a matter that may require further investigation, and in any case it does not affect the value of the locality for the production of spat and the rearing of young oysters which may be fattened elsewhere before being placed on the market. The whole question of the disposal of sewage and the pollution of our rivers, estuaries and sea shores is one that is in an unsatisfactory condition, and requires more careful consideration than it has yet received.

I desire to draw the attention of the Committee to some points in connection with the so-called "Bacterial treatment" of sewage (by coke filter beds or by septic tanks), which is now being adopted in various parts of the country. The recently published report to the London County Council by Professor Clowes and Dr. Houston shows that the effluent discharged after such treatment, although it may seem pure and have some objectionable features removed, contains practically all the bacteria found in the crude sewage.* From the public health point of view the clarified effluent apparently may be little if at all better than the original untreated sewage. Under these circumstances I would ask—is it not a very serious matter that such an effluent should be allowed to discharge anywhere in the neighbourhood of shell-fish beds, or where any fishery contaminations† could take place? I may also remark in passing that however pure such an effluent may look in mixing with the sea, bathers should be warned against its dangers. Another point with which we are not directly concerned at present, although it is of great interest to the scientific man, and may be of practical importance to the country, is whether enormous quantities of valuable fertilising materials which ought to be applied to the land are not now being wasted in the sea. We can leave the bathers to the sanitary authorities, the question of fertilisers is one for the chemist and the agriculturist; but we are directly concerned with the coast fisheries, and I would urge that the Committee, and all fisheries authorities, should give most careful consideration to the relations between shell-fish beds and any sewage effluents, whether "treated" or not.

Early in the year I asked Mr. Johnstone and Dr. J. T. Jenkins, who was at that time working in my laboratory at Fisheries subjects, to devote a certain amount of time in each week to a careful examination and classification of all our fisheries statistics (accumulated during eight or nine years), with a view to the drawing of any conclusions

* London County Council Bacterial Treatment of Crude Sewage. Third Report by Dr. Clowes and Dr. Houston, 1900.

† I am not alluding to the conditions in the Thames, which I do not know personally. It may be that no difficulty arises there. I am speaking of the question generally, as such effluents may be likely to increase around our coast, and will require careful attention.

which might be indicated. It has been a lengthy and troublesome piece of work, lasting most of the winter, and over a thousand sheets of statistics have been very carefully analysed. The results, I regret to say, are by no means commensurate with the labour that has been expended. For the majority of fishes and localities the statistics are so defective or so vitiated from one cause or another that we felt that no reliable conclusions could be drawn. In fact it was decided in the end that the only area in regard to which we had sufficiently detailed information was the shrimping area at the mouth of the Mersey. Hence the article on that area by Mr. Johnstone and Dr. Jenkins which I include in this Report (p. 39).

But it must not be thought that I regard the time and labour which these gentlemen have spent in trying in vain to draw conclusions from the remaining statistics as lost because they have deduced nothing which we are able to publish yet. Far from it: it has led to the very important conclusion that the system we have hitherto employed on the fisheries steamer and elsewhere in the district is really inadequate, that the statistics are not taken sufficiently often or with sufficient regularity, and are not taken with sufficient detail. If this discovery leads to the adoption of a better scheme (such as the one I suggest below, p. 24), and to its faithful performance in the future, the disappointment we have had in finding one after another of the series of statistics broken by unfortunate omissions* will be mitigated, and we may then hope that the next decade will be so traversed by

* Due to the circumstance that we have only one small steamer available for all the police and other administrative work of a large district, in addition to what I cannot but regard as of still greater importance—viz., the observational work on the condition and variations of the fisheries and their causes.

observations as to leave no doubt as to the conditions of fisheries and the progress of events.

I have spoken of the statistics as being incomplete and inadequate; but although they do not give us the information we expected, they are by no means useless. Every correct observation, and there are many thousands of such in our sheets, is of value even if it deals with isolated facts. It may give useful information which may be required at any time, and we hope that all these observations may fit in with our future records of facts, and so play their part eventually in the elucidation of important points.

Statistics obtained as the result of investigations made with regularity at fixed spots in accordance with a definite scheme are the more necessary since such very different conclusions have been drawn of late years from the commercial statistics as supplied by the Board of Trade. One of the most recently expressed of these is an article by Mr. Walter Garstang, entitled "The Impoverishment of the Sea," in which the conclusion is arrived at that the fish population is decreasing because although the total catch increases year by year, the take *per unit of catching power* diminishes. I do not quarrel with Mr. Garstang's conclusion, but the argument by which he arrives at it does not carry conviction. Except on ground where there is practically an unlimited number of fish, doubling the number of boats would surely not lead to doubling the catch, and consequently as the boats increased the *take per boat* would diminish to some extent without there being necessarily a permanent reduction of the fish population.

Turning to another important side of fisheries work, namely, experimental investigation, it is of interest to note that in the twenty-fifth Report of the United States

Commission of Fish and Fisheries, just published. Commissioner G. M. Bowers states, "Our leading fishery product, the oyster, worth about $14,000,000 annually, is readily susceptible of increase by methods of cultivation, and each season shows a larger proportion of the marketable output taken from planted grounds, thus insuring a permanent and increasing supply." He states further that while the natural supply of oysters is surely becoming exhausted, the areas of the sea-bottom which are being artificially cultivated are becoming more and more productive, and certain States which have adopted "advanced cultural methods" are "reaping important pecuniary returns."

Then again, "There is unmistakable evidence of an increased abundance of Cod in the inshore waters along the entire coast from Maine to New Jersey. This may, without hesitation, be attributed principally to the work of artificial propagation centering at the stations of the Commission at Gloucester and Woods Hole."

The Commissioner urges that new work should be undertaken for increasing the lobster supply by artificial propagation. He states:—"During the past five years over 500,000,000 young lobsters have been artificially hatched by the Commission and planted on the East Coast. As practically all the eggs from which these were produced would have been destroyed had not the Commission purchased the egg-bearing adults from the fishermen, it can hardly be doubted that these operations have had a decided influence on the supply, but they have not as yet seemed to arrest the decline, in the face of overfishing and the destruction of short lobsters and brood lobsters carrying eggs." I have had an interesting letter from Professor H. C. Bumpus, who has charge of the work at Woods Hole, telling of the details of the methods he has devised "for the rearing of young lobsters up to the fourth moult, at which time, as you are well aware, the animals become pugnacious, their shells become hard, and they adopt many of the peculiarities of habit of the adult, and, moreover, they appear to be hardy and well able to look out for themselves." Professor Bumpus goes on to say— "For convenience I have termed this stage the 'Lobsterling' stage, and I am inclined to think that if we should succeed in raising even a small percentage of the fry to this lobsterling stage before liberating them, we might accomplish for the lobster fishery what the release of 'fingerlings' has accomplished for the trout fishery. Inasmuch as you are experimenting in the same line, and since one of the most important, and at the same time one of the most inviting problems of marine biology to-day is the preservation of the lobster industry, I take the liberty to tell you of our experiments during the past year, and if you should have opportunity or inclination to adopt similar methods, I should be very glad to learn of your results." The further details which are given have been sent to Mr. Andrew Scott for use in his work at Piel. During last summer the disturbance of work consequent upon the sale of the old steamer and the purchase of the new one prevented any supply of lobsters from reaching the hatchery until it was too late, but during the coming season we hope to resume work upon the hatching and rearing of this very important economic animal.

In concluding this general part of the Annual Report I desire to draw the Committee's attention once more to the pressing need of a pond or some large open-air tanks at Piel, both for the reception of spawning fish and also, later in the season, for the purpose of rearing the fry obtained by the hatching operations. The tanks would also be useful during the remainder of the year for many other purposes.*

In the special parts of this Report which follow will be found:—Mr. Scott's account of the hatching operations at Piel, with a description of the new apparatus he has devised for keeping the water in motion: Mr. Johnstone's statistics of the Mersey Shrimping Grounds; a report upon the deposits on these grounds in relation to shrimps and young fish; a note on a new parasite in the plaice; Mr. Scott's memoir on the two Copepod Fish-Parasites; and an article I have thought it well to write on the necessity for a more detailed examination of our fishing grounds, with an outline of a scheme of observational work for use on board the steamer, to which I desire to call the special attention of the Committee.

W. A. Herdman.

University College, Liverpool,
January, 1901.

* These were referred to in detail in last year's report, at p. 10

Required Survey of our Fishing Grounds, with New Scheme of Work at Sea.

By W. A. Herdman.

In last year's Report, at p. 14, in an article on "Sea-Fisheries Conferences and the need of a 'Census' of our Seas," I pointed out that "what we stand most in need of at present is full and accurate statistics in regard to our fisheries, and much more detailed information than we have as to the distribution round the coast both of Fishes, in all stages of growth, and also of the lower animals with which they are associated, and upon which they feed." I then proceeded to propose a scheme of investigation which I characterised as "the nearest possible approximation to a census of our seas—beginning with the territorial waters and those offshore grounds that supply them and are definitely related to them." The work would be partly of a statistical nature and partly scientific observations and investigations, and it seems clear that it is only by such methods that we can hope to settle many important fishery questions.

I do not think that I am under-estimating the magnitude, the difficulties and the probable imperfections of such a scheme as I propose. I am aware that all we can hope to attain is an approximation, but even a rough approximation will be of use, and if carried out on the right lines it is an approximation which will approach more and more nearly to the truth with each successive year of work.

The fishery statistics collected and published at present by the Board of Trade are, I contend, inadequate. They do not give us the information we require. The system does not seem to be designed so as to realise and tackle the problem which ought to be tackled. What we should aim at ascertaining is not what a fisherma catches, but what there is for him to catch. We must in fact get series of accurate observations which will give us fair samples of the more sedentary populations of our seas on the different grounds, such as trawling grounds, shrimping grounds, nurseries and spawning banks, at the different seasons. I have spoken of this in brief as to aim at taking an approximate "census" of the sea, but that, of course, is too ambitious a word, and indicates an exactness to which we probably could never hope to attain. Still the word serves to remind us of our approximate aim, and if we can even determine the numbers of a species on an area between wide limits, it will be of great importance.

The investigation is, of course, beset with difficulties, but they are not insuperable. One great difficulty is to determine to what extent we can safely draw conclusions from our observations. In speaking of this matter recently to a Liverpool audience I made use of a homely illustration, which may be worth repeating here as a possible help to some readers in realising the problem. I compared the investigation to the case of an aeronaut in a balloon trawling along the streets of Liverpool through a thick fog. We may suppose that a drag in the neighbourhood of University College would yield some students—male and female—and a professor; one somewhere about the docks would doubtless capture some sailors, dock labourers, and a stevedore or two, while a lucky shot opposite the Town Hall might bring up a policeman, an electric car, and a couple of Aldermen. Now, if such experiences were repeated over and over again, would the conclusions that might naturally be drawn by the intelligent aeronaut as to the relations between organisms and environment in Liverpool be correct? The observed association of students with a professor, and of both with a college, would be justifiable. It would be correct to conclude that sailors, dock labourers and stevedores frequent the docks, and that Aldermen have some connection with a Town Hall; but the fact that electric cars are also abundant in front of the Town Hall is non-essential, and any conclusion such as that Aldermen and electric cars are usually associated with the same habitat, and are in any way inter-dependent, would be erroneous.

We can imagine many other cases of this kind where appearances might at first be deceptive, and false inferences might be drawn from observed facts. On the other hand, some true conclusions would be clearly indicated; and I do not doubt that it is much the same in our investigations as to the condition and population of the sea-bottom. It is probable, moreover, that the false inferences would be corrected by the accumulation of a greater number of statistics. It might be made out from further observations that electric cars are liable to become massed in various parts of the town, and have no necessary connection with Aldermen, and that policemen are widely but sporadically distributed. The more numerous our observations, the more our statistics accumulate, the less chance is there of erroneous conclusions.

My contention, then, is that such an investigation of our seas must be made, that it is urgent and should be made now, and that the Irish Sea is favourably situated and circumstanced at present to be made a test case before undertaking the much wider and still more difficult expanse of the North Sea, complicated by international questions. The Irish Sea is of moderate and manageable dimensions (see fig. p. 19). It is all bounded by British territory and by sea fisheries authorities who might agree as to their regulations. It is a "self-contained" fish area, containing spawning banks, feeding grounds and "nurseries." It has several laboratories (Liverpool,

Plan of the Irish Sea, showing depths of water. The deepest shading is from 50 to 80 fathoms.

Dublin, Port Erin and Piel) on its borders which would form centres for investigation, and it is controlled by powerful sea-fisheries authorities, two of which at least (Lancashire and Ireland) are provided with excellent steamers which might combine in the work. All that is required, beyond a carefully considered scheme of work, is authority from the Government to the local Committees to carry out such work, and a subsidy for say five years to meet the increased expense.

The Select Committee of the House of Commons, which considered the Undersized Fish Bill last summer, clearly recognised in their report the need of some such scheme of investigations, and they recommended that a Government Department should be equipped to carry it out. I am of opinion that the matter would be better entrusted, as I have indicated above, to the local Sea-Fisheries Committees. However, there are the two methods—

1. To form a properly equipped Government Department (comparable with the Geological Survey), with laboratories and steamers and a scientific staff competent to tackle the scientific problems involved. This is the method adopted in the United States and elsewhere.
2. The other, and perhaps the more characteristically English method, is to give fuller powers to the local authorities, and to encourage them to spend money on the necessary investigations in their own districts.

Correct statistics are very important, and they could probably be taken at least as efficiently by the sea-fisheries officers, under the control and supervision of the Fisheries Superintendent in each district, as by the Board of Trade officials; but no system for the collection of statistics even if much better than that now employed can take the place of a scheme of periodic scientific observations and investigations such as I desire to see carried out all around the coast by the local Sea-Fisheries Committees.

It is, I think, agreed on all hands that what is most urgently required is facts—but facts that can only be ascertained by continuous work on a sufficiently large scale. The Select Committee on the Sea-Fisheries Bill last summer reported that the Scottish Fishery Board's "investigations have been hampered by inadequate means. They have not much money at their disposal, and the vessel which they have for the purpose of scientific investigation is undoubtedly too small."

But, incredible as it may seem, *England has no vessel at all*, large or small, devoted to the purpose of such investigations. How long will this absurd condition of affairs be allowed to continue in this rich country, with its boasted advanced position, enlightened views and keen eye to practical applications? Not only other civilised countries but even some of our own colonies are far in advance of us in the public utilisation of Marine Biological investigations.

Norway is a poor country, but, in some directions at least, an enlightened one. Here is the latest item of news in regard to her fisheries investigations:—"The Norwegian Government has built and fitted out a steam vessel for the express purpose of marine scientific research, and has placed her, as well as a trained staff of assistants, in charge of Dr. Johan Hjort as leader of the Norwegian Fishery and Marine Investigations. The vessel herself, the "Michael Sars," has been constructed in Norway on the lines of an English steam trawler—that type of boat being regarded as the most seaworthy and suitable for such an expedition but considerably larger, being 132 feet in length, 23 feet beam, and fitted with triple-expansion engines of 300 horse-power. The fishing gear includes *inter alia*, trawls, nets, and lines of all kinds, with massive steel hawsers and powerful steam winches to work the heavy apparatus; while the numerous scientific instruments are of the very best and latest description. The expedition left Christiania in the middle of July on what may be termed its trial trip along the Norwegian coast (accompanied for part of the time by Dr. Nansen, who was desirous of testing various instruments in which he had made improvements), and has just sailed from Tromsö on a lengthy cruise to the North Atlantic and Arctic Oceans. Dr. Hjort has already added so much to the knowledge of pelagic fishes, their life, habits, and the causes affecting their migrations, that, with the means now at his disposal, a considerable amount of valuable information will probably be gained which will prove of service to the fishing industry of all nations."

What Norway can do, surely the whole western seaboard of England, from Cumberland to South Wales, now united in one Sea-Fishery District, ought to be supplied with, or be able to afford. Surely we may hope to see in the immediate future a steamer, at least of the size and equipment of a modern steam trawler, devoted solely to that combination of scientific and economic oceanographic investigations in the Irish Sea of which every conference of Fisheries Authorities, Commissions and Select Committees of recent years has had to deplore the absence.

In addition to the investigation of the bottom by dredging and trawling, the plankton in the surface and other waters of the sea would require periodic examination. This matter has been discussed fully during the past summer, both at Port Erin and Liverpool, amongst our local naturalists, some of whom have had much experience of late years in plankton work. In order to get an adequate idea of the distribution of the minute floating organisms of our seas, we should certainly require to have weekly observations (or possibly even twice a week) taken, at both surface and bottom, at certain specified stations round the coast, of which we should recognise four as being necessary in the Irish Sea, and about 15 round the whole British Coast. The Lancashire Naturalists are willing to play their part in any such general scheme, but in the meantime we are going on with the work in our own district. Mr. Isaac

Thompson at Liverpool, Mr. A. Scott at Piel, Mr. Chadwick at Port Erin, and Mr. Ascroft at Lytham, are all at work, and we have drawn up and agreed upon the following common list of pelagic organisms the occurrences and relative abundance of which in the various parts of our district will be periodically registered for each week in the year:—

Fish eggs, fish larvæ, Appendicularia, gastropod larvæ, larval lamellibranchs, larval crabs, other larval crustacea, Alteutha interrupta, Jonesiella hyænæ, Acartia sp., Temora longicornis, Isias clavipes, Centropages sp., Euterpe acutifrons, Calanus finmarchicus, Anomalocera patersoni, Pseudocalanus elongatus, Oithona spinifrons, eggs and larvæ of copepoda, Podon intermedium, Evadne nordmanni, larval Cirripedia, Echinoderm larvæ, Autolytus sp., Tomopteris onisciformis, larval Polychæta, Sagitta sp., larval Polyzoa, Ctenophora (state which), Medusæ (do.), Medusoid Gonophores (do), Noctiluca sp., Ceratium sp., Rhizosolenia sp., Chaetoceros sp., Biddulphia sp., Coscinodiscus sp., Nitzchia sp.

Mr. Ascroft is especially devoting his attention to our plankton work, and is now receiving and examining collections from various parts of the district. We hope that he will be able to contribute an account of these to our next Report.

With a view to making the best use of the time until the "census" investigations which I have recommended above are started, or until a steamer is obtained solely for scientific work in the Irish Sea, I drew up in October the following scheme of observational work which I hoped would be carried out by the new Lancashire Sea-Fisheries steamer when she started on her routine work. The scheme was submitted to the Committee, and although it has not yet been formally adopted for execution, I hope that it will now, in the light of the arguments as to the importance of such work which I have urged above, receive further consideration, and become as soon as possible an important part of the monthly work of the steamer. I reprint the scheme *verbatim* from the document privately issued in November:—

"Lancashire and Western Sea Fisheries.

"Dr. Herdman's Scheme of Investigations.

"Preston, 1900.

"*To the Lancashire and Western Sea Fisheries Committee.*
"From Professor W. A. Herdman, D.Sc., F.R.S.,
"University College, Liverpool,
"October, 1900.

"If there is one point more than another that the numerous Fisheries Congresses and Enquiries of recent years have made quite clear, it is that what we now need most for a proper understanding of the condition of the Sea Fisheries of North-Western Europe is a much more detailed knowledge than we have of the populations of all parts of our seas. Such knowledge can only be obtained by trawlings and other observations conducted regularly, frequently, and according to a definite scheme. Accurate practical work of this kind is usually called 'scientific investigation,' but it must be remembered that science is merely organised common-sense; and that any observations made accurately, and intelligently directed towards the ascertainment of facts, are scientific. The Select Committee of the House of Commons refused, last summer, to recommend the Sea Fisheries Bill because of the want of statistics based upon such 'scientific investigations.' It is thus evident that the systematic scientific investigation of our seas is of practical importance, and is very urgent, since Fisheries legislation is blocked for want of the information which such investigations alone can give.

"A scheme of scientific work has been carried out for some years on board the 'John Fell,' but the observations—although useful for many purposes—have been neither sufficiently numerous nor sufficiently regular to admit of reliable conclusions as to the abundance, movements, and life-histories of the fish being drawn. Now that a more efficient steamer has been obtained, I would urge strongly upon the Committee the importance—and even necessity—if we are to make any advance in our knowledge of how and where fishes live in the sea, of devoting a certain amount of the steamer's time to the taking of regular periodic observations at fixed points according to a definite plan.

"After full consideration of what is desirable and what is possible in our District, with a steamer which has also to carry out police and other administrative duties, I have drawn up the following, which I believe to be a workable scheme, and one which is calculated to give us the kind of information we require as a basis for the just and adequate regulation and administration of our District.

"I venture to think that if some such plan of observations had been adopted fifty or even twenty years ago, it is not too much to say that the results would be invaluable at the present day to the Naturalist and to the Fisheries Administrator alike. In face of the statistics so acquired, many of our Fisheries questions could not have arisen. There could no longer be doubt as to whether a particular Fishery, or Coast Fisheries in general, had or had not declined; as to whether the destruction of immature dabs benefitted or not the neighbouring population of young plaice; as to whether solenettes can possibly interfere with young soles of the same size; as to whether "nurseries" are already overstocked with young fish, or may with advantage be replenished as the result of artificial hatching operations.

"If public opinion has advanced, and Fisheries administration is more enlightened now than it was fifty or twenty years ago, let us see to it that the reproach of the nineteenth century is not continued on into the twentieth. I submit this Scheme to the Committee in the hope that they will authorise its immediate adoption on board the steamer, with a view to starting the new century well by having reliable and adequate monthly Fishery Statistics taken for the first time in January, 1901." "W. A. Herdman."

"Suggested Scheme of Fishery Observations.

"Regular Monthly Observations (as far as possible during the first week or ten days of each month) should be made on the following five Stations—as shown on a Chart marked by Mr. Dawson:—

Station 1.—Blackpool Closed Ground.

Station 2.—A similar area a little further South.

Station 3.—Mersey Shrimping Ground, Burbo Bk.

Station 4.—Outside N.W. Lightship to 20 fath. line.

Station 5.—Red Wharf Bay, Anglesey.

"Stations 1 and 2 are important for comparison with one another; Station 3 gives information on shrimping and immature fish questions: Station 4 is on interesting ground, just outside the territorial waters: and Station 5 is an important trawling area in the newly amalgamated Welsh portion of the District.

"The Observations made should include:—

I. Drags with the fish trawl and shrimp trawl.

II. Plankton collections with surface and bottom tow-nets.

III. Physical Observations with thermometers, hydrometers, &c.

I.—Fish and Shrimp Trawling Observations.

" (*a*) Drags should be made under strictly uniform conditions: that is, the same trawl net should always be used, and the drags should be of uniform length and duration, in order that they may be as strictly as possible comparable with one another. In addition to the fish trawl, it would be very useful—especially at Stations 1, 2, and 3—if a haul of the shrimp trawl could also be taken.

" (*b*) Every drag should be recorded, irrespective of the numbers of fish caught. A poor haul is just as important for statistical purposes as a successful one.

" (*c*) All the fish caught should be measured, and the numbers of each kind and size accurately recorded on a Form similar to the one appended.

" (*d*) Two or three individuals of each of the more important kinds of fish—such as plaice, sole, cod, haddock—from every haul should be weighed and measured separately. The ovaries should then be taken out and weighed, and the results recorded on the Form. Anything noteworthy in the condition or appearance of the ovaries should also be added.

" (*e*) Mention should be made of any unusual fishes or invertebrata taken in the trawl, and also of any special abundance of common things such as star-fishes, crabs, molluscs, jelly-fish, zoophytes, worms, or other fish food.

Unusual specimens, or anything not recognised should always be preserved for examination in the Liverpool Laboratory.

II.—"Plankton" (or Tow-Net) Collections.

"Tow-nettings should be taken along with every drag of the fish trawl. One haul with a bottom and one with a surface net should be made on each occasion. The collections should be at once preserved in formaline solution, and sent to the Liverpool Laboratory as soon as convenient after landing. Extra tow-nettings should be taken as frequently as possible. All such observations on the floating life of the sea (which includes the eggs and the microscopic food of many fishes) are most useful. Even short hauls of half-an-hour's duration, taken twice a week, will probably suffice to give a fairly accurate idea of the movements of the Plankton in the District.

III.—Physical Observations.

"(*a*) SEA TEMPERATURES.—Surface and bottom observations should be taken at the beginning and end of each drag. Bottom temperatures should be taken with a reversing thermometer.

"(*b*) SPECIFIC GRAVITY OF THE SEA WATER.—Surface and bottom observations should be taken at the beginning and end of each drag. Bottom observations should be made on samples of the bottom water, taken with a Mill's bottle.

"(*c*) AIR TEMPERATURE.—One observation at the beginning of each drag should be taken for comparison with the sea temperature.

"(*d*) BAROMETRIC PRESSURE.—One observation taken at the beginning of each drag is sufficient.

"(*e*) TRANSPARENCY OF THE SEA WATER.—One observation should be taken at the beginning of each drag, and if any notable change has taken place in the water, a second observation should be made at the end.

"(*f*) THE STATE OF WIND, TIDE, SEA, WEATHER, &c., should be recorded on the Form supplied.

"The above scheme applies only to the work on board the steamer. The observations carried on by the bailiffs in inshore waters should, of course, be continued, and weekly tow-nettings should be taken in each division of the District.

"The Forms containing the results of the above observations should be posted to the Fisheries Laboratory, University College, Liverpool, with the least possible delay, as it is important that early information should be obtained of any unusual occurrence or any change in the distribution of fish and Plankton throughout the District.

"A copy of the Form upon which the observations should be recorded is appended."

[N.B.—The Form on p. 30 is a compressed version of the original.]

Record of Observations made on Station No.

Date

Positions at beginning and end of drag.

Description of net.

Time net down, beginning and end of drag.

State of tide at beginning of drag.

Weather.

Wind.

Depth during drag, beginning and end of drag.

Nature of bottom.

General remarks.

PHYSICAL OBSERVATIONS.

Transparency of water, beginning and end of drag.

Barometer, beginning of drag.

Air temperature, beginning of drag.

Surface temperature of water, beginning & end of drag.

Bottom temperature of water, do.

Specific gravity of surface water, do.

Specific gravity of bottom water, do.

General remarks.

	No. of fish selected.	Size.	Weight.	Wt. of Ovaries.	General condition.
Plaice ...					
Sole ...					
Cod ...					
Haddock..					

DESCRIPTION OF CATCH.

Name of fish.	Size in inches. 4	6	8, &c	Total No.
Sole ...				
Plaice ...				
Dab ...				
Flounder				
Lemon Sole				
Cod ...				
Whiting ...				
Haddock . .				
Skate ...				
Any other food fishes.				

Surface tow-netting—To be filled up in Laboratory.

Bottom tow-netting—To be filled up in Laboratory.

Note any unusual fishes or invertebrates.

The Fish Hatchery at Piel.

By Andrew Scott.

In last year's Report, p. 25, it is stated that white flukes were being collected and kept in the tanks at Piel in the hope of their spawning in the spring. Before the end of January 150 fish had been placed in the tanks. The ratio of the sexes was three females to two males. The fish were all collected in Barrow Channel by the local police boat in charge of Mr. Wright.

The fish thus collected, owing to unforeseen circumstances, proved to be the main source from which the eggs were obtained for incubation during the spawning season of 1900. The rough weather which prevailed in the earlier part of the year, along with the necessary arrangements for the sale of the steamer, which took place in the middle of the spawning season, prevented the steamer from doing very much to help in collecting eggs at sea or from the trawlers.

In the earlier part of the year, however, the steamer made a number of visits to the spawning grounds. On three occasions eggs were obtained, twice from the Clyde and once from fish caught by the trawlers working on the offshore grounds. The first eggs, collected from fish caught in the Clyde, March 12th-16th, were practically all lost through the rough weather encountered on the homeward journey. The second lot, also from the Clyde, arrived on March 28th in much better condition, and yielded good results. The third lot, from the offshore grounds, collected April 5th to 6th, were equally satisfactory. Altogether 2,434,800 fry were hatched and set free from the eggs collected by the steamer. A number of nearly ripe plaice were brought from the Clyde on the first visit. Some of these spawned in our tanks, yielding an additional 65,000 fry.

The first fertilised eggs from the flounders stored in our tanks were obtained on March 8th. These fish continued to supply eggs until the middle of May, and from these nearly twelve millions of fry were eventually set free. The total number of living eggs placed in the boxes was 16,000,000, and the number of fry set free 14,144,400, so that the loss during incubation was only a little over 11·5 per cent., a very low percentage. The duration of incubation was 16 to 17 days for the plaice, cod, and haddock, and 7 to 9 days for the flounder.

The success of the incubation was probably due to the healthy condition of the eggs dealt with, and also to the employment of apparatus giving a rocking motion to the hatching boxes (see below, p. 33).

The following list gives the number of fry set free, and the dates on which they were liberated. Those marked with an asterisk were hatched from eggs collected by the steamer. All were placed in some part of that wide area of our sea known as Morecambe Bay.

March	21.	1,126,000	flounder.
,,	31.	848,000	,,
April	2.	598,000	,,
,,	2.	20,000	haddock.*
,,	5.	520,000	flounder.
,,	5.	15,500	plaice.*
,,	5.	23,000	,,
,,	9.	934,400	,,
,,	9.	583,300	,, *
,,	12.	830,200	,,
,,	12.	219,800	cod.*
,,	12.	285,700	haddock.*
,,	17.	87,500	plaice.*
,,	17.	128,600	flounder.
,,	20.	1,896,000	,,

April	20.	42,000	plaice.
,,	20.	43,000	,, *
,,	23.	718,000	cod.*
,,	23.	462,000	haddock.*
,,	23.	581,000	flounder.
,,	26.	861,000	,,
May	1.	865,000	,,
,,	7.	1,447,000	,,
,,	10.	530,400	,,
,,	14.	368,000	,,
,,	22.	111,000	,,
	Total	14,144,400	

During the autumn the hatching apparatus has been thoroughly overhauled, and is now ready for use again.

A fresh stock of flounders (amounting to over 225 large healthy fish) has been collected during the last three months of 1900, so that part of the supply of eggs for the season 1901 is practically secured. With the help of the new steamer, and favourable weather, it is probable that there will be a larger number of fry set free this year than has yet been possible.

Description of an Apparatus for keeping Eggs in motion.

(See Plate A.)

To successfully incubate large numbers of floating eggs in the limited areas of the usual hatching tanks the water must be kept in constant movement. When the eggs are not disturbed they gravitate towards each other, forming a layer on the surface of the water. Consequently the result is a high mortality, chiefly due to suffocation. It becomes necessary, therefore, to employ some means to break up these masses. This is usually done by slowly raising a weighted rod placed along the rows of boxes which allows the free ends of the boxes to float up. The rod is then suddenly released, and the boxes depressed rapidly into the water, which is forced up in powerful currents through the perforated bottom of the boxes. This separates the eggs in all directions, but without injury to the developing embryos.

The mechanism employed in other establishments which use the same kind of hatching apparatus is driven by a water wheel. This wheel turns a cam which has a lever resting on its rim. One end of the lever is weighted to give the necessary pull to the wires that suspend the rods. The other end has the main wires attached, and from these branches are led over pulleys to the various weighted rods. As the cam revolves the lever is alternately raised and depressed so pulling up and then releasing the wires.

The arrangement of the hatching apparatus at Piel does not readily lend itself to the adoption of this method. Some other system had, therefore, to be planned, and after various experiments, the apparatus now adopted by us was devised. This apparatus has given complete satisfaction during the last season, and as it is less complicated than the older systems, a description and illustration may be useful to others, and will now be given.

The apparatus may be briefly described as a direct-acting balance of the beam and scale pattern. It consists in the main of a balanced beam (see Plate A, 3). One end of the beam is attached to the middle of a light framework, which carries the wires connected to the weighted rods (5). The other end bears a frame containing a "tumbling" box (4) of a similar design to those used in automatically measuring rainfall, washing photographic prints, flushing drains, &c. The box is so constructed that when empty it remains in a horizontal position, but as it fills with water the centre of gravity gradually alters until the box turns over and discharges the contents, immediately returning to the horizontal position again. The weight of the box and its frame should just be sufficient to raise the arm carrying the frame with the wires, but without the weighted rods. The quantity of water required to lift the rods and weights is found by weighing one rod with its weight, and then multiplying that by the number of weighted rods employed. The box should be made to contain rather more than the exact quantity of water required. In the Piel Hatchery the waste water from the apparatus and other tanks is used for filling the box. When the box is empty the rods are down and all the hatching boxes are depressed. The box (4) gradually sinks to the floor as the water pours in, pulling up the weighted rods (5). By the time the rods are raised high enough (6 inches) the box has lost its stability, and it falls over, discharging its contents at once. The rods at the same instant return rapidly to rest, depressing the hatching boxes. The rate of movement is easily controlled by regulating the flow of water, and also by retarding or hastening the period of instability of the tumbling box. This latter can be done by adding weights to the side of the box at B, or by placing pieces of wood on the frame under the box at D.

The apparatus when fitted up can be attached to a beam in the roof of the room, and the whole should be so placed that the framework carrying the wires attached to the rods is vertically above the point of attachment.

Explanation of Plate A.

The drawing represents the front view of the apparatus.

1. Longitudinal beam resting on the cross beams supporting the roof.

2. Support for apparatus.
3. Balanced beam.
4. Tumbling box. At C a brass rod is rigidly fixed working freely in lignum vitæ bearings fastened to the frame. AB = $35\frac{1}{2}$ inches, AC = $27\frac{1}{2}$ inches, CD = $9\frac{1}{2}$ inches, BD = 11 inches. Width = 12 inches.
5. Wires to rods.
6. End view of hatching tanks, containing little boxes for eggs.
7. Waste pipes leading into main pipe, taking water to tumbling box.

a End view of top and bottom of main suspender.

b End view of suspenders of framework for wires and tumbling box. The suspender to the tumbling box works through a guide (*g*).

c Side view of tumbling box in its frame.

Note on the Spawning of the Mussel (Mytilus edulis), By A. Scott.

The determination of the spawning period of the mussel on the Lancashire coast has occupied our attention for some time. Hitherto we have mainly examined the condition of the reproductive organs, both *in situ* in the living animal, and by thin sections of prepared material during periods of twelve months. Tow-nettings from the vicinity of the beds have also been examined for the larvæ. These investigations enabled us, approximately, to state when the eggs were shed. It is obvious, however, that all the information regarding the actual spawning, the fertilisation of the eggs, and the period that elapses before the resulting embryos become free-swimming larvæ can only be ascertained by carefully observing the living animal. It is not possible to do this under natural conditions on the beds, and it becomes necessary to fall back upon other methods which may not give altogether conclusive results from a critically scientific point of view. To remove animals from their natural surroundings and place them in confinement in a limited area of water is undoubtedly detrimental to life processes at first. After some time the effects produced by the change may however be diminished, and the animals become acclimatised and live probably very much as they would have done had they been left in their original state. We are thus enabled to carry on observations which would be quite impossible under natural conditions.

Large samples, about ½ cwt., of mussels were collected from the Roosebeck outer scar and from a scar in Barrow Channel which only ebbs dry at low water of spring tides. These were placed in the tanks in September, 1899, and kept under observation for twelve months. A constant current of sea water was maintained, and from time to time, usually twice a week, small quantities of mud, known to contain diatoms, &c., were added to supply the animals with food. The animals were examined microscopically at intervals, and the reproductive organs compared with samples taken direct from the beds. The rate of development was found to be practically the same in the mussels in the tanks and in those on the beds.

On May 6th the mussels from both beds commenced to discharge eggs. These were isolated and examined under the microscope. No development took place. No ripe males were found at this period, and it may be concluded that these eggs were not fertilised. The mussels continued to discharge eggs which underwent no change until June 14th. On June 13th the first obvious discharge of spermatozoa occurred. This was from the mussels from Barrow Channel, and so abundant was the supply that the water in the tanks was rendered quite turbid, as if milk had been poured in. A drop examined under the microscope was found to be teeming with spermatozoa in active movement. Two days afterwards the Roosebeck mussels discharged spermatozoa. From that date onwards, although no further discharge of spermatozoa was observed, the eggs were always fertilised. With a very few exceptions the eggs were discharged during the night. Many of the mussels were actually observed in the act of shedding their eggs.

The embryos flow from the female in a slow distinct stream. When not disturbed by currents they settle down on the mud close to the parent as an obvious pink mass. They remain in this position undergoing the early stages of development, which last from eight to twelve hours. They then rise to the surface as free swimming larvæ, and are dispersed by the currents. The duration of the free swimming stage was not determined, but the larvæ remained free swimmers for at least four days. The minute size of the larvæ (they are only from $\frac{1}{363}$ to $\frac{1}{250}$ of an inch in diameter) prevents accurate observations being made for one individual. They can only be kept in jars where no circulation is going on, consequently the surroundings soon become unfavourable to life. Attempts to strain them through fine sieves, and so allow the foul water to escape, were not a success, as the larvæ passed through our finest sieves.

Fertilisation of the eggs has generally been thought to take place in the water after they were discharged from the parent. That has not been our experience at Piel. After the obvious discharge of sperms all the eggs subsequently extruded were found to be fertilised, even though no further discharge of spermatozoa could be detected. In several instances the eggs were isolated as they were leaving the parent and put into water direct from the sea that had been carefully filtered through fine filter paper. These eggs always developed into free swimming larvæ. Fertilisation therefore probably took place in the branchial chamber of the parent.* It was also observed that practically the whole of the reproductive elements were discharged at one emission extending from one to three hours. The same mussel did not again set free any more reproductive elements. When such a spent mussel was opened up and examined the whole reproductive organ was found to have collapsed.

The mussels on the beds, by the time those in the tanks had ceased to emit reproductive elements and had become quite thin, also took on the same appearance. From the observations carried on at Piel the conclusion has been arrived at that the spawning period of the mussels in the northern part of our district may be set down as having lasted this year (1900) from the beginning of May to the middle of July.

Report on the Shrimp Trawling Statistics Collected by Mr. G. Eccles on the Mersey Shrimping Ground during the period 1893—1899.

By Jas. Johnstone, B.Sc., and J. T. Jenkins, D.Sc.

In 1893 the Committee began a series of observations, on the lines indicated in a scheme drawn up by Professor

* Professor M'Intosh some years ago investigated various points in the reproduction of the mussel. Amongst other things, he determined that the sperms were capable of living for twenty-four hours after being removed from the parent. This has been confirmed by the work at Piel, but the intervals between the obvious shedding of sperms and eggs in the tanks were much longer than twenty-four hours, and during these periods the sperms, even if alive, would be carried away in the waste water.

Herdman,* on the occurrence and distribution of the commoner food fishes on the principal inshore and offshore grounds of the Lancashire District. From time to time selections from the results so obtained have been published either in the Superintendent's Reports or in those of this Laboratory. In the autumn of 1899 it was thought advisable to make a study of all the data obtained, and as a result all the forms (over 1,000) containing the records of the observations have now been abstracted.

These observations were made by the Captain and crew of the "John Fell" and by the bailiffs in charge of the sub-districts, and are as complete as the police work and other administrative duties of the officers permitted. They include experimental hauls with fish-trawl nets of various sizes and made under various conditions, hauls with shrimp trawls and shank nets, and observations on the sizes, spawning, feeding, &c., of the common food fishes. On account of the limited staff employed, the extent of the district to be worked over and the pressure of the police work, these statistics are necessarily very imperfect. It would be premature to publish many of the data obtained, especially those of the fish-trawl, at present, and we therefore confine ourselves to what seems most complete and reliable, viz., the series of experimental hauls with shrimp-trawl nets made by Mr. G. Eccles, head bailiff for the Southern District, on the Mersey Shrimping Grounds.

It would not serve any useful purpose to publish the results of these hauls as recorded by Mr. Eccles in full, so we have prepared an abstract of all the data collected and present it in the form of Tables I. to VI. Altogether 248 hauls with a shrimp trawl were made during the period 1893-1899. By far the greatest number of these

* Lancashire Sea Fisheries Laboratory Report for 1892, pp. 41-45.

were made from the New Brighton sailing boat. A few were made by the "John Fell," and are included amongst the others. The conditions under which the hauls were made were not strictly uniform. As a very general rule a shrimp trawl of 21 feet beam and 33 feet length of net, with a mesh measuring half an inch from knot to knot, was employed. Very occasionally a slightly longer beam (24 feet) has been used. The greater number of the drags made were two miles in length and one hour in duration, and these conditions were adhered to as closely as circumstances permitted. Occasionally, however, the length and duration of the drags were greater, more often less, than the values stated, and from this cause individual hauls are, strictly speaking, not comparable with each other. In the treatment of the data it has, therefore, been thought advisable to make the average hauls per month the values compared, and as the averages of a number of hauls have generally been used in whatever comparisons we make, to that extent the error due to fishing under slightly inconstant conditions has, we consider, been eliminated.

The recorded results of these hauls include (1) the total numbers of edible fish caught, (2) the numbers of quarts* of shrimps taken, (3) the numbers of the various species of food fishes with (generally) their average sizes, (4) state of weather, sea, wind, &c., (5) physical observations. The commoner fishes taken are:—The sole (*Solea vulgaris*), the plaice (*Pleuronectes platessa*), the dab (*Pleuronectes limanda*), the haddock (*Gadus æglefinus*), the whiting

* We employ the quart of shrimps (the economic unit) as the measure of the catch. A quart contains a variable number of shrimps, 200 to 400, the variation being due to the varying sizes of the animals. The market value varies from 6d. to 8d., that is the price paid by the consumer; the fisherman himself receives only about 3d. per quart on the average if he sells his catch to the fishmongers. But a considerable proportion of the shrimps caught (about one-third) are retailed by the fishermen themselves.

(*Gadus merlangus*), the cod (*Gadus morrhua*), and the herring (*Clupea harengus*). Less commonly the lemon sole (*Pleuronectes microcephalus*), the brill (*Rhombus lævis*), and the gurnard (*Trigla gurnardus*) are taken. Various inedible fishes are frequently caught, the commoner of which are *Solea lutea, Trachinus, Cottus, Centronotus, Ammodytes*, and with every haul a great number of invertebrates are taken. Often the crabs (*Portunus*) brought up form half the bulk of the catch. Starfishes (*Asterias*) are nearly always caught. In the warmer months large medusæ are abundant.

We quote a few individual hauls in detail as samples.

I.—August 28th, 1893. Near Deposit Buoy (see chart on p. 46), in 5 fathoms of water, bottom of sand and mud. Length of drag = 2 miles, duration = 70 minutes. Shrimp trawl of 21 feet beam.

Sole ...	43,	length = $4\frac{1}{2}$ inches mostly, but 16 were over 4oz. in weight.	
Plaice ...	1620,	,,	6 inches.
Dab ...	604,	,,	6 ,,
Whiting	757,	,,	6 ,,
Cod ...	88,	,,	5 ,,
Gurnard	30,	,,	4 ,,
Ray ...	2,	,,	7 ,, broad across pectoral fins.

Total food fishes 3144. Shrimps, 27 quarts.

II.—September 27th, 1893, near Deposit Buoy, in 5 fathoms of water; bottom of sand. Length of drag = 2 miles, duration = 90 minutes. Shrimp trawl of 21 feet beam. Twenty boats were fishing immediately around.

Sole ...	12,	length =	$4\frac{1}{2}$ inches.
Plaice ...	10407,	,,	$4\frac{1}{2}$,,

Dab ...	375,	length = 4	inches.
Whiting	169,	,, 5	,,
Cod ...	69,	,, 5	,,

Total food fishes 11032. Shrimps, 32 quarts.

The soles and plaice taken in this haul are described as "deadly," dabs, whiting and cod as "lively."

III.—August 30th, 1899, near Deposit Buoy, in 6 fathoms of water: bottom of mud and sand. Length of drag = 2 miles, duration = one hour. 21 feet shrimp trawl.

Sole ...	257, 11 were over 8 inches long, $\frac{1}{3}$ of the catch were over 2 and under 8 inches, the remainder were 2 inches long.
Plaice...	265, 6 were over 8 inches long, the remainder were 2 to 4 inches in length.
Dab ...	896, 2 were over 8 inches long, $\frac{1}{4}$ of the catch were about 2 inches, the remainder $1\frac{1}{2}$ inches long.
Ray ...	18, 7 inches broad.
Whiting	285, 5 inches.

Total food fishes 1721. Shrimps, 20 quarts.

IV.—March 15th, 1895, in Crosby Channel (see chart), in 4 fathoms of water. Bottom of sand. Length of drag = 1 mile, duration = 30 minutes. Shrimp trawl 24 feet beam.

Flounders ...	2,	length = 4	inches.
Cod ...	10,	,, 7	,,

Total food fishes 12. No shrimps were caught.

II. is one of the largest hauls made on the ground. IV. is one of the smallest. It will be seen later, however, that the hauls made on the ground dealt with in II. differ considerably from those made near the Deposit Buoy.

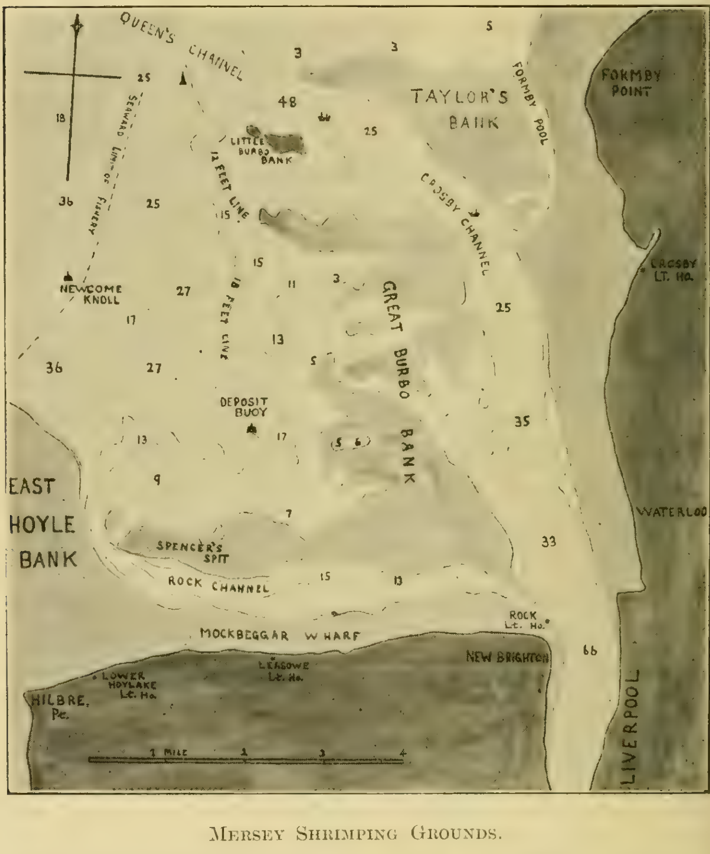
The actual data considered here are given on Tables I. and II. Of the various species of edible fish enumerated above only 4 are dealt with—the sole, plaice, dab, and whiting. Consequently the totals under the heading "Total numbers of fish" are not the sums of the numbers representing the catches of the four fishes mentioned. Those sums are less than the totals by the numbers of fish of various kinds which are not tabulated. For each of the years 1893-99 the tables give (1) the number of hauls made during each month, (2) the total number of fish caught in all the hauls and the average number of fish caught per haul, (3) the total number of quarts of shrimps caught in all the hauls and the average catch per haul, (4) the total number of each of the four kinds of fishes caught in all the hauls and the average numbers caught per haul.

Table I. deals with the observations made on a portion only of the whole Mersey shrimping ground. Most of the hauls have been made within two miles of the Deposit Buoy, that is on the shallow water immediately behind Burbo Bank. A few were made in a small portion of the Rock Channel (see Chart, p. 46).

Table II. gives the hauls made in the deeper water of the Channels—part of Rock Channel, Horse Channel, Queen's and Crosby Channels. The division of the whole ground into these two sub-divisions is not quite natural since all the Rock Channel ought, strictly speaking, to have been dealt with in Table II. But it was found convenient for various reasons to include the eastern portion of Rock Channel in Table I.

It will be seen that there is no complete series of observations, including at least one haul in each month of the year in either Table I. or II. On this account and also with the object of eliminating as far as possible accidental conditions and variations, all the hauls taken during the Januarys in each of the years 1893-99 have been collected, and from these the total fish and shrimps caught and the averages per haul have been calculated. The same has been done for the other months, and the results are tabulated in Tables III. and IV. III. deals with the portion of the ground considered in Table I., and IV. with the portion considered in Table II. In Table VI. all the fish caught in the third quarters (July, August, September) of each of the years 1893-9 are collected, the numbers of hauls taken in each of those quarterly periods are given, and the average catches are calculated. In Table V. an attempt is made to compare the varying destruction of young fishes at different times and on the different grounds.

We give on next page a map of the Mersey Shrimping Ground which has been reduced from the Liverpool Dock Board's Chart of the area. It represents the extent of the sandbanks at low water of a spring tide ten feet below the level of the Old Dock Sill Datum at Liverpool. Almost the whole of the area shown is regularly fished over. More exactly, a line drawn from the N.W. extremity of East Hoyle Bank to Newcome Knoll Buoy, and from Newcome Knoll Buoy to the first red conical buoy in Queen's Channel, defines the seaward limit of the Burbo Bank area. Shrimping is carried on over almost all this ground, the extent of which is roughly 16 to 18 square miles. Queen's Channel, Formby Channel, Crosby Channel, Horse Channel, and the western portion of Rock Channel are also regularly fished. Shrimping is also carried on in the gutters through the banks, and when there is sufficient water on the margins of the banks themselves. A portion of this area, about 4 square miles in extent, lying between Newcome Knoll and Deposit



MERSEY SHRIMPING GROUNDS.

Buoys and to the north of these, has a bottom of fine mud, which to some extent hinders the working of shank nets. Over almost all the rest of the area the bottom consists of fine sand. Shrimp fishing, however, is not confined to this area. A considerable area to the north of Queen's

Channel and a portion of the Mersey estuary lying above the Liverpool Landing Stage are also fished on.

Now with regard to the relative quantities of shrimps and immature fishes caught in the shrimp trawl, considerable differences exist on different parts of the whole area referred to above. We have, therefore, separated the hauls taken on the portion lying seaward from Burbo Bank and south of Queen's Channel from the portion including Queen's, Formby, Crosby and Horse Channels, and the eastern part of Rock Channel. For convenience the former portion will be referred to hereafter as Area A and the latter as Area B. The hauls taken on Area A are abstracted in Table I., those taken on Area B on Table II.

In Plate B we have represented graphically the results of Tables III. and IV. The method adopted has been to take each fish separately, and to superpose the curves representing its distribution on the two sub-divisions of the shrimping ground referred to above. Curves I., II., III., IV., and V. represent the variation from month to month in the numbers of immature whiting, plaice, dabs, soles and shrimps taken per average haul. In all these curves the number plotted along the vertical axes represent these average hauls; months are represented on the horizontal axes. The vertical scale of I., II., and III. is the same; the corresponding scale of IV. is one-tenth, and V. one-twentieth that of I. This change of scale has been necessary on account of the small values dealt with in IV. and V. In all the curves the thick line represents the average hauls on Area A, the thin line the average hauls on Area B. It ought to be remembered that the fishes dealt with in these tables and curves are nearly all immature. The hauls quoted on pp. 42-3 represent fairly their average sizes.

In the case of the whiting (I.), the maximum catch (1,180) has been taken in August. This is the case on both areas, and it is the case also for Area A in 1893, 1894, 1895, and 1899. In 1896 the maximum catch was taken in July, in 1897 and 1898 in September. The series for individual years are not so complete for Area B, and it is to be noted that in 1895 the catches increase during the latter half of the year to a maximum in November. The catches of whiting during the third quarter of the year were greater in 1895 than in any other year of the period under consideration. In both areas very low catches were made in June, and after this month the curve rapidly rises towards the maximum in August. A secondary maximum (on both areas) occurs during April. It is remarkable that the form of the curve is the same for both areas, the maxima and minima occurring at the same time. The curve also shows that throughout the year greater catches were always taken on Area A, and that between June and November the catches there were very much greater than on Area B.

In the case of plaice (II.) the maximum catch was made on Area A in September. This is also true for the three years, 1893, 4, and 5, having the most complete series of observations. The minimum occurs at the end of the year. It is generally the case in the individual years that the lowest catches were made at the beginning or end of the year. As in the case of whiting, a secondary maximum occurs during the spring.

The form of the curves for plaice differs completely for the two areas. In B there are three maxima, January, July and November, and two minima, May and August. Generally it would appear that plaice are more abundant in the Channels during the winter months, that during the late winter and spring their number decreases, and increases again toward midsummer. After midsummer they become less abundant, but during the autumn and early winter they increase again. That is to say, that except for the increase towards midsummer, which is characteristic for both grounds, and is largely due to the appearance of fish of that same year's spawning, their distribution on the two areas is to some extent complementary. The general conclusion is confirmed by the study of the figures for the separate years (as far as these go). This curious behaviour of the same fish on two adjacent areas is perhaps to be explained by supposing that migration from the one area to the other takes place during the spring and autumn. What the causes of such migration may be we are not in a position to say. The migrating fish are largely those of that same year's spawning.

It might be expected that the distribution of dabs would follow closely that of plaice. It will be seen that the curve of distribution (III.) on Area A is very similar to that for plaice. The minimum for both fishes occurs at the beginning or end of the year, but the maximum catch was taken earlier in the year in the case of the dab. In the three years, 1893, 4, and 5, for which the data are most complete, the maximum catches of dabs were made earlier than those of plaice. As in the case of whiting the curve shows two maxima which have the same positions.

The distribution of dabs on Area B is not exactly similar to that of plaice, but seems to be rather irregular. It is, however, the case that large catches were made there at the beginning and end of the year. The catches made about the middle of the year are, however, somewhat irregular.

Soles (IV.) have much the same distribution on Area A as the other fishes dealt with. The maximum catch was made in August. The secondary maximum occurs in March, a month earlier than that of dabs and whiting. The minimum catch was made at the end of the year. Three hauls were made on this ground during December, in none of which were soles caught. The distribution on Area B is more irregular, and no general statement can be made with regard to it.

Shrimps (V.) have been caught at any time during the year on both areas, except in one exceptional haul (quoted on p. 43). It is to be noted that their distribution differs somewhat from that of the food fishes; the minimum catches were made (on both areas) in February. From then the average catch rises with small variations to the maximum in October. During August, September and October the catches do not vary much, rising very slowly. After October they fall very rapidly.

A study of the curves representing the monthly variation of shrimps on the two areas shows this remarkable condition: from December till the following August shrimps are always more abundant on Area A than on Area B; conversely from August to November they are more abundant on Area B than on Area A. That is to say, during the four months, August to November, shrimps are more abundant in the channels than on the banks. We think it necessary, however, to state that this may be due to the fact that most of the fishing is carried on during these four months on Area A.

Since all shrimp fishing, whether on Area A or B, is necessarily attended by the capture of a variable number of immature fish, we have thought it useful, in view of the practical importance of this fact, to study the variation in the relative quantities of shrimps and fish caught in the shrimp trawl. If the number of fish caught in any one haul be divided by the numbers of quarts of shrimps taken at the same time, a measure is obtained of the amount of destruction of young fishes caused by shrimp trawling. Taking the total monthly catches of shrimps and fish during the year, as shown in Tables III. and IV., as a basis, we have constructed Table V. That table shows for each month in the year, and for both areas, how many soles, plaice and whiting were caught for every quart of shrimps. And if it be possible to determine by any means the total number of quarts of shrimps landed from the Mersey Shrimping Grounds in each month during the year, the numbers on this table will serve as factors which will enable the amount of destruction of immature food fishes to be calculated.

The numbers of plaice caught per quart of shrimps on Area B during February and March seem excessive. This is due first to the relatively large numbers of plaice found on that ground during the early months of the year; second, to the very small catches of shrimps made there during those months.

The tables show that the numbers of soles, plaice and whiting caught per quart of shrimps on Area A is always much greater during the third quarter of the year than on Area B during the same period. More exactly, more whiting are caught on Area A from June to December, and more plaice and soles from August to October, than on Area B during those same months. More whiting were caught on Area B than on A during February, and more soles during March, May, June, July, November and December.

We have used the term destruction as synonymous with capture of young fish, but perhaps we are not strictly justified in doing so. All the fish brought up in a shrimp trawl do not necessarily die. It will be seen by reference to the hauls quoted on pp. 42-3 that a few large fish are generally taken. These are always alive when brought up from a drag of moderate duration, and if immediately thrown back into the sea will most probably survive. We refer to plaice, soles and dabs over 8 inches in length. Flat fish from 3 to 8 inches are not so hardy, but many of these are alive when the "net is fished," and probably recover when put back into the sea. The vitality experiments made by Mr. Dawson* and others in our district have shown that quite a large proportion of such fish recover when taken from the contents of the net and immediately put into a tub containing running sea water. But the flat fish under 3 inches long are in a worse case, and the greater number of these are probably really destroyed. They are small, and in the process of "sorting the catch," all the larger animals (large fish, crabs, star-fish) are thrown overboard first, so that small flat fishes have to lie on the deck for a longer period than the others. Small round fish, whiting, haddock and cod of less than 5 inches long are almost always dead when the contents of the net are emptied on the deck. The larger round fishes may be alive, but they seem to be less hardy than the flat fishes.

Of course the mortality among the fishes caught in the shrimp trawl must depend to a very great extent on the care of the fishermen in sorting the catch, on the facility with which the net can be hauled, on the duration of the drag, and on the temperature; in warm weather the water adhering to the gills is more easily evaporated and contains less dissolved air. It is to the interest of the fishermen to sort the catch quickly, and get the

* Lancashire Sea Fisheries Laboratory Reports for 1893, (p. 23) and 1894, (p. 30).

shrimps put aside, and we believe that they really wish to preserve the life of as many of the immature fish caught (which are not marketable, and are of no use to them) as possible. And we have seen that the contents of the net can be very rapidly sorted out. But in a large catch the process is somewhat tedious, and as the deck space in a shrimping boat is very limited, part of the catch may be put into fish baskets *unsorted*, while the remainder is being dealt with. In these circumstances the immature fish in the reserved portion have little chance of life.

It is clear that with long drags, with large catches, and in warm weather the mortality among the immature fish taken in the trawl is much greater. Considering all things, there is not much doubt that of the immature fish taken in the course of shrimp trawling, as at present carried on, a large proportion must necessarily be destroyed.

We have made an attempt to determine the distribution from year to year of the four fishes considered above. The average hauls for each fish for the third quarters of each of the years 1893-9 have been calculated, and these are the values compared. The third quarters (July, August, September) are selected since those are the periods during which the greater number of hauls were made, and because they contain the maximum catches for all the years and fishes considered. The values dealt with, therefore, are those representing most probably the condition of the fishery in each year. The results are tabulated in Table VI., and they are represented graphically in the corresponding set of curves (VI.) on Plate C.

During this period the average catches of plaice have decreased from the maximum catch (2,045) in 1893 to the minimum (176) in 1899. The decrease from 1893 to 1894 was very great. From 1895 to 1897 the catches were nearly constant, dropping again in 1898. The maximum catch of dabs was made in 1894; from 1894 to 1897 the catches of dabs steadily declined, recovering again in 1898. The maximum catch of whiting was made in 1895, and the catches then decreased till 1897, when they again began to increase. It is singular that the maximum catches of these three fishes, plaice, dabs, and whiting, are observed in three consecutive years.

The catches of soles, on the contrary, show a nearly regular increase during those seven years. The minimum catch was made in 1894, the maximum in 1898. The decrease from 1898 to 1899 is very slight. We have evidence that a similar, though greater, increase in soles has taken place on the Blackpool closed ground.

No deduction as to the effect of fishing on the distribution of these fishes during the period considered can, of course, be made. The period is too short and the variations observed are too great. There can be little doubt but that the fluctuations are due in the main to the operation of natural causes.

We must insist on the inadequacy of these statistics to a thorough understanding of the causes influencing the distribution, on different areas and at different times, of the fish population of the Mersey shrimping grounds. So far as they go they are valuable, and they do give some information regarding the seasonal variation and the relation to each other of the various forms considered. But they suggest many more problems than they aid us in answering. The increase in the catches of soles on the Blackpool and Mersey grounds is an instance. This happening on two grounds, one preserved against, the other open to, shrimp trawling, is remarkable. A satisfactory answer might have been given by a much more complete series of observations than we possess, which might have enabled us, from a consideration of the relative increments in the catches from year to year, to have connected the increase on the Blackpool ground with its closure against the destruction of immature soles by shrimp trawling. But comparatively few hauls have been made on the Blackpool ground, and the opportunity has been lost.

No regular observations regarding the distribution of the plankton or of the bottom invertebrate fauna of the Mersey ground have been made, and we have therefore no material for a possible explanation of the fluctuation in the fish fauna outlined above. It is particularly unfortunate that regular and exact physical determinations of temperature, specific gravity, salinity, &c., were not made during the last eight years. These must be essential portions of any future investigation of this area.* The nature of the sea bottom is very peculiar, and a complete investigation of this is to be desired.

We believe that observations on this ground, with a view to the regulation of the fishing, will be unsatisfactory unless accompanied by enquiries into the relations of its fish population with the spawning fish on the offshore grounds on the one hand, and with the larger immature fish population of the offshore grounds on the other. Such investigation and enquiries into the stability of the immature fish population of the shrimping ground are very relevant.

* See scheme given in this Report, p. 21.

Report on the Deposits from the Liverpool "Hoppers" in Relation to Shrimps and Young Fish.

By W. A. Herdman.

Early in the year the General Purposes Committee asked for a report on the effect produced upon the movements of shrimps and young fishes by the materials carried out to sea from Liverpool in the hopper barges and deposited near the Burbo Bank. It had, I believe, been suggested (1) that the shrimps were attracted to this particular ground—where young fishes are also found in great abundance—to feed upon the refuse in the deposits; and (2) that if the attractive material were deposited on some other neighbouring ground not frequented by small fish the shrimps would follow, thus leading to such a separation of shrimps from young fish on the bottom as would admit of shrimping being carried on freely without causing any destruction of young fish. It would certainly be very convenient if it were so, but a careful examination of the facts shows that there is no real foundation for the ingenious suggestion.

Mr. Dawson, after discussing the matter with me, caused the necessary samples and specimens to be obtained from chosen localities in the area in question, and these were sent to the laboratory where Mr. Johnstone and I carefully examined them, and drew up the following report for the Committee:—

"Report by Dr. Herdman on Deposits, Shrimps, and Young Fish.

"A number of samples have been obtained during the last two weeks by Mr. G. Eccles, and were brought by him to the Laboratory for examination.

These represent:—

1°. Samples of the sea bottom at and about the "Deposit buoy." (See map on page 46).

2°. Samples of the sea bottom near the Rock Channel (No. 7 buoy).

3°. Samples of the deposit found in gutters on the edge of the Burbo Bank at low tide.

4°. Material taken from a "Hopper" in the Manchester Ship Canal.

5°. Samples of shrimps caught near the Deposit buoy.

6°. Samples of young flat fish caught near the Deposit buoy.

"These have all been carefully examined in the Sea-Fisheries Laboratory, and microscope preparations of the various substances have been made and compared.

The examination has shown:—

1°. That there is comparatively little fine mud or dirty material at the Deposit buoy. The bottom appears to consist largely of coarse crystalline sand.

2°. At No. 7 buoy the deposit is dirtier, and has more mud and amorphous decomposing material.

3°. In the gutters at low tide the deposit is also dirtier than at the Deposit buoy, and more like the refuse from the Hoppers.

4°. The material from the Hopper was very dark coloured, and had much more yellow and black amorphous decomposing stuff than is found on the sea bottom at or near the Deposit buoy.

5°. The shrimps caught about the Deposit buoy contained in the stomachs—sand, vegetable tissue, animal debris, legs, &c., of small Crustaceans, Foraminifera, Annelid setæ, along with a certain amount of sand.

6°. The stomachs and intestines of the young fish (mainly dabs) brought to the Laboratory from near the Deposit buoy were full of sand, with fragments of shells and remains of animals.

"CONCLUSIONS.—So far as these samples show, there is no reason to think that either the shrimps or the young fish feed upon the stuff deposited by the Hoppers. They did not show any traces of it in their stomachs, nor are they specially abundant where the bottom shows the greatest amount of dirt and decomposable material."

"University College, "W. A. HERDMAN."

"*March 15th, 1900.*"

Mr. Dawson and I therefore agree that it is a mistake to suppose (1) that the Liverpool refuse is especially abundant at the bottom in the neighbourhood of the so-called "deposit" buoy, which is on the Burbo Bank Shrimping Ground, and (2) that shrimps feed specially upon such refuse. Consequently the idea that the shrimps are attracted to the ground they frequent by the Liverpool deposits may be relinquished, and it is very improbable that changing the place of deposition would have any favourable effect upon the present distribution of shrimps and young fish.

As a matter of fact, as Mr. Dawson has pointed out in one of his quarterly reports, the steam hopper barges conveying the refuse generally go much further out to sea than the area in question before discharging; and, with the exception of sand, no material of any kind has apparently been deposited in the neighbourhood of the deposit buoy and from there to the Burbo Bank for some time.

It is probable that the conditions in these shallow sandy channels which suit the shrimps are also the most suitable conditions for young fish—especially flat fish—in certain stages of growth, and consequently it is futile to hope that any artificial operations will lead to the separation of the two kinds of animals.

Note on a Sporozoon Parasite of the Plaice. (Pleuronectes Platessa).

By James Johnstone.

(With Plate D.)

Two specimens of plaice have come to the Fisheries Laboratory during the year which showed a peculiar modification of the intestinal wall. One specimen was sent by Mr. G. Eccles, Chief Fishery Officer at New Brighton. It was caught near the Mersey Bar at the beginning of October. The other was sent to me by Mr. A. Scott. It had been caught by Mr. Wright, Fishery Officer, in Barrow Channel, on October 1st, 1900.

The first specimen was a female about 8 inches long. It had been opened, and the head cut partly off. Mr. Eccles was struck by the granular appearance of the viscera, suggesting the presence of a large quantity of spawn. As however the fish was much too small to contain ripe ovaries, he thought it worth sending to the Laboratory. It was fresh when it came to hand, and the fish looked in good enough condition. The ovaries were about one inch in length but perfectly normal for a fish of this size. The intestine, liver, kidney, &c., had their usual relations.

But the greater portion of the intestine, from the pylorus to about $1\frac{1}{2}$ inches from the anus was thickened, and had the appearance of a ripe ovary. That is, the surface was studded with little round white opaque bodies lying close together, and shining through the peritoneum. The fresh intestine was precisely similar to that of the second specimen, which is represented in Plate D, fig. 1. On cutting open a portion of the gut it was seen to have a much reduced lumen. The wall was 3 or 4 mm. thick. Its internal surface was thrown into close set and deep longitudinal folds pursuing a zigzag course. All the surface of these showed the same round white bodies projecting from their surfaces.

The stomach was normal in form and relations except that its walls seemed thinner than usual. No food contents were present. In the modified portion of the intestine there were traces of decomposed food matter. A few fragments of Lamellibranch shells were found, and were identified as young *Donax vittatus*.

The second specimen, sent by Mr. Scott, was the intestine of a female plaice 11 inches long. It had been preserved in corrosive-acetic fixative before reaching here. From Mr. Scott's description the fish seems to have been quite normal in other respects. The ovaries were of normal size and relationships.

Almost the entire post-pyloric portion of the intestine in this specimen was modified in precisely the same way as in the other case described above. Fig. 1 represents a portion of the intestine of this fish. The maximum diameter was about 1 inch. This thickest portion lay immediately behind the stomach. The pyloric caeca could be recognised, but were greatly flattened out. Near the anus the inclusions in the wall became fewer, and a small portion was free from them. No traces of food matter could be recognised in the lumen.

Pieces of both intestines were hardened in alcohol, embedded in paraffin, and sections were made. Fig. 2 represents a small portion of the wall of the first specimen cut in transverse section. No mucous membrane is recognisable, and the whole wall is filled up with roundish bodies, each of which appears on examination with a moderately low power to be filled up with a homogeneous material. These bodies are closely packed together, and between them lie a few connective tissue fibres. Some masses of disintegrated tissue lay between the folds which may possibly have represented the disintegrated mucosa. Fig. 3 represents a small portion of the same section under a much higher magnification. Outside of all may be seen a layer of peritoneum (*Per.*) and internal to this is a thin longitudinal layer of plain muscle fibre (*Ml.*). Within this layer of longitudinal muscle fibres is a layer of circular fibres (*M.c.*), also unstriated and about three times the thickness of the former layer. Within this, again is a layer of loose areolar tissue (*S. muc.*) from which fibres pass through the thickness of the wall of the intestine between the spherical bodies.

The arrangement of the muscle layer is therefore normal, and the foreign structures lie in the sub-mucosa. Of the mucosa itself there is no definite trace. A delicate sheet of connective tissue covers the free surface of the folds. This is easily torn, and the little spherical bodies can be readily dissociated. They are perfectly spherical in the fresh state, and have an average diameter of about 0·6 mm. The structure of a portion of one of these cysts is shown in Fig. 3. There is a capsule (*C.c.*), consisting of an outer cuticular layer and an inner irregular layer, which is fibrous in appearance, and apparently contains no nuclei. Within this capsule the cyst is filled up by a vast number of minute spore-like bodies. These are oval in shape. They have a maximum diameter of about 5 μ. They do not stain, and present no obvious internal structure.

It is obvious from the above description that we have to deal here with a Protozoon parasite, most probably a Sporozoon form. Possibly it is one of the Gregarinida, but at present I am unable to determine the genus.

Explanation of Plate D.

Fig. 1.—A small portion of the gut of the second specimen. Natural size.

Fig. 2.—Part of a transverse section of the wall of the gut of the first specimen. × 15 diameters. *I* internal, *E* external, surface.

Fig. 3.—Part of the same transverse section; × 350 diameters. *Per.* peritoneum; *Ml*, longitudinal muscle layer; *Mc*, circular muscle layer; *S.muc*, sub-mucosa; *Cc*, capsule of a cyst; *Sp*, spore contents of the cyst.

Fig. 4.—Several spores from the first specimen × 2,500 diameters.

On the Fish Parasites, Lepeophtheirus and Lernæa.

By Andrew Scott,

Resident Fisheries Assistant at the Piel Hatchery.

(With five Plates.)

Introduction.

There are comparatively few fishes that do not, at some period of their life history, prove on careful examination to be the host of at least one kind of parasite, either crustacean or worm. The worm parasites are usually found infesting the alimentary canal (Nematodes and Cestodes), the gills and skin (Trematodes and Bdellodes), while Crustacean (Copepod) parasites are almost entirely confined to places in direct communication with the exterior, such as the skin itself, the fins, the mouth, the branchial chamber, attached to the gills and operculum, in the nostrils, and in the mucous canals. They may even be found attached to the eye, as *Lernæenicus sprattæ* in the sprat (*Clupea sprattus*); and *Lernæopoda elongata* in the Greenland Shark* (*Acanthorhinus carcharias*), causing in the latter at any rate partial blindness; or burrowing into the abdominal cavity, as *Penella ëxocœti* in the flying fish† (*Exocœtus volitans*), till only the ends of the ovisacs are visible from the exterior.

The Copepod fish parasites have attracted much attention from Zoologists for a very long period, since the time when Aristotle, in his "Historia Animalium," tells us that the tunny and the sword fish are tormented by a sort of worm which fastens itself under the fin. Many of

* Mr. R. L. Ascroft, of Lytham, who visited Iceland on a "steam liner," fishing for halibut, &c., a year or two ago, says nearly all the sharks caught on the lines had these parasites in their eyes.

† One was exhibited at a meeting of the Liverpool Biol. Soc. in 1897, infested by two such parasites, recorded as *P. blainvilli*, which in turn were covered with a number of small Cirripedes.—Trans. L'pool Biol. Soc., vol. xi., p. xii.

the parasites now known to be Copepods were not at first recognised as Crustacea, chiefly because of the difficulty of making out the true characters and the absence of knowledge as to the life-histories. There was much difference of opinion even as to which were really the anterior and posterior extremities of these animals, due to the fact that the posteriorly placed ovisacs of the then known forms are cylindrical tubes which were by some supposed to be the antennules, and therefore that end was called the anterior. Hence many of the drawings of the earlier authors represent the animals standing on their heads.

Baird's "British Entomostraca," published by the Ray Society in 1850, marks an important epoch in our knowledge. This author gives an interesting historical account of the group, brings together all that was previously known, and gives a very full account, with excellent figures, of all the British species known at that time, and although some of these are inaccurate in detail, or have been added to by more recent investigations, still Baird's monograph is indispensable to any one working at the subject. Since 1850 comparatively little has been done in this country to increase our knowledge regarding the distribution or habits of these crustaceans. Within the past few years, however, the study has revived and some important papers, mainly speciographic, have been published.

The latest classification of the Copepod fish parasites arranges them under seven families, as follows:—Ergasilidæ, Caligidæ, Dichelestidæ, Philichthyidæ, Lernæidæ, Chondracanthidæ, and Lernæopodidæ. With the exception of the Philichthyidæ, all these families have representatives living on fishes found in the seas around our coasts.

These parasites vary considerably in size, ranging from one-thirtieth of an inch to nearly two inches in length. They also differ very much in shape. Some have their locomotor organs well developed, and are capable when necessary of leading a pelagic life for a period. Others have lost all swimming power, and become mere inert sacs, securely attached to their host by anchor processes, embedded in the tissues, and when taken off their host they soon die from want of food and oxygen.

The sexes are separate, the males as a rule being much smaller than the females. In many cases the males are practically parasitic on the females, especially those of the Chondracanthidæ and Lernæopodidæ. The fact that the males are found upon egg-bearing females of the above families is due to their power of locomotion having been lost when they reached maturity. When once they have settled down and matured they are unable to change their position to any extent. Fertilisation of the female is effected early in its life history, before the metamorphosis is completed. One copulation, apparently, is all that is necessary to fertilise the female for life. The resulting embryos remain attached to the external opening of the oviducts, either in a single or multiserial column, enclosed in a sac, until they hatch. The period of incubation extends over several weeks. The young parasites hatch out as nauplii, with three pairs of appendages. The nauplii undergo metamorphosis, which in some forms after a certain stage is reached is retrogressive, finally leading to the adult condition.

The Copepod fish parasites are generally regarded as being composed of about sixteen somites. Usually, however, some of these somites are suppressed or fused together, forming one compound segment, the true character of which is rendered evident by the appendages attached to it, each pair indicating a somite. At one end of the series, these parasites approach very nearly in structure and general appearance to the non-parasitic Copepods. At the other end they are extremely different, exhibiting most remarkable examples of retrograde development, and without a complete study of their life history it would be quite impossible to recognise them even as Crustacea.

In the following pages an account is given of the anatomy and metamorphosis of one member from each of the two very different families, the Caligidæ and the Lernæidæ, the forms chosen being *Lepeophtheirus pectoralis* and *Lernæa branchialis*.

The Caligidæ is the most extensive family of the Copepod fish parasites, and contains a larger number of genera and species than any of the others. As it stands at present, there are 124 species representing 25 genera. Three-fifths of the known species of Caligidæ belong to two genera, *Caligus* and *Lepeophtheirus*. Some earlier authors have not recognised the latter genus, and include the various species belonging to it in *Caligus*. There are, however, very important differences between the two which make their appearance early in life. These differences are constant, and give good cause for establishing a separate genus. *Caligus* has two semicircular suckers on the frontal margin of the cephalic shield, which are developed before the "chalimus"* stage is completed, and the biting part of the second maxillæ has only one tooth. In *Lepeophtheirus* these suckers are entirely absent all through life, and the biting part of the second maxillæ has two teeth. The changes that take place between the "nauplius" stage, when the animal is hatched from the

* The stage at which the animal first becomes attached to its host. (see p. 94).

egg, and the adult condition are practically the same in the two genera, and probably also in the other members of this family. From investigations carried on during the past two years, it may reasonably be concluded that *Lepeophtheirus*, throughout the remainder of its life and under normal conditions remains on the same fish that it attached itself to at the beginning of the "chalimus" stage. It is very rarely met with in tow-net collections. On the other hand, *Caligus* does not always remain on the same fish. At the completion of its "chalimus" stage it frequently leaves its host, and for a time leads a pelagic life. Tow-net collections often contain immature males and females, and occasionally mature males of *Caligus*, especially of *Caligus rapax*. Amongst these some may be found with a large notch in the middle of the frontal margin. This is due to the breaking of the chitinous filament by which they were secured to their host. The metamorphosis is a progressive one.

I.—LEPEOPHTHEIRUS (Müller).

This species was first described by O. F. Müller* under the name *Lernæa pectoralis*.

Mode of Occurrence.

Lepeophtheirus pectoralis is most frequently found upon the "white fluke" or flounder (*Pleuronectes flesus*). It also occurs on the plaice, dab, sole, &c. It does not confine itself to any particular part of the exterior. Males and immature forms of both sexes are to be found all over the skin on each side of the fish. Mature egg-bearing females, however, are usually found under the pectoral, the pelvic, the ventral and the dorsal fins. With careful

* Prodrom. Zoolog. Dan., 1776.

examination it is possible to collect a series of these parasites, from the early "chalimus" stage to the adult condition, from one fish. Sometimes only a few specimens occur on the fish. At other times large numbers are to be found. It is by no means rare to find between twenty and thirty mature females under each pectoral fin alone, as in the case which is illustrated in the cut. One hundred specimens of another species, *L. hippoglossi*, have been collected from the "white" side of a halibut in the Aberdeen Fish Market. The average length of a mature

Lepeophtheirus pectoralis, 32 specimens, on the pectoral fin of a Flounder, from a photograph.

egg-bearing female is one-fifth of an inch, and of a male one-ninth of an inch. A mature female measures about one-tenth of an inch at its greatest breadth, and a male one-twelfth of an inch. These parasites attach themselves to the fish by means of their powerful second maxillipedes, assisted by the antennæ, and a decided pull has to be exerted before they can be torn away. By depressing the edges of the carapace and applying them closely to the skin, the parasite can increase its holding power to such an extent that the posterior end can be torn from the anterior part without detaching it. The anterior part, when thus separated from the posterior, retains its vital powers for at least twenty-four hours. At first it swims about vigorously, but after some hours begins to get sluggish in its movements, and then finally dies. The posterior part does not live long when separated from the anterior. The parasites can be kept alive in sea water for upwards of six weeks after removal from the fish.

External Characters.

The animal is depressed dorso-ventrally, and is of a more or less oval shape, and distinctly divided into four parts (Plate I., fig. 1). The foremost one of these parts, and usually the largest, is almost circular in outline, and has all the appendages, with the exception of the fourth and fifth pairs of feet, attached to it. This part is known as the cephalo-thorax.

Viewed from above, this region is seen to be slightly convex and divided into four portions by imperfect sutures. Two of these sutures are longitudinal, and separate the lateral parts of the region from the central. The remaining suture joins the centre of the two longitudinal sutures like the cross line of the letter H, dividing the centre of the cephalo-thorax into an anterior and a posterior portion, of which the anterior is the greater. There is also an apparent suture near the frontal margin. The frontal margin is indented, the greatest depth being in the middle line. This indentation to some extent is due to the scar caused by the breaking away of the filament for attachment in the "chalimus" stage. In the centre of the hollow, situated on the ventral surface, is an oval-shaped opening (*b*) with a chitinous fringe. This is evidently a sucker, and represents the remains of a median sucker which is considerably developed during the "chalimus" stage, when the maxillipedes are rudimentary. Probably in the adult, it acts as a first aid in securing the animal to its host. Passing backwards from this sucker, but distinctly over it, there is a transparent rod (*c*, fig. 1, Plate I.; fig. 3, Plate III.), lying inside a triangular blood space, which terminates in a gland (*c g*, fig. 3, Plate III.). The gland is probably the organ that secretes the substance for the filament in the "chalimus" stage and the rod the remains of the filament. The filament and duct are in actual contact during the early part of the parasite's life (Plate I., figs 4 to 6, *c*). The eyes, two in number, are situated in the middle of the cephalo-thorax. The frontal and lateral margins are surrounded by a transparent membrane with faint transverse lines. This membrane is simply an extension of the chitinous exoskeleton which covers the whole animal. It has frequently a serrated edge caused by tearing.

The second part of the body is very small, and represents the fourth thoracic segment of the pelagic Copepoda. The fourth feet are attached to the external margins of this segment.

The third part of the body known as the "genital segment," is of variable shape, according to the degree of maturity of the reproductive organs. In an immature female (Plate II., fig. 6), it is usually very little larger than the fourth part, whilst in a mature one it is nearly as large as the cephalo-thorax. The genital segment of a mature female is somewhat quadrangular in outline, slightly wider posteriorly than in front. The same segment in a mature male (Plate I., fig. 2) is oval in shape and about one-third wider than the fourth part.

The fourth part of the body is short and narrow, being only one-fourth of the width of the female genital segment, and corresponds to the abdomen of the pelagic Copepoda. There is an incomplete articulation near the middle. At the apex of the abdomen there are two short papillæ known as the furca or caudal stylets, which usually have four or five plumose hairs on their posterior margins.

There are twelve pairs of appendages* (Plate II., fig. 1) as follows:—One pair of antennules, one pair of antennæ, one pair of mandibles, two pairs of maxillæ, two pairs of maxillipedes, and five pairs of feet, the first three pairs of feet only being adapted for swimming.

The eyes appear as a reddish spot in the living animal, and are situated on the dorsal surface mid-way between the frontal margin and the transverse line of the cephalothorax. When this spot is examined microscopically (Plate III., fig. 13) it is found to consist of two lateral eyes closely approximated, embedded in a mass of reddish-black pigment, and wholly under the carapace. Each eye has a simple, spherical, crystalline lens, beneath a thin cornea. Behind the lens is a row of retinal cells of fairly large size, lined internally with a tapetum or pigment layer. A chitin division lined with deep red pigment separates the two eyes. The earlier Zoologists had considerable doubt as to the true position of the eyes, some even believed the animals were blind. Others mistook the semi-circular suckers on the frontal margin of *Caligus* already referred to for the organs of vision, giving them the name "Binoculus."

The antennules are placed at the external margin, just behind the suture on the frontal plate, and each consists of two joints. The basal joint is much larger than the apical, and is clothed on its upper margin with plumose setæ.

* The minute details of the jointing and setæ of the appendages are not shown in these figures.

The other appendages are all on the ventral surface. The first are the antennæ. These consist each of two joints, a short stout basal one, and an apical one in the form of a strong prehensile claw. The antennæ are used to assist the second maxillipedes in grasping.* The apex of the claw projects into a small cup in front of the first maxillæ.

The mandibles are enclosed in the suctorial mouth (Plate II., fig. 8). They are stylet shaped, and composed of four joints. The apical joint of each mandible is flattened, curved inwardly, and serrated on its inner margin. There is no mandibular palp.

The appendages described here as the first maxillæ are given that name with some doubt. The pelagic Copepoda have only one pair of maxillæ, which correspond to the second pair in this memoir. The identification of the appendages now to be described as maxillæ is based upon the fact that they are innervated by a nerve from the sub-œsophageal ganglion that has its origin just anterior to the nerve supplying the maxillæ proper. The first maxillæ consist of one joint which is considerably swollen at the base, and tapers to a sharp point at the apex, forming as a whole, a curved claw. Two minute setæ are attached to the basal part, and probably represent the exopodite or palp. These appendages are situated near the lateral margins, and slightly posterior to the base of the antennæ.

The second maxillæ are placed at the sides of the mouth, and consist of a single joint, robust at the base and dividing into two slightly curved teeth at the apex, representing the exopodite. There is a distinct endopodite, with two setæ at its apex, attached to the base of the anterior surface of the exopodite. The second maxillæ

* Baird (op. cit. p. 263) describes these organs as the first pair of footjaws.

appear to act as a scraping apparatus for removing the skin of the host.

The first maxillipedes consist of two-jointed appendages placed mid-way between the apex of the mouth, when it is at rest, and the lateral margin. Their chief function is apparently to keep the mouth free from obstruction.

The second maxillipedes situated near the middle line, mid-way between the first maxillipedes and the first pair of feet, are composed of two joints. The basal joint is considerably swollen and the apical is in the form of a powerful claw, which closes upon the basal joint, forming a strong grasping apparatus. According to Claus, and others, the first and second maxillipedes are really only the exopodite and endopodite of one and the same appendage.

The first three pairs of feet consist of an endopodite and an exopodite attached to a two-jointed protopodite. In the first pair the endopodite is rudimentary, and is represented by a single minute joint bearing a few setæ at its apex. The exopodite is two-jointed. In the second pair both the endopodite and exopodite are three-jointed. The third pair has the protopodite well developed, forming a lamella. The endopodite and exopodite are very small, the former being composed of two joints and the latter of three joints. Each of the first three pairs of feet is attached to a median sternal plate. The exopodite of the first, and the endopodite and exopodite of the second and third pairs, are provided with a number of plumose setæ along the internal margins of the joints. The dorsal and ventral margins of the protopodites of the second and third pairs of feet are furnished with movable setose plates. The sterna of the second and third feet are clothed with setæ on the posterior margins. The fourth pair of feet (Plate I., fig. 1) have two-jointed protopodites, and exopodites also two-jointed, but no trace of endopodites. The external angles of the joints are furnished with short spines. The fifth pair are rudimentary, are attached to the posterior end of the genital segment, and consist of a thin lamella, furnished with three setæ along the posterior margin. Situated on the middle line between the second maxillipedes is a strong chitinous plate with a bifid apex pointing posteriorly. This is known as the sternal fork, but its function is unknown.*

The external openings are the mouth, the vulvæ, the openings of the oviducts and vasa deferentia and the anus. The mouth (Plate II., fig. 1 and fig. 8) is situated on the ventral surface of the cephalo-thorax, and is placed at the apex of a short, movable, conical tube. This tube is composed of the upper and lower lips fused together. The vulvæ (Plate II., fig. 6) are situated on each side of the middle line near the posterior end of the genital segment, and communicate with the "receptacula seminis." They are difficult to see in the adult female, but have each frequently a spermatophore attached which indicates the position. The openings of the oviducts are in the same segment, but nearer the lateral margins and just under the fifth feet. The openings of the vasa deferentia (Plate II., fig. 5) are situated on the postero-lateral margins of the genital segment of the male. The anus is situated in the middle line at the apex of the abdomen. In addition to these more important openings, there are also apertures of pore-canals and glands on the anterior surface of the basal joint of the protopodites of the second and third pairs of feet, and also on the dorsal surface of cephalo-thorax and abdomen. The opening in some cases

* Mr. I. C. Thompson suggests that the sternal fork appears to him to be a support or crutch, serving to raise the body sufficiently from the host to enable either the swimming feet or the mouth organs to be used, but I have not seen it used in this manner.

is at the apex of a small papilla, and communicates with a sac in the interior.

When resting, *Lepeophtheirus* lies upon the ventral surface, keeping the first three pairs of feet moving with spasmodic jerks. When irritated, as in attempts to remove them from their host, the males and immature females move very rapidly over the skin of the fish. The mature females make no attempt to escape, only clinging more securely. On transferring them to clean sea water they settle on the sides and bottom of the vessel, and sometimes adhere to the surface film of the water, remaining quiescent for long periods. When the water is shaken slightly they detach themselves and swim about rapidly on their backs. They soon tire, however, and return to rest again. *Lepeophtheirus* makes no attempt to leave the water when kept in small aquaria. The allied form, *Caligus*, on the other hand, crawls out of the water and up the sides of the glass, where it remains, making no attempt to return, and soon dies owing to the evaporation of the water from under the carapace. These parasites are very tenacious of life, and live for a considerable time after the host has died if they are not allowed to dry up. In some instances, although the host had been dead over twelve hours, and the parasites to all appearance were also dead, they soon revived when placed in sea water. Increase of temperature to 16° C. and over is fatal to them. They can, however, stand very considerable decrease of temperature. On one or two occasions during February, 1900, the small aquaria in the tank room at Piel, some of which contained parasites under observation, were frozen, and the temperature of the room itself stood at —1° C., but the parasites suffered no harm. They can also be kept alive in sea water for weeks without change if the aquaria are kept cool.

The colour of the living animal varies with the position in which it lives. On the dark side of the fish they are of a deep brown, almost black, colour. On the "white" side and under the fins they are nearly colourless, due to the contraction of the pigment cells, which appear as brown spots under the microscope. The dark coloured forms soon become almost colourless when exposed to light.

The Body-wall and Body-cavity.

The body-wall consists of (1) the chitinous cuticle or exoskeleton, which has been described in the external characters, (2) the cellular hypodermis, and (3) the connective tissue laminæ which line the integument, traverse the body cavity, and support the alimentary canal and other organs. The only cavity left inside the body-wall is the system of lacunæ, in which the colourless blood flows (see below under blood system, p. 81).

The Alimentary Canal.

The mouth, already described, leads into a short, narrow curved œsophagus, lined with a thin chitinous coat which is continuous with the exoskeleton. Near the anterior end the chitinous coat is much folded. The œsophagus (Plate III., figs. 3 and 5) passes through the anterior part of the nervous system, and in a transverse section of that region appears as a minute pinhole. After leaving the nervous system, it courses over the sub-œsophageal ganglion, and under a short cæcal projection of the stomach, finally entering the stomach on its ventral aspect, at the posterior end of the sub-œsophageal ganglion.

The stomach lies along the ventral surface, and is lageniform in shape (Plate II., fig. 3) At the anterior end it is produced into a short cæcum which extends over the posterior end of the œsophagus and it terminates by opening into the intestine in front of the second pair of feet.

The intestine is the direct continuation of the stomach. It commences in front of the second pair of feet, and passes through the thoracic and genital segments into the abdomen. It widens slightly behind its junction with the stomach, and then contracts as it passes through the fourth thoracic segment. It expands again in the genital segment, and contracts as it enters the abdomen. It terminates in a short rectum leading into the anus at the apex of the abdomen. There are no convolutions in this alimentary canal.

The intestine at its anterior end lies on the ventral surface of the animal. In the centre where it passes through the genital segment, it courses along the dorsal surface. It bends down as it approaches the abdomen, and occupies the centre of that part of the body. In transverse sections of a mature female the stomach is triangular in shape, with the apex pointing dorsally. The intestine in the genital segment is also triangular in transverse section, but the apex is directed ventrally. In immature females the stomach and intestine are of almost circular outline when cut transversely, so that the alimentary canal is considerably compressed when the reproductive organs arrive at maturity.

The wall of the whole alimentary canal is lined with a thin layer of chitin continuous with the exterior. In many places it is considerably broken up, giving it the appearance of fine striation. Underneath the chitin is a layer of nucleated cells, which extends from the posterior portion of the œsophagus to the rectum. There does not appear to be any marked regional differentiation in the cells. The lining of the stomach and intestine is thrown into a number of longitudinal folds (Plate III., fig. 11), the height of which varies considerably. In the anterior portion of the stomach these folds are very little higher than the general line, but as they pass posteriorly they increase considerably, diminishing again in the intestine as they approach the rectum. The greatest height of the folds is reached in the portion of the intestine passing through the genital segment. In the intestine and posterior portion of the stomach there are a number of glandular cells, usually at the apices of the longitudinal folds, the contents of which stain deeply with eosin. In many of these the cell contents have disappeared, leaving a clear space, only the cell wall remaining.

The wall of the stomach and intestine is marked by a series of transverse constrictions, giving it a crenate appearance, which is easily seen in the living animal. In the living animal an intermittent movement of the intestine and stomach is kept up. The action is wave-like, starting at one end, and passing to the other. After continuing in one direction for a time, it reverses and passes the opposite way. There is no valve between the stomach and intestine, and when the peristaltic motion is reversed the fluid in the intestine is sent back into the stomach again. The only portions of the alimentary canal that can be closed are the œsophagus and anal end of the rectum. The former is controlled by two longitudinal muscles which compress it, the latter by a number of muscles passing obliquely to the body-wall at the sides of the abdomen. The fluids contained in the alimentary canal are usually colourless, but occasionally when taken direct from the fish and placed under the microscope, a reddish tint may be detected at the posterior end of the œsophagus.

In connection with the alimentary canal there is a distinct paired digestive gland (Plate II., fig. 3 and fig. 9).

It consists of three portions, two moderately large masses on the lateral margins of the cephalo-thorax, just behind the antennules, and a median, smaller one, in front of the base of the mouth. The lateral portions are connected with the median by a duct. The median portion gives off a duct, which passes posteriorly along the œsophagus and enters the cæcum at the anterior end of the stomach. When the parasite is first removed from the fish the digestive gland is usually of a dark brown colour, but after starving for a few weeks it becomes colourless. The product of the gland is a pale, yellow fluid, which can be seen as it passes along the duct between the lateral and median portions.

Situated between the first and second pairs of thoracic feet is a pair of glands visible in the living animal as brown spots. A minute duct passes downward and then forward along the stomach. The duct appears to enter the stomach near the posterior end.

The food of this parasite is said to be mucus, and blood has not been detected in the stomach.* This fact gives some cause for the opinion advanced by many Zoologists that *Lepeophtheirus* and other allied genera are therefore not parasites in the strict sense of the term, and may not be hurtful to their hosts. There is considerable difficulty in settling the question of their true food. Specimens taken direct from the living fish and placed under the microscope, rarely show even the faintest trace of red colouring matter in the alimentary canal. The difference in structure between the Caligidæ and the obviously blood-sucking Lerneæ is very great. This will be pointed out in the section dealing with *Lernæa branchialis*, and may account for the apparent absence of blood. Mucus at the best is a poor food, but *Lepeophtheirus* can live for upwards

* They do not hesitate, however, to eat their comrades when these become feeble.

of six weeks in filtered sea water without visible food of any kind.

From the large numbers of flounders examined in the Piel laboratory, partly in connection with this memoir, but chiefly in connection with fisheries work, during the past year or two, the conclusion has been arrived at, that *Lepeophtheirus pectoralis* to some extent feeds on blood, and may be hurtful to the fish, especially when present in numbers (see figure on p. 68).

The appendages are more suited for a sedentary life than even a semi-pelagic one. The animals can only remain swimming for short periods, and their presence in tow-nettings, therefore, is accidental. They do not, under normal conditions, and as long as the fish remains in a healthy state, leave their host. In the fish tanks at Piel over 150 flounders, all more or less infested with *Lepeophtheirus*, are kept during the spawning season. The waste water from the tanks is carefully filtered for periods of at least three months in the spring, to collect the eggs shed by the fish. Yet not even one specimen of the parasite has been found in the filter. When the fish are examined and the parasites removed, no matter how carefully, the skin, especially where there are a number close together, is usually lacerated and bleeding. The males and immature females on the general surface of the body do not seem to remain long enough in one place to cause obvious injuries. Under the fins, however, and on the fins themselves, where the egg-bearing females are usually found, and where they lie for weeks in the same position if not disturbed, is the part of the fish chiefly injured. The pectoral fin in some instances may be partially destroyed, and pieces of the tissues are frequently found enclosed in the second maxillipedes of the parasite.

The antennæ and claws of the second maxillipedes are plunged into the tissues of the fish along with the teeth of the maxilla, lacerating the skin, and into this wound the suctorial mouth is directed. The blade-like mandibles assist in collecting the particles of food material. These are sucked up, pass down the œsophagus into the stomach, where they are at once acted on by the fluid from the digestive glands, and the colour of any blood present may then be discharged. It is usually at the junction of the œsophagus with the stomach that any red coloured particles occur. The food can then be traced along the stomach and intestine, and the waste matter is expelled from the anus in long strings.

On comparing transverse sections of the alimentary canal of *Lepeophtheirus* and of *Lernæa* which happen to contain food, and have been stained in eosin and hæmatoxylin, there is seen to be a marked similarity in the nature of the food in the two cases. Both are finely granular, and stain red with eosin. Mucus from the flounder has no such granular appearance.

It is stated by some Zoologists that copepod parasites are generally found most abundantly on weak and diseased fishes. It is not so with *Lepeophtheirus pectoralis*. Flounders with many parasites in our tanks were in as good condition as those that had none. They were never found on flounders which were thin and in poor condition, as they detach themselves and swim away when the fish becomes feeble. This was proved by actual experiments and observations at the Piel Hatchery.

The Blood and Circulation.

There is no heart in *Lepeophtheirus*, nor are there any proper blood vessels.

The circulation is wholly lacunar, and simply consists of broad, irregular streams passing through the spaces left among the internal organs, and between the connective-tissue bands of the body-wall. These streams have in general certain definite directions, but they are not uniform, continuous currents. The fluid advances by successive jerks, depending upon the movements of the alimentary canal and, in part, of the reproductive system. The blood is a clear fluid, containing numerous colourless corpuscles. The corpuscles vary in size and shape, and can accommodate themselves in diameter to the spaces through which they pass.

Plate II., fig. 2, shows the course of the main blood currents. Starting from behind the eye, there are two currents passing posteriorly, one flowing to each postero-lateral angle of the cephalo-thorax, where it turns and courses forward along the lateral margin of the carapace till it reaches the group of muscles connected with the mandibles. It then divides, one portion continuing along the margin to the base of the antennules, where it splits up into minute currents, all converging to the base of the mouth, while the other branch of this cephalo-thoracic current passes along the muscles of the mandibles and duct of the digestive gland, and meets the currents of the former branch at the base of the mouth.

A second main current courses posteriorly through the cephalo-thorax and the fourth thoracic segment, into the genital segment. It flows there along the reproductive organs in a broad stream, and turns round at the end of the segment. The currents from both sides meet in the middle line, and flow forward under the alimentary canal. In the region of the second maxillipede, this median ventral current breaks up into a complicated series of smaller currents, some of which pass into the two currents flowing posteriorly, and the others into the currents passing to the base of the mouth.

The main currents are easily seen by placing the living animal on its back, in a drop of sea water on a slide then covering with a thin cover glass and examining with a $\frac{1}{4}$in. objective.

The blood currents described above do not continue to flow for any length of time in the one direction. At one period they may be flowing as indicated by the arrows in Plate II., fig. 2. Then they suddenly slacken and reverse, and stream for a time in exactly the opposite course. Sometimes the blood corpuscles are seen to simply oscillate backwards and forwards, making no advance, but at other times they pass rapidly along in a definite manner.

There are no independent organs of respiration. It has been suggested by Hartog and others that the blood is probably aerated from the sea water contained in the thin-walled alimentary canal by the method of "anal respiration," which has been described in *Cyclops*, *Caligus*, *Argulus*, *Daphnia*, *Cypris* and other lower Crustacea.

The cuticular exoskeleton over the surface of the body is in most places so thick that the respiratory change of gases may be supposed to take place much more readily through the very thin layer of chitin which lines the rectum. There are dilator muscles attached to the wall close to the anus, and the peristaltic movements of the whole alimentary canal may aid in the production of inhalent and exhalent currents of water. It appears, however, to the present author that further precise observations are required to substantiate this hypothesis.

No organ corresponding to the "shell gland" described in various lower crustacea, and shown by Claus, Hartog and others to be a renal organ, has been found.

The Muscular System.

The muscles moving the appendages and segments of the body can be distinctly seen and traced to their extremities through the transparent exoskeleton (Plate II., fig. 1 and fig. 2).

The frontal portion of the cephalo-thorax is controlled by two short slender muscles, *mlf.*, (Plate II., fig. 2) passing postero-laterally from near the lateral edge of the carapace. They act in depressing the margin so as to produce a close attachment to the host. The posterior region of the cephalo-thorax is supplied with a number of pairs of muscles, some passing forward and others laterally, which contract and expand that part of the body. The lateral margins are controlled by long muscles passing obliquely outwards from the anterior end of the lateral suture. The muscles of the fourth thoracic and genital segments arise near the median line of the posterior portion of the cephalo-thorax, and pass backwards. They produce a lateral motion of the posterior parts of the body, and also a sort of telescoping contraction which draws the genital segment into the cephalo-thorax. The muscles of the abdomen arise near the middle of the genital segment and pass backwards. They produce a telescoping movement of the abdomen.

The various appendages and other organs are also well supplied with muscles. The antennules have each a pair, which elevate and depress the joints. The grasping action of the antennæ is produced by muscles passing obliquely to the lateral margins. The movements of the mouth are controlled by a complicated series of muscles passing anteriorly, posteriorly and laterally, all of which assist in elevating and depressing it when sucking up food. The mandibles are provided with muscles of extra-ordinary length and power, which pass obliquely backward to the lateral margins of the carapace nearly opposite the first pair of feet. The muscles of the first maxillæ are very short and thin. They pass along the posterior surface of the muscles of the antenna, to the lateral margins. The second maxillæ are controlled by powerful muscles passing to the lateral margins. The muscles of the first maxillipedes pass obliquely forward to the lateral margins. The second maxillipedes are supplied with short and powerful muscles which pass forward under the second maxillæ. The terminal claw is provided with muscles of great strength. The first three pairs of feet are supplied with a complicated series of muscles passing dorsally amongst those controlling the posterior portion of the cephalo-thorax. The fourth pair of feet are apparently little used, and consequently are only supplied with feeble muscles. The alimentary canal is controlled by longitudinal muscles, and also by muscles passing transversely, which produce the wave-like peristallic motions and crenated appearance. The anus is opened and shut by muscles passing obliquely, which open and shut each side alternately or simultaneously according to the requirements of the animal. The reproductive organs are also controlled by muscles, which give rise to pulsating movements, and assist in expelling the ova and spermatophores.

The Nervous System.

The central nervous system in *Lepeophtheirus* consists of a cerebral or supra-œsophageal ganglion and a large sub-œsophageal ganglion placed on the ventral surface, in the median line, and extending from slightly in front of the second pair of maxillæ to near the articulation of the second pair of maxillipedes with the body. The ganglia are connected by broad commissures passing on each side of the œsophagus, leaving only a narrow opening for its passage. The sub-œsophageal ganglion projects slightly forward under the supra-œsophageal, giving it the appearance of being separated from it, when viewed from the ventral aspect (Plate III., fig. 2). These are the only ganglia, and they supply the various parts of the body with nerves.

The supra-œsophageal ganglion is about half the size of the sub-œsophageal. It is produced on its dorsal surface into an optic lobe (Plate III., fig. 5), from which arises a distinct pair of optic nerves. Horizontal sections of the optic lobe show that the roots of these nerves cross each other (Plate III., fig. 12). Each optic nerve, therefore, is supplied by fibres from both sides of the brain.

The nerves supplying the antennules arise from near the anterior angles of the ganglion. They pass obliquely forward to the base of the antennules, and there subdivide into a number of branches which pass to the setæ clothing the anterior surface of the basal joint and apex of the second (Plate III., fig. 4). From the manner in which the antennules are supplied by this nerve it is evident that they are important sensory organs (Plate III., fig 4).

The antennæ are supplied by nerves arising from the anterior angles of the ganglion, which pass anteriorly under the nerves of the antennules and enter the base of the antennæ. These are the only appendages supplied from the supra-œsophageal ganglion.

The sub-œsophageal ganglion is heart-shaped, and fully twice the size of the supra-œsophageal. It represents the whole of the thoracic and abdominal ganglia of the higher crustacea, and supplies the remainder of the appendages.

The nerves passing to the mandibles have their origin on the anterior margin near the middle line. They course along the muscles of the œsophagus, and reach the mandibles near the base of the mouth.

The next pair of nerves arise at the anterior angle of the ganglion, course forward, under the nerves of the antennæ and antennules, to the frontal plate which they enter about midway between the lateral margin and middle line. They then turn abruptly and pass out to the lateral margins of the frontal plate, just above the antennules. The margin at this point is destitute of the transparent membrane which surrounds the carapace. The nerves terminate in a shallow cup, evidently a sensory organ.

Three other pairs of nerves arise from the anterior angles of this ventral ganglion. The first passes to the rudimentary first pair of maxillæ, the second, a short nerve, passes to the second pair of maxillæ, and the third to the muscles controlling the lateral margins of the cephalo-thorax.

The nerves supplying the first pair of maxillipedes arise from the anterior portion of the lateral margin. They are large nerves at their origin, but immediately divide into four branches, passing to the maxillipedes and muscles. The second pair of maxillipedes are also supplied by nerves arising from the lateral margins. Like those of the first maxillipedes they have strong roots, and at once divide into three branches which pass to the second maxillipedes and their muscles.

The remaining nerves have their roots in the posterior end of the ganglion. There are three pairs. These supply the five pairs of feet and the abdomen. The outer pair of nerves supply the first pair of feet. Near the origin a branch is given off which passes to the muscles of the stomach. The next pair supply the second pair of feet. They course along the median nerves as far as the sternal fork and then diverge. Just under the sternal fork a branch is given off which appears to pass to the muscles of the posterior region of the cephalo-thorax.

The median pair course close together, and unless carefully examined are easily mistaken for a single nerve. There is a distinct division, however, which is apparent even in the roots. Between the second and third pairs of feet a strong branch is given off which passes to the third pair of feet. The nerves then diverge, and just before entering the fourth thoracic segment give off a branch that passes to the fourth feet. The main trunks course on through the genital segment, still further diverging. Shortly after entering the broad part of this segment a third branch is given off which takes a semi-oval course along the ventral surface of each half of the segment, finally passing to the setæ of the fifth feet. On entering the abdomen the main trunks split into two branches, one passing to the anus and the other to the setæ on the apex of the caudal stylets (Plate III., fig. 2).

Each nerve, after leaving the main trunk, sends out numerous branches which pass to the various muscles controlling the appendages innervated by that nerve. Excepting the nerve passing to the fifth feet, the branches are not shown in the figure (Plate III., fig. 1). There is considerable difficulty in tracing the endings of the branches when they pass amongst the muscles.

The chief sense organs connected with the nervous system are the conspicuous eyes which are described above (p. 71). There are also the numerous setæ scattered over the surface of the body and appendages, which are possibly tactile in function. Probably the setæ upon the antennules, which are richly supplied with nerves from the supra-œsophageal ganglion, have a special function, which may be olfactory.

The Reproductive Organs.

The reproductive organs are paired, and as already stated, the sexes are separate.

In the female (Plate II., fig. 4) the ovaries are large kidney-shaped organs lying on each side of the anterior portion of the stomach and extending from under the first pair of feet to the base of the second maxillæ, when fully matured. Each oviduct (*od.*) arises near the anterior end of the ventral surface of the ovary, and courses posteriorly as a narrow tube till it enters the genital segment. It then expands rapidly, and passes to near the end of the segment. It then reverses its course, passing forward to the central portion of the segment, where it turns again in a posterior direction, and passing out to the centre of each half of the segment, it opens to the exterior just under the fifth feet. Each oviduct thus forms two loops in the genital segment. On the ventral aspect of the loops of each oviduct there is a short, semi-transparent cylindrical tube (*sg.*) with the anterior end closed and rounded, and the posterior produced into a fine duct, which communicates with the oviduct near its extremity. This organ is evidently a cement gland for secreting the enclosing membrane of the ovisac. Each vulva (fig. 6, *vu.*) is situated near the middle line behind the junction of the genital segment with the abdomen. It appears to consist of a simple opening leading into the vagina which expands into a "receptaculum seminis." This is an elongated sac passing from the median line to the oviduct, which it enters alongside the duct of the cement gland.

In the male the reproductive organs (Plate II., fig. 5) consist of a pyriform testis, on each side, situated in a position corresponding with that of the ovary. It is only about one-fourth the size of the ovary. Each vas deferens courses posteriorly into the oval genital segment. It communicates with the sac of the spermatophore on the external margin near the posterior end. A short cement gland furnishes a duct which passes in at the anterior end of the sac. The spermatophore, an oval body containing the spermatozoa, is expelled from an opening near the posterior angle of the segment.

In *Lepeophtheirus* the fertilisation of the female is accomplished soon after the "chalimus" stage is completed. The genital segment is then very small, about one-fifth the length of that of a mature female. It is grasped by the male on the dorsal aspect. The antennæ close round the junction of the genital segment with the fourth thoracic, and the second maxillipedes seize the segment immediately in front of its junction with the abdomen. The animals remain in this condition for some time, and can only be separated with difficulty. The spermatophores are discharged in pairs. When they are ready for discharging the male folds the whole of the posterior portion of its body along the ventral surface of the female. The openings of the spermatophore sacs are thus brought in contact with the vulvæ. The spermatophores are then discharged, and being in a viscid condition, at once stick to the female. One end of the covering, probably the last part that leaves the opening, is drawn out into a fine thread, which helps to secure the spermatophore. The spermatophores are not, apparently, always fortunate in reaching the vulvæ. It is by no means uncommon to find them planted amongst the appendages in little clusters like grapes. These have been mistaken by some of the earlier Zoologists for the eggs, when the true egg sacs were considered to be antennules.

One copulation apparently fertilises all the eggs produced by the female. It is obvious, when one compares the male with a mature female (Plate I., figs. 1 and 2), that fertilisation cannot be accomplished when the female genital segment is fully developed. Hence the need of it being effected at an early stage.

The exact period at which the eggs are fertilised by the spermatozoa is unknown. The spermatophores may be found attached to the body for some time after the female has begun to produce eggs (Plate II., fig. 4, *sp.*), but they are then simply empty sacs. Plate II., fig. 7, shows a pair of spermatophores that have been detached from an egg-bearing female. The little opening at *d.* was in direct communication with the vulva. These sacs were empty. In an immature female (Plate II., fig. 6), the vulva leads into a short vagina, passing directly into the oviduct. The spermatozoa probably remain in the vagina which becomes a "receptaculum seminis." In transverse or longitudinal sections through the region of the vagina of a mature female masses of spermatozoa are frequently found in the swollen part (Plate II., fig. 4, *rep.*). The oviduct in the immature female has no communication with the exterior except through the vulva.

The ovary of a mature female appears as shown in Plate II., fig. 10. It consists of a number of tubules lined with nucleated cells representing a germinal epithelium, which will form the eggs. The interior of the tubules is filled with a granular substance, staining faintly blue with hæmatoxylin and eosin. When the eggs become mature the walls of the tubule break down and the eggs pass out into the oviduct. They are then very small, about ·02 mm. in diameter, and do not fill up the duct. They are simply nucleated cells. As they pass posteriorly they increase in size. In the fourth thoracic segment they measure ·06 mm., and appear as oval bodies with a thin vitelline membrane. The cell contents are finely granular. The nucleus is a large oval body, with a sharp outline. A single rounded nucleolus is also present. After passing into the genital segment the cell contents increase in amount, causing a great enlargement of the egg, which finally passes out at the opening between the vulva and the lateral margin of the segment, already described. As the eggs pass out they are probably fertilised by the spermatozoa from the "receptaculum seminis." They are then enclosed in a thin chitinous tube, secreted by the cement gland, which gradually extends as more eggs are expelled. The ovisacs are often longer than the animal. The eggs in this tube are biscuit-shaped, measuring ·36 mm. in diameter and ·11 mm. in thickness. They are arranged in a single column. When the animal is irritated the tubes are frequently detached. When the embryos hatch, the empty, ruptured tube is left, and remains attached to the animal for a time. After examining many specimens, the conclusion has been come to that additional eggs are not developed in the tubules of the ovary after the first lot have been expelled. Adult females in which the ovary is only an empty sac are not uncommon.

Life History.

Lepeophtheirus has no regular breeding season. Mature females with ovisacs may be found at all times. The state of development reached by the embryos carried by various females collected at the same time is frequently widely different. In some the germinal disc has just begun to segment, in others the larvæ are ready to hatch.

The changes that take place in the developing embryo have not been worked out by the author. The period of incubation was found to extend over several weeks at least. In one case the ovisacs were kept for six weeks, and in another eight weeks, before the embryos hatched. The incubation takes longer than that, however. In both cases the embryos were pigmented when placed under observation. The first appendages that make their appearance are the antennules, antennæ and mandibles. They are in a rudimentary state, and the embryo is now ready to hatch. During this period the embryo increases in size as it develops.

The whole of the embryos contained in the tube hatch practically at once. The enclosing membrane ruptures, then the membrane of the tube splits, and the nauplii after freeing themselves from the fragments swim to the surface. Plate I., fig. 3, represents a newly hatched nauplius, the natural size of which is ·46 mm. It leads a pelagic life for a time, and grows by successive moultings. It next settles down on some fish, and passes into a cyclopoid state (Plate I., fig. 5). The young parasite immediately develops a thin chitinous filament from the median frontal gland already described, which passes into the tissues of the host, and it becomes fixed. The median sucker (*b.*, Plate I., fig. 5), with the help of the rudimentary antennæ and second maxillipedes, enables the animal to bring its mouth into contact with the host.

If young plaice, flounder, cod, &c., one to three inches in length, be examined very carefully at the end of the summer, it is practically certain that some recently attached *Lepeophtheirus* or *Caligus* will be found either on the fins or some other part of the integument. On examining fins which have parasites attached, the filament is seen passing through the skin, under it, and along one of the fin rays, as shown on Plate I., fig. 5 (natural size ·77 mm.). The filament may have the end bluntly pointed or flattened into a disc (Plate I., fig. 4). This is the "chalimus" stage referred to on previous pages, so called because Burmeister, in 1831,* described it as a new genus under the name "Chalimus." This was afterwards shown by Hesse and others to be only a young stage of the Caligidæ. The young parasite continues to grow by successive moultings, and the various appendages make their appearance in regular order. The duration of this attached stage has not been determined. When the appendages are fully developed, as in Plate I., fig. 6, the filament separates at its junction with the frontal margin leaving a notch, the remains of which persist all through the adult life.

The male, at the conclusion of the attached stage, is practically fully developed. The female remains in an immature condition until fertilisation is effected and the ova begin to pass down the oviducts. The genital segment then increases in size from that shown on Plate II., fig. 6, to the mature condition of Plate I., fig. 1.

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* Nov. Act. Acad. Natur. Cur. Bonn., vol. xvii., p. 294.

II.—LERNÆA.

The LERNÆIDÆ, although not so extensive a family in numbers of genera and species as the CALIGIDÆ, are more interesting to the specialist. They present some of the most remarkable instances of retrograde development that are to be found in the whole group of parasitic Copepoda. There is great excuse for the difficulty experienced by the earlier Zoologists in giving certain members of this family their true place in the animal kingdom. The fact that these animals were placed first in one group and then in another by successive workers is not surprising, considering that nothing was then known about their life history. It requires some study even at the present day to show that *Lernæa* is a Crustacean, still more to demonstrate that it is related to *Lepeophtheirus*.

The genus *Lernæa* as it now stands contains only five species. Formerly it was very extensive, and included many forms, such as *Lepeophtheirus pectoralis*, that had not the least apparent resemblance to each other in the adult state. Careful research, along with a better knowledge of the minute structure, gradually eliminated the unlike species, which were removed to other genera. An excellent historical account of our knowledge of the group will be found in Baird's "Entomostraca."

The species described here is *Lernæa branchialis*, Linn.

MODE OF OCCURRENCE.

The adult female is found on the gills of the Gadidæ, such as cod, haddock and whiting. Immature (cyclops stage) males, and females with adult males attached, are found on the apex of the gill filaments of the flounder, sometimes in large numbers. Full-grown females are not plentiful on the fishes caught in the vicinity of Piel.

Two to four specimens have been found after examining numerous catches of young cod of one dozen each. The ratio thus varies from one in three fish to one in six. In one or two instances two and sometimes three specimens were found on young cod eight inches long. The length of a full grown female *Lernæa* is a little over one inch.

The adult female is securely fastened to its host by strong branched horns, three in number, which are buried in the tissues of various parts of the gill arches. In many instances the head was found to have actually penetrated the ventral aorta. To obtain the specimens in an entire condition the tissues of the host have to be carefully dissected. Attempts to remove them by force always result in the head being left in the fish. The parasite, when once fixed, remains in the same position throughout life. When it dies the softer parts decay, but the head continues for a long time embedded in the tissues of the host, and is often met with there when dissecting out living specimens.

External Characters.

The adult female (Plate IV., fig. 1) is cylindrical. It is unsegmented, but roughly divided into three parts—a globular head with anchor-like processes, connected by a narrow neck to a much swollen posterior part.

The globular head corresponds to part of the cephalo-thorax in *Lepeophtheirus*. It is furnished with three more or less branched horns, two lateral and one median and dorsal. The head is slightly curved downwards, terminating in a conical apex.

The anterior portion of the neck represents the remainder of the cephalo-thorax and the fourth thoracic segment. The whole of the neck is marked by fine transverse lines.

The remainder of the neck and the greater part of the swollen mass behind corresponds to the genital segment. The abdomen is represented by the terminal portion of the swollen part, and gradually tapers to a blunt end. The swollen region of the genital segment is abruptly bent into the form of the letter S (Plate IV., fig. 1).

The appendages are rudimentary, the greater number being entirely absent. Those present are the first pair of maxillipedes placed at the apex of the head, immediately under the mouth, and four pairs of swimming feet at the anterior end of the narrow neck. The swimming feet are exactly as they exist in the cyclops stage both in size and structure. The protopodite is two-jointed, the exopodite of the four pairs is two-jointed. The endopodite of the first two pairs is also two-jointed. The third and fourth pairs of feet have no endopodite.

The external openings are, the mouth placed at the apex of the head, the openings of the oviducts situated on the ventral aspect of the S-shaped region, and the anus at the blunt apex of the abdomen (Plate IV., fig. 1, *an.*).

The colour of the living animal is dark red, due to the contained blood. When removed from the fish and placed in sea water the colour changes to white. *Lernæa* does not live long after being taken from the fish. The longest period observed was about twelve hours. They are simply inert sacs quite incapable of movement. Occasionally the parasites are covered with colonies of hydroids which sometimes entirely obscure them. The exoskeleton consists of a chitinous cuticle moderately thin and soft in the region of the swollen part, but thick and hard on the neck and head.

Immature *Lernæa branchialis* living on the apex of the gill filaments of the flounder (Plate IV., figs. 3, 4, and 5) are cyclopoid in appearance. The animal is oval in transverse section. It is composed of five distinct parts—an oval cephalo-thorax, three thoracic, and one terminal segment, representing the genital segment and abdomen. The anterior portion of the genital segment in the female is indistinctly divided into eleven joints.

The cephalo-thorax attains its greatest width just behind the eyes; beyond that point the sides converge until they reach the first thoracic segment. The cephalo-thorax is produced anteriorly into a broad blunt rostrum. In the very early cyclops stage (Plate IV., fig. 3), the rostrum is further produced into a short triangular filament which secures the parasite to its host. The eyes (Plate V., fig. 3) are situated on the dorsal surface a short distance behind the rostrum. In the living animal they appear as a dark red spot with a crystalline lens projecting slightly at each side. When examined microscopically the structure is found to be the same as that described in *Lepeophtheirus*. A thin cornea encloses a spherical crystalline lens. Behind the lens a row of fairly large retinal cells is lined internally with a tapetum layer. A chitinous septum lined with deep red pigment separates the two eyes. The appendages attached to the cephalo-thorax are as follows:—

The antennules are placed at the posterior angles of the lateral margins of the rostrum. They are short, and are composed of four nearly equal joints furnished with fine setæ.

The antennæ are composed of two joints. The apical joint is provided with a strong claw on its external angle. The antennæ usually project beyond the rostrum, and it is by means of these that the attachment to the host is maintained when the filament is broken off.

The mandibles are not enclosed in the suctorial mouth. They are situated at the base of the lateral surfaces of the conical tube of the mouth, and consist of two parts. The basal joint is cylindrical. The second joint is flattened, and terminates in a broad blade, which is serrated on the inner margin.

The single pair of maxillæ are placed at the base of the mandibles. They consist of two lobes, one of which is very small. The larger lobe has two moderately long setæ at its apex, the smaller one has one seta.

The first pair of maxillipedes are placed immediately behind the mouth. They consist of four joints, the last joint being furnished with a strong claw. The basal joint has two short hooks near its apex.

The second pair of maxillipedes in the female are rudimentary, and are represented by a minute knob. In the male they are composed of two joints, the apical one being in the form of a powerful claw. It is by the aid of the second maxillipedes that the male grasps the female during copulation.

The first pair of swimming feet consist of a two-jointed protopodite, an endopodite and an exopodite, both two-jointed. The apical joints of the endopodite and the exopodite are furnished with long plumose setæ on their inner margin and apex. This pair of feet is attached to the posterior end of the cephalo-thorax.

The second pair of swimming feet is attached to the first free thoracic segment, the third pair to the second free thoracic, and the fourth pair to the third. These free segments really represent the second, third and fourth thoracic segments, the first being a part of the cephalo-thorax. The second pair of swimming feet in every respect resemble the first pair. The protopodites of the third and fourth pairs are two-jointed; the endopodites in both pairs are absent. The exopodites are similar to those of the first and second pairs. The fifth pair of feet is represented by minute papillæ. The caudal stylets are very short, and furnished with three or four short plumose setæ at the apex.

The external openings are the mouth, the vulvæ, the openings of the vasa deferentia and the anus.

The mouth is situated on the ventral surface of the cephalo-thorax, at the apex of a conical tube, composed of the upper and lower lips fused together. In the very early cyclops stage the lips are not fused. The vulvæ and openings of the vasa deferentia are placed at the posterior angles of the genital segment. The anus is at the apex of the abdomen, in the middle line. The vulvæ open into the receptacula seminis, which are in direct communication with the oviducts.

The whole of the genital segment and abdomen in the female is marked by fine transverse lines. The colour, which is arranged in patches, varies from dark violet to light red.

Alimentary Canal.

In the adult the mouth opens into the intestine, which probably acts as the stomach, the œsophagus and true stomach having disappeared in the metamorphosis of the cephalo-thorax. The intestine is at first narrow where it passes through the neck, then it widens considerably in the swollen part of the genital segment, contracting slightly in the abdomen, and finally terminates in a short, narrow rectum leading to the anus (Plate V., Fig. 4). The intestine is lined with a single layer of nucleated cells. Attached to this layer, and in some cases embedded in it at irregular intervals, are large cells filled with fine granular material. In some parts these large cells are grouped together two and three rows high. In other parts they are quite free (Plate V., figs. 5 and 6). The layer supporting the nucleated cells appears to be composed of fine muscle fibres. There is no chitinous inner lining as in *Lepeophtheirus.* Between the basement layer of the intestinal wall and the integument there is a network of muscles passing in various directions. This tissue represents the body-cavity and body-wall. The spaces between the muscles are filled with the red blood. The peristaltic movement of the intestine is similar to that observed in *Lepeophtheirus.*

In the cyclops stage the mouth leads into a short, narrow œsophagus (*œ*, Plate V., fig. 2), which passes into the comparatively wide stomach on its ventral aspect. The stomach is lageniform, with the narrow end pointing posteriorly. On the dorsal aspect, at the anterior end, it is produced into a short, blunt cæcum. The narrow end of the stomach connects with the intestine, a long straight narrow tube, greatly compressed over the region of the receptaculum seminis. The intestine terminates in a very short rectum leading to the anus. The cells both free and attached along the wall of the stomach and intestine are similar to those in the adult. Sometimes the stomach is filled with free cells, which are kept constantly travelling backward and forward by the movement of the intestine. At other times few free cells can be seen. No trace of blood between the alimentary canal and the integument, as found in the adult, has been observed in the young.

No trace of a digestive gland could be found in the adult. In the young it is probably represented by a series of groups of cells running along the lateral margins of the cephalo-thorax (Plate V., figs. 1 and 3, *l.r.*). A short duct could be traced leading from these groups into the stomach, just posterior to its junction with the œsophagus.

When the alimentary canal of a living parasite is opened, and the free cells are isolated and examined with a high power, they are found to be subspherical, granular, and of various shades of greenish yellow colour. Some of the cells exhibit faint amœboid movement. It is probable, therefore, that the digestion is intracellular.

The food of these parasites is undoubtedly blood which we find in the alimentary canal, but whether the absence of digestive glands in the adult accounts for its unchanged appearance has not been ascertained. In the young, where there is an apparent digestive gland, the contents of the alimentary canal are not red.

Circulation and Respiration.

There is no heart or vascular system, and in the adult no movement of fluids could be observed which would indicate a blood circulation. The animal is probably dependent upon the blood sucked from its host for the supply of oxygen necessary to maintain life. It is therefore possible that the early death after removal from the fish is due largely to the inability to take up oxygen from the water. The blood circulation could not be satisfactorily traced in the cyclops stage.

The Muscular System.

The muscular system in the cyclops stage, although not so highly developed, is practically similar to that of *Lepeophtheirus*. In the adult female it is simply a network between the integument and the alimentary canal forming a supporting medium for the latter.

The Nervous System.

In the cyclops stage the central nervous system is the same as in the adult *Lepeophtheirus*. The nerves supplying the various appendages have also the same origin and direction as described in that type. The nerves marked 4a, 4b, and 5a in Plate III., fig. 2, could not be traced.

The nerve supplying the antennules has a similar branching at its termination to that of *Lepeophtheirus*.

In the adult *Lernæa* no trace of a nervous system could be made out, and certainly if present at all it is very much reduced.

The Reproductive Organs.

The reproductive organs of *Lernæa*, like those of *Lepeophtheirus*, are bilaterally symmetrical. In the cyclops stage of the female (Plate V., fig. 1) the ovaries (*o.*) are pyriform organs lying on each side of the stomach. They are situated on the ventral surface near the posterior end of the cephalo-thorax. Each oviduct (*od.*) arises near the posterior end, and courses posteriorly as a narrow tube. When it enters the genital segment it expands rapidly, ending in a large sac, the receptaculum seminis (*s*), communicating with the vulva (*vu.*). The oviduct has no distinct loops, and no cement gland is found.

In the adult male (Plate IV., fig. 5) the testes (*t.*) occupy the same positions as the ovaries in the female. The vasa deferentia are straight, narrow tubes coursing posteriorly and terminating in the sacs of the spermatophores. A cement gland is present, as in *Lepeophtheirus*.

The ovary in the course of the metamorphosis undergoes great change of position. It is removed from the cephalo-thorax into the genital segment. It occupies a narrow region at the apex of the deep indentation (Plate V., figs. 4 and 5, *o.*). The two ovaries have also practically fused together, no separation is visible in transverse section. The united ovaries are produced into horn-like projections anteriorly and posteriorly (Plate V., fig. 5). The oviducts (*od.*) arise near the apex of the anterior horns, pass across the segment to its ventral surface, and then course along each side of the median line to the external openings. Each cement gland (Plate V., figs. 4, 5 and 7, *sg.*) is a long crystalline organ of nearly the same length and breadth as the oviduct, lying ventrally to it. The anterior part terminates at the base of the neck, in a blunt end. The posterior end communicates with the oviduct just inside the opening to the exterior.

The structure of the ovary of *Lernæa* differs considerably from that of *Lepeophtheirus*. In the cyclops stage it consists of a mass of minute nucleated cells. In the adult condition there are no tubules, and all the eggs are in close contact. The size of the eggs in the ovary of the adult varies from ·04 to ·08 mm. They are of the same structure and undergo the same changes in their passage along the oviduct as the eggs of *Lepeophtheirus* when they enter the thoracic ends of the oviducts. The ovisacs consist of long slender tubes very much twisted. (Plate IV., fig. 1, *os.*). When straightened out each tube is often found to attain the length of seven or eight inches. The eggs are arranged in a single column, and the period of incubation is of the same duration as in *Lepeophtheirus*. The death of the parent or detachment of the ovisacs has no effect on the vitality of the embryos.

Fertilisation of the female is effected during the fixed period of the cyclops stage. The spermatophores are attached to the female in a similar manner to that described for *Lepeophtheirus*. The contents pass into the receptacula seminis, and the empty sacs fall away. They are then replaced by others in succession, until the receptacula are filled. Each fully charged receptaculum represents the contents of four spermatophores (*rep.*, Plate IV., fig. 4). At first there is a distinct division between each lot, but this soon disappears, and the whole becomes one mass of spermatozoa. From a large number of females sectioned in various directions, the conclusion has been arrived at that the spermatozoa at once pass up the rudimentary oviduct to the ovary and fertilise the eggs. This probably accounts for the difference between the ovary of an adult *Lernæa* and *Lepeophtheirus*. No trace of a receptaculum seminis could be made out in the adult.

Life History.

The development of the embryo has not been worked out by the present author. An excellent work by D. Pedaschenko* contains a full description and figures of the developing embryo.

The young *Lernæa* hatches out as a nauplius, with three pairs of appendages, representing the rudimentary antennules, antennæ, and mandibles (Plate IV., fig. 2, nat. size, ·45 mm.). It then after a short pelagic life, settles on the apex of the gill filaments of the flounder, to which it adheres by a broad chitinous filament, and passes into a cyclopoid form (Plate IV., fig. 4). The young *Lernæa* are occasionally found on the gills of the plaice and lumpsucker. The parasite, by its attachment to the gill filament, produces a marked change in that organ. The whole of the apex assumes a tumid character, and the filamentous plates on both sides for some little distance disappear (Plate IV., figs. 8 and 9). While attached to the gills the various appendages develop. The male here reaches maturity (Plate IV., fig. 5), and undergoes no further change. In the female a considerable lengthening of the genital segment accompanies the appearance of the various appendages. Fertilisation next takes place: then the young female severs its connection

* Development of the embryo and metamorphoses of *Lernæa branchialis*. Trad. Soc. Imp. des Naturalistes de St. Petersbourg, vol. xxvi., livr. 4, No. 7, Sect. de Zool. et de Physiologie, 1898, in Russian, with German resume.

with the chitinous filament, and leads a pelagic life (Plate IV., fig. 4. Nat. size 2·3 mm.). This condition is frequently found in collections of plankton, and unless care be taken may readily be confused with immature stages of allied forms. I. C. Thompson, F.L.S.,† was the first to recognise certain copepods taken in collections of plankton from Liverpool Bay, &c., as the young of *Lernæa*, from Claus' figures. The presence of the males of *Lernæa* in plankton is to some extent accidental, as only the females lead a pelagic life. The males remain on the gills after the females have gone. The result of the examination of the contents of a fine filter, through which the waste water was passed from the tanks containing flounders in the Piel Hatchery, showed that females were always more numerous than males. The ratio, after a number of trials, was found to be one male to twenty-five females.

At the conclusion of the pelagic life the young *Lernæa* again fixes itself to the gills of a fish, and the retrogressive metamorphosis commences. The parasite buries its cephalo-thorax into the tissues. This region then develops into horns, which are situated one at each side and one dorsal. These pass out at right angles to the body into the tissues of the host. At first they are simple, but by gradual division in each horn they acquire the characters found in the adult (Plate V., fig. 8). The anterior part of the segment curves over, taking up the position shown on Plate V., fig. 4. The eyes, antennules, antennæ, mandibles and maxillæ disappear, leaving only the first maxillipedes, which are represented by small hooks in the adult. The free thoracic segments fuse, but the feet remain as in the cyclops stage. The genital segment elongates until fully fifteen times the original

† Revised Report on L.M.B.C. Copepoda. Trans. L'pool Biol. Soc., vol. vii., p. 212.

length. The abdomen only lengthens a very little. The elongation takes place during the development of the horns and before the eyes and the other organs disappear. This condition is shown on Plate IV., fig. 6; the nat. size is 11·4 mm. The next phase, represented on Plate IV., fig. 7. shows that the development of the horns, the disappearance of various appendages, and the great lengthening of the genital segment is followed by a looping of the posterior region of the latter. This loop gradually expands, and finally takes on the adult condition.

In the metamorphosis of the cephalo-thorax the ovaries are thrust into the genital segment, and take up a position on the dorsal aspect of the posterior region of that segment, in such a manner that the more anteriorly placed portion of the ovary in the adult is what was the posterior part in the cyclops stage (see Plate V., figs. 1 and 4).

The cyclops stage of *Lernæa* was first found *in situ* by Metzger,* who published a short note on the observations made and the conclusions arrived at early in 1868. Claus† later on in the same year, from specimens supplied by Metzger and fresh material, confirmed the observations of that Zoologist.

Concluding Remarks.

In the account set forth on the above pages, it will be seen that there are remarkable differences between the changes that take place in the life history of the two copepods before they reach maturity. In the one case (*Lepeophtheirus*) the life history exhibits a series of progressive developments. In the other (*Lernæa*), although

* Ueber das Männchen u. Weibchen der Gattung *Lernæa*, vor dem Eintritt der sog. rückschreitenden Metamorphose. Jany., 1868.

† Beobachtungen ueber *Lernæocera*, *Peniculus*, und *Lernæa*. 1868.

for a time it advances, yet after a particular period has arrived the remainder of its development is retrogressive. The various appendages in each parasite are developed in the same order. In the one they become perfected when the creature is fully developed. In the other, long before the animal has reached maturity some have disappeared, the remainder continue in a rudimentary condition, and it is incapable of further movement. The internal organs of both copepods are developed in the same way. In one they continue advancing until perfected, and the animal is thus capable of living for considerable periods apart from its host. In the other, such organs as the digestive gland, the brain and nerves, and the blood system become rudimentary, if they do not altogether disappear. The ovary loses its original position and passes into the genital segment. The animal dies when removed from its host.

If only the adults were known, it would practically be impossible to recognise that such a form as *Lernæa* was in any way related to such a typical free-swimming Copepod as *Calanus*, and it would therefore still occupy an uncertain position. But when the whole life history of both copepods is known, tracing the connection becomes comparatively easy. Both originate from a free larval stage known as the nauplius, which has been regarded as the representative of a far back common ancestor. Both pass through a cyclops stage. The one ancestral cyclops form, we may suppose, by maintaining a free swimming life, gradually acquired more perfect appendages, and became at last the form now known as *Calanus*. The other cyclops form by adopting a sedentary life, and depending on other animals for its food, became semi-parasitic like many of the ascidian- and sponge-frequenting forms of copepoda. The transition from *Lichomolgus*-like copepods to such forms as *Bomolochus* and *Ergasilus* became simple. Further change in form and habit continued as the various appendages, through constant rest, degenerated. The animal became in consequence more and more dependent on its host for food. Such changes extending over a long period of time, have apparently resulted in such a form as *Lernæa.*

Some Zoologists divide the fish parasites into blood-suckers and mucus-eaters, on account of the apparent presence or absence of blood in the alimentary canal. It is doubtful if such a division is really satisfactory. The probability is that they are all blood-suckers in different degree, and that the presence of blood is only obvious because certain organs are absent. *Læmargus muricatus,* one of the *Caligidæ,* appears to make excavations into the skin of its host, *Orthagoriscus mola* (the short sun-fish). Several individuals are usually found in each excavation.* No obvious appearance of blood can be observed even in these parasites.

One or two parasites on a fish may not be hurtful, but when the numbers increase they probably have an irritating effect, and finally, when they remain in one position for some time, the skin and tissues become lacerated. Consequently even such external parasites as have been regarded as harmless mucus-eaters may really have an injurious effect upon the fish.

There is much opportunity for investigating the internal structures of the various families of fish parasites. The most of the literature hitherto published deals with the external characters only.

The specimens necessary for the work connected with this memoir have been almost entirely collected from fish caught in the vicinity of Piel. The author is indebted to Mr. R. Newsham, Jun., the Laboratory Assistant at Piel,

* A. Scott. Trans. Nat. Hist. Soc., Glasgow, vol. iii., part 3, p. 266. 1892.

for help in collecting. The important stage of *Lernæa*, shown on Plate IV., fig. 6, is drawn from a specimen sent by Mr. T. Scott, F.L.S., the author's father. It was found on the gills of a whiting caught in the Bay of Nigg, Aberdeen, in 1900, and was the only one met with in the course of these investigations.

Explanation of Plates.

Reference Letters.

a. antennule.
ai. antenna.
aii. lateral frontal sucker.
an. anus.
b. median frontal sucker.
bls. blood space.
c. filament duct.
cg. filament gland.
cn. chitin.
D. dorsal.
d. opening of spermatophore.
e. eyes.
f. filament.
g. ganglia.
gl. gland.
i. intestine.
K^1 left anchor process.
K^2 median ,,
K^3 right ,,
L. left.
ld. duct of digestive gland.
lns. lens.
lv. digestive gland.
M. mouth.
m. mandible.
ml. muscle.
ml.a. antennule muscles.
ml.an. anal muscles.
ml.f. frontal muscles.
ml.i. intestine muscles.
ml.l. lateral muscles.
ml.m. mandible muscles.
ml.mxp. first maxillipede muscles.
ml.pt. posterior cephalic muscles.
ml.rt. rectum muscles.
ml.st. stomach muscles.
mx. first maxilla.
mxi. second ,,
mxp. first maxillipede.
mxpi. second ,,
n. nerves.
nc. nucleus.
o. ovary.
od. oviduct.
œ. œsophagus.
og. optic lobe.

om. muscles of the oviduct.
os. ovisacs.
ov. ova.
$p^{i.}$ first pair of feet.
$p^{ii.}$ second ,,
$p^{iii.}$ third ,,
$p^{iv.}$ fourth ,,
$p^{v.}$ fifth ,,
pg. pigment.
R. right.
r. rostrum.
rep. receptaculum seminis.
rt. rectum.
rtn. retina.
ry. fin ray.
S. spermatozoa.
sbg. subœsophageal ganglion.
sf. sternal fork.
sg. cement gland.
sp. spermatophore.
spg. supra-œsophageal ganglion.
st. stomach.
t. testis.
V. ventral.
va. vagina.
vd. vas deferens.
vu. vulva.
y. opening of digestive duct into the stomach.
z. pore canals.
Nos. 1 to 13 nerves, as follows:—
1. optic.
2. antennules.
3. antennæ.
4. mandibles.
4a. lateral frontal margins.
4b. first maxillæ.
5. second maxillæ.
5a. lateral cephalic muscles.
6. first maxillipedes.
7. second maxillipedes.
8. first feet.
8a. stomach muscles.
9. second feet.
9a. posterior cephalic muscles.
10. third feet.
11. fourth feet.
12. abdomen.
13. fifth feet.

Plate I.

Fig. 1. *Lepeophtheirus pectoralis*, mature female, dorsal view. × 17.

Fig. 2. *Lepeophtheirus pectoralis*, mature male, dorsal view. × 17.

Fig. 3. *Lepeophtheirus pectoralis*, nauplius stage, newly hatched. × 52.

Fig. 4. *Lepeophtheirus pectoralis,* "chalimus" stage. × 26.

Fig. 5. *Caligus rapax,* early "chalimus" stage attached to fin ray of young cod, the line *d' e'* represents the surface of the skin. × 54·4.

Fig. 6. *Caligus rapax,* "chalimus" stage, previous to throwing off the filament attachment. On tail of young lumpsucker. × 15·24.

Fig. 7. *Caligus rapax,* mature, part of the frontal plate showing a lateral sucker. × 22.

Plate II.

Lepeophtheirus pectoralis.

Fig. 1. Female, ventral view, showing the various appendages and their muscles. × 17.

Fig. 2. Female, dorsal view, showing the chief muscles and blood currents. The arrows indicate the course of the blood. × 17.

Fig. 3. Female, ventral view, showing the digestive gland, its duct and alimentary canal. × 17.

Fig. 4. Female, ventral view, showing the reproductive organs. × 17.

Fig. 5. Male, ventral view, showing the reproductive organs. × 26.

Fig. 6. Genital segment and abdomen of an immature female, ventral view, showing vulva (*vu.*). × 40.

Fig. 7. Spermatophores detached from genital openings of a female. × 25.

Fig. 8. Mouth from the anterior base, with the mandibles inside, showing the muscles and ducts of digestive gland. × 25.

Fig. 9. Digestive gland. × 77.

Fig. 10. Longitudinal section of the ovary. × 50.

Fig. 11. Transverse section of pore-canal at the base of the mouth. × 350.

Plate III.

Lepeophtheirus pectoralis.

Fig. 1. Female, ventral view, showing the nervous system *in situ*. × 17.

Fig. 2. The nervous system from the ventral aspect. × 38.

Fig. 3. Female, nearly median longitudinal section. × 17.

Fig. 4. One of the antennules, showing the nerve endings. × 76.

Fig. 5. Median longitudinal section of the ganglia, showing the "pinhole" œsophagus passing through between the supra and sub-œsophageal parts. × 77.

Fig. 6. Transverse section in the region of the eyes. × 38.

Fig. 7. Transverse section in the region of the supra- and sub-œsophageal ganglia. × 35.

Fig. 8. Transverse section in the region of the second maxillipedes. × 30.

Fig. 9. Transverse section through the genital segment, female. × 30.

Fig. 10. Transverse section through the genital segment, male. × 38.

Fig. 11. Part of a transverse section of the intestine. × 76.

Fig. 12. Horizontal section of the dorsal aspect of the supra-œsophageal ganglion, showing the crossing of the fibres of the optic nerves. × 152.

Fig. 13. Transverse section of the eyes. × 152.

Plate IV.

Lernæa branchialis.

Fig. 1. Mature female, from the right side. The line $f' \; g'$ shows how much of the anterior portion is buried in the branchial arch. × 4·3.

Fig. 2. Nauplius stage, newly hatched. × 50·8.

Fig. 3. Very young female, unfertilised, dorsal view. From gills of flounder. × 51·5.

Fig. 4. Fertilised female, dorsal view. Just after leaving the gills of flounder. × 27·6.

Fig. 5. Mature male, dorsal view. From gills of flounder. × 28·5.

Fig. 6. Fertilised female, "Penella" stage, dorsal view. Just after settling on gills of *Gadus* (whiting). × 15·5.

Fig. 7. Later stage than Fig. 6, from the left side. The folding has just finished. Nat. size.

Fig. 8. Apex of gill filament of flounder, showing malformation caused by the young *Lernæa*. × 18·6.

Fig. 9. Apex of gill filament of flounder, normal. × 18·6.

Plate V.

Lernæa branchialis.

Fig. 1. Fertilised female, ventral view, showing the appendages, the reproductive organs, and nervous system. × 47·6.

Fig. 2. Nearly median longitudinal section of the same. × 47·6.

Fig. 3. Transverse section in the region of the eyes. × 80.

Fig. 4. Mature female, from the right side, showing the first maxillipede and the four pairs of feet, the alimentary canal and the reproductive

organs. The specimen was cleared in xylol, and the right anchor process removed. × 4.

Fig. 5. Transverse section through $\alpha\ \beta$, (Fig. 4,) showing the muscular wall, the ovary, oviduct, cement gland, and intestine. × 9.

Fig. 6. Transverse section through $x\ \beta$, (Fig. 4,) just anterior to the rectum. × 20.

Fig. 7. Portion of the cement gland. × 20.

Fig. 8. Front view of the anchor processes of an adult female. × 4.

Table I.—Abstract of the results of Hauls with a Shrimp Trawl made on the Burbo Bank Shrimping Ground (Area A) during the period 1893—1899.

Date.	Number of Hauls.	Total Nos. of Fish.	Average Nos. of Fish per haul.	Shrimps. Total Nos. of quarts.	Shrimps. Average Nos. of quarts per haul.	Plaice. Total Numbers.	Plaice. Average Numbers per haul.	Soles. Total Numbers.	Soles. Average Numbers per haul.	Dabs. Total Numbers.	Dabs. Average Numbers per haul.	Whiting. Total Numbers.	Whiting. Average Numbers per haul.
1893—May ...	4	1005	251	$16\frac{1}{4}$	4	742	185	28	7	127	32	69	17
June ...	4	5948	1489	38	$9\frac{1}{2}$	1868	467	48	12	3304	826	965	241
August ...	3	8165	2722	61	$20\frac{1}{3}$	1810	603	109	36	2276	758	3850	1283
September	5	19593	3919	78	15·6	14548	2910	173	35	2115	423	2480	496
October ...	1	662	662	0·125	0·125	280	280	2	2	241	241	53	53
November	2	866	433	2·25	1·125	170	85	2	1	536	268	130	65
December	2	621	310	10	5	162	81	0	0	426	213	18	9
1894—January ...	2	1235	617	14	7	492	246	15	7·5	531	265	165	82
February	4	1792	448	16	4	699	175	20	5	746	186	266	66
March ...	5	5237	1047	48	9·6	1474	295	301	60	2084	417	1101	220
April ...	4	3922	980	30·5	7·6	1067	267	83	21	2379	595	524	131
May ...	4	5376	1344	26·75	6·7	2010	502	82	20·5	2545	636	571	143
June ...	9	6599	733	76·5	8·5	2932	326	318	35	2633	293	227	25
July ...	3	3838	1279	24·5	8·1	461	153	69	23	983	327	2160	720
August ...	6	21913	3652	62·5	10·4	3329	555	95	16	10801	1800	7493	1249
September	4	8111	2028	133	33·2	2283	571	39	9	1283	321	4014	1003
October ...	3	3682	1227	130	43·3	680	226	28	9	1410	470	1561	520
1895—March ...	2	53	26	0·5	0·25	40	20	0	0	0	0	0	0
April ...	3	734	245	18	6	170	56	4	1·3	306	102	237	79
May ...	8	3671	459	102·5	13	571	71	158	20	1977	247	683	85
June ...	4	3575	894	50	12·5	272	68	29	7	2765	691	302	75
July ...	5	19245	3849	136	27	3104	621	129	26	5117	1023	9500	1900
August ...	3	8750	2916	22	7·3	982	327	63	21	1621	540	5272	1757
September	1	4404	4404	7	7	2315	2315	5	5	705	705	1224	1224
October ...	3	8897	2965	25·5	8·5	1747	582	0	0	3003	1001	2434	811
November	1	1000	1000	9	9	284	284	0	0	345	345	292	292
December	1	385	385	6	6	62	62	0	0	193	193	71	71
1896—March ...	2	1911	955	12	6	954	477	5	2·5	546	273	258	129
April ...	2	2819	1409	5	2·5	1258	629	13	6·5	626	313	741	370
May ...	2	1481	740	10·5	5·25	649	324	5	2·5	498	249	294	147
June ...	3	4199	1399	13	4·3	1703	568	29	10	1963	654	361	120
July ...	2	6996	3498	8·5	4·25	2219	1109	49	25	1169	584	3534	1767
August ...	1	2608	2608	0·75	0·75	206	206	1	1	981	981	1433	1433
September	1	723	723	8	8	120	120	57	57	150	150	298	298
October ...	3	2920	973	92	30·6	397	132	128	43	1534	511	800	266
1897—February	1	446	446	1·5	1·5	94	94	34	34	96	96	215	215
April ...	2	490	245	2·5	1·25	190	95	66	33	88	44	257	128
August ...	1	1913	1913	2·5	2·5	1278	1278	197	197	287	287	150	150
September	2	2591	1295	5·5	2·75	685	342	62	31	658	329	1186	593
October ...	1	1228	1228	7	7	111	111	58	58	756	756	252	252
1898—July ...	4	5464	1366	41	10·2	1175	294	1060	265	1628	407	1352	338
August ...	3	4226	1409	16	5·3	166	55	341	114	1678	559	1967	656
September	7	20330	2904	57·5	8·2	1316	188	979	140	8374	1196	9677	1382
October ...	2	4686	2343	7	3·5	625	312	254	127	1071	535	2676	1338
1899—June ...	6	1308	218	60	10	112	18	223	37	718	119	94	16
July ...	1	201	201	7	7	30	30	43	43	3	3	71	71
August ...	15	31718	2114	292	20	2951	197	2361	158	8340	556	17608	1174
September	2	2133	1066	39	19·5	190	95	209	104	982	491	654	327
October ...	4	1237	309	23	5·7	79	20	236	59	829	207	933	233

Table II.—Abstract of the results of Hauls with a Shrimp Trawl made in the Horse, Rock, Queen's and Crosby Channels (Area B) during the period 1893—1899.

Date.	No. of Hauls.	Total No. of Fish.	Average No. of Fish per haul.	Shrimps. Total No. of quarts.	Shrimps. Average No. of quarts per haul.	Plaice. Total numbers.	Plaice. Average No. per haul.	Soles Total number.	Soles Average No. per haul	Dabs. Total number.	Dabs Average No. per haul.	Whiting. Total number.	Whiting. Average No. per haul.
1893.													
April	5	1019	204	13	2·6	378	76	22	4·4	196	39	385	77
May	1	312	312	0·5	0·5	283	283	14	14	9	9	6	6
August	3	7065	2355	43	14	13	4	14	4	0	0	6292	2097
September	1	425	425	7	7	321	321	29	29	20	20	28	28
October	5	3739	748	36	7	1846	369	22	4	855	171	966	193
November	2	1054	527	8	4	843	421	2	1	454	227	158	79
December	4	2933	733	1·75	0·5	1591	398	0	0	1136	284	76	19
1894.													
January	11	5310	483	45	4	3400	310	0	0	1280	116	214	19
February	1	669	669	0·125	0·125	530	530	0	0	7	7	0	0
March	1	647	647	0·125	0·125	284	284	0	0	161	161	0	0
May	3	430	143	12	4	166	55	109	36	17	5	61	20
June	1	257	257	4·25	4·25	212	212	15	15	10	10	5	5
July	1	753	753	13	13	367	367	55	55	110	110	156	156
August	1	132	132	6·5	6·5	61	61	3	3	58	58	10	10
December	1	394	394	6	6	201	201	0	0	164	164	22	22
1895.													
January	2	1141	570	1·5	0·75	328	164	0	0	427	213	28	14
March	1	12	12	0	0	0	0	0	0	0	0	0	0 Flounders and Cod only.
April	2	758	379	15	7·5	62	31	0	0	238	119	102	51
May	3	399	133	10·5	3·5	26	8	2	0·6	66	22	292	97
June	2	3946	1973	12	6	674	337	87	43	3155	1577	17	8
September	1	466	466	2	2	166	166	11	11	67	67	135	135
October	1	666	666	22	22	52	52	0	0	338	338	211	211
November	2	4591	2295	8	4	1135	567	0	0	2767	1383	389	389
1896.													
January	2	3830	1915	1	0·5	2393	1196	0	0	1331	665	28	14
February	1	591	591	0·5	0·5	365	365	0	0	147	147	29	29
June	1	17	17	4	4	6	6	0	0	1	1	9	9
1897.													
March	1	213	213	1	1	129	129	34	34	23	23	14	14
April	1	243	243	0·5	0·5	158	158	50	50	14	14	0	0
1898.													
January	2	2749	1374	11	5·5	1772	886	99	50	820	410	23	11
July	2	1344	672	8	4	933	466	352	176	40	20	19	9
September	1	417	417	18	18	18	18	108	108	100	100	220	220
November	2	2350	1175	60	30	410	205	628	314	1106	553	143	71
December	1	724	724	16	16	174	174	240	240	140	140	20	20
1899.													
June	1	167	167	2	2	62	62	95	95	18	18	1	1
August	4	3851	963	106·5	26·6	413	103	84	21	2782	695	466	116
September	7	2977	425	198	28	622	89	258	37	1636	234	733	105
October	4	1100	275	202	50	266	66	44	11	705	176	15	4

Table III.—Shewing the average monthly catches of Shrimps and Fish on the Burbo Bank Shrimping Ground (Area A).

Date.	No. of Hauls.	Total No. of Fish.	Average No. of Fish per haul.	Shrimps. Total No. of quarts.	Shrimps. Average No. of quarts per haul.	Plaice. Total No.	Plaice. Average No. per haul.	Soles. Total No.	Soles. Average No. per haul.	Dabs. Total No.	Dabs. Average No. per haul.	Whiting. Total No.	Whiting. Average No. per haul.
January	2	1235	617	14	7	492	246	15	7½	531	265	165	82
February ...	5	2238	447	17·5	3·5	793	158	54	11	842	168	481	96
March	9	7201	800	60·5	6·7	2468	274	306	34	2630	292	1359	151
April	11	7965	724	56	5	2685	244	166	15	3399	309	1759	160
May...........	18	11533	641	156	8·7	3972	221	273	15	5147	286	1617	90
June	26	21629	832	237·5	9·2	6887	265	647	25	11383	438	1949	75
July...........	15	35744	2383	217	14·4	6989	466	1350	90	8900	593	16617	1108
August	32	79293	2478	456·75	14·27	10722	335	3167	99	25984	812	37773	1180
September ...	22	57885	2631	328	14·9	21457	975	1524	69	14267	648	19533	888
October	17	23312	1371	284·6	16·7	3919	230	706	41	8844	520	8709	512
November ...	3	1866	622	11·25	3·7	454	151	2	0·6	881	294	422	141
December ...	3	1006	335	16	5·3	224	75	0	0	619	206	89	30

Table IV.—Shewing the average monthly catches of Shrimps and Fish in the Mersey Channels (Area B).

January	17	13030	766	58·5	3·4	7893	464	99	6	3858	227	293	17
February ...	2	1260	630	0·625	0·312	895	447	0	0	154	77	29	14
March	3	872	291	1·125	0·375	413	138	34	11	184	61	14	5
April	8	2020	252	28·5	3·6	598	75	72	9	448	56	487	61
May...........	7	1141	163	23	3·2	475	68	125	18	92	13	359	51
June	5	4387	877	22·25	4·45	954	191	197	39	3184	637	32	6
July...........	3	2097	699	21	7	1300	433	407	136	180	60	175	58
August	8	11048	1381	156	19·5	487	61	101	14	2840	355	6768	846
September ...	10	4285	428	225	22·5	1127	113	406	41	1823	182	1116	112
October	10	5405	540	260	26	2164	216	66	7	1898	190	1192	119
November ...	6	7995	1332	76	13	2388	398	630	105	4327	721	690	115
December ...	6	4051	675	24	4	1966	328	240	40	1440	240	118	20

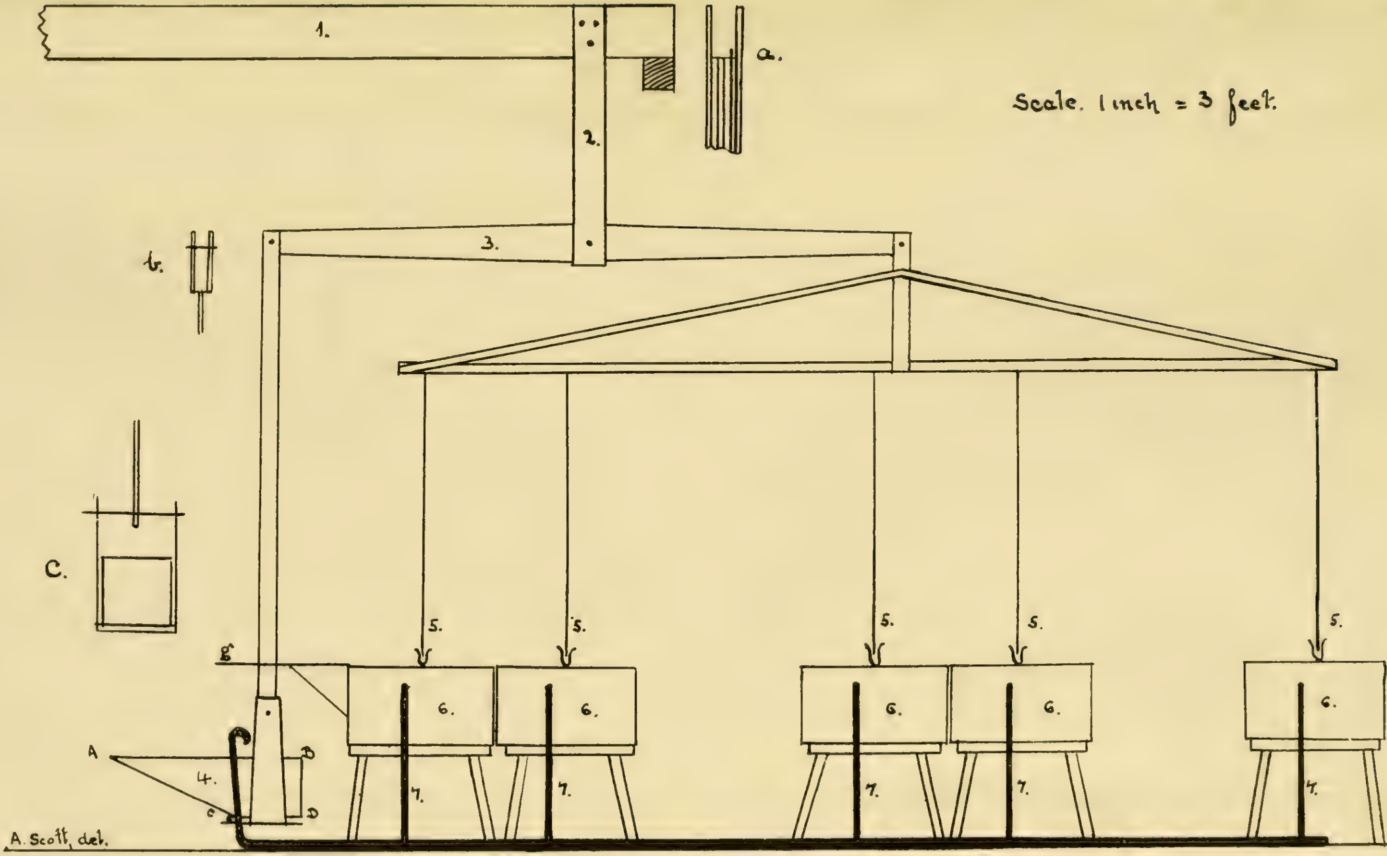
Table V.—Showing the ratio of Immature Fishes to Shrimps in the average monthly catches (Tables III. and IV.) taken on the Mersey Shrimping Grounds :—

Months. 1893-1899.	Area A. Soles. per Qt. Shrimps	Area A. Plaice. per Qt. Shrimps	Area A. Whiting. per Qt. Shrimps.	Area B. Soles. per Qt. Shrimps	Area B. Plaice. per Qt. Shrimps.	Area B. Whiting. per Qt. Shrimps.
January ...	1·1	35·1	11·8	1·7	134·9	5
February ...	3·1	45·3	27·5	0	1432	48·3
March	5·1	40·8	22·4	30·2	367	12·7
April	3·0	47·9	31·4	2·5	20·9	17·1
May	1·7	25·5	10·3	5·4	20·7	13
June	2·7	29	8·2	4·7	22·6	0·8
July	6·2	32·2	71·9	19·3	61·9	8·3
August	6·9	23·5	82·7	0·6	3·1	43·7
September ...	4·6	65·4	59·5	1·8	5	5
October	2·4	13·8	34·1	0·3	8·3	4·6
November ...	0·2	40·4	37·6	8·3	31·4	9
December ...	0	14	5	10·0	81·9	5

Table VI.—Shewing the Average Hauls made with a Shrimp Trawl during the 3rd quarters of the years 1893—1899 on the Burbo Bank Shrimping Ground (Area A) :—

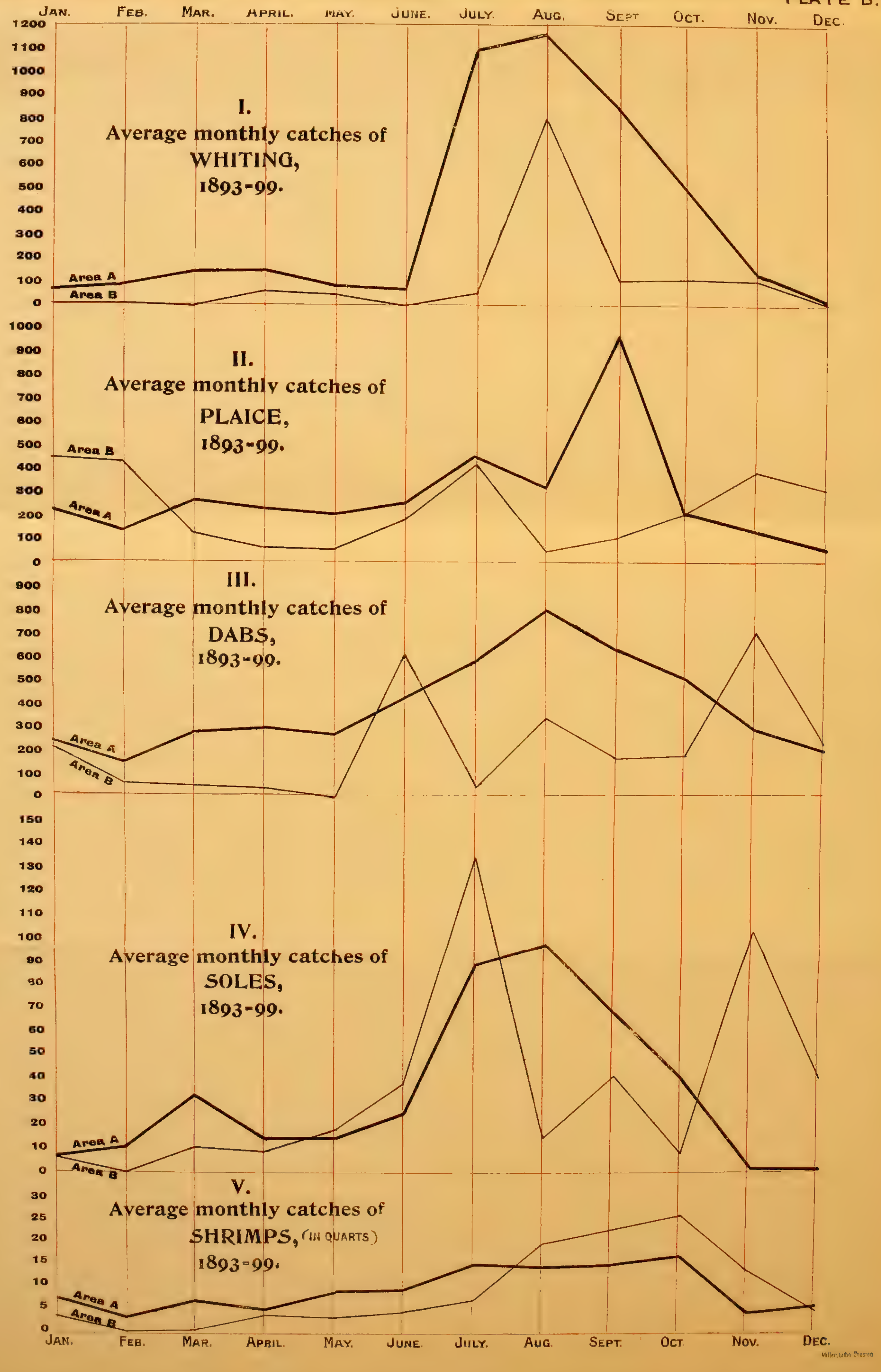
Date.	No. of hauls.	Shrimps. Total Quarts.	Shrimps. Av. Quarts.	Plaice. Total.	Plaice. Average.	Soles. Total.	Soles. Average.	Dabs. Total.	Dabs. Average.	Whiting. Total.	Whiting. Average.
1893—3rd quarter...	8	139	17	16358	2045	282	35	4391	549	6330	791
1894—3rd quarter...	13	220	17	6073	467	203	16	13067	1005	13667	1051
1895—3rd quarter...	9	165	18	6401	711	197	22	7443	827	15996	1777
1896—3rd quarter...	4	17·25	4·3	2545	636	107	27	2300	575	5265	1316
1897—3rd quarter...	3	8	2·6	1963	654	259	86	945	315	1336	445
1898—3rd quarter...	14	114·5	8	2657	190	2380	170	11680	834	12996	928
1899—3rd quarter...	18	338	19	3171	176	2613	145	9325	518	18333	1018

PLATE A.



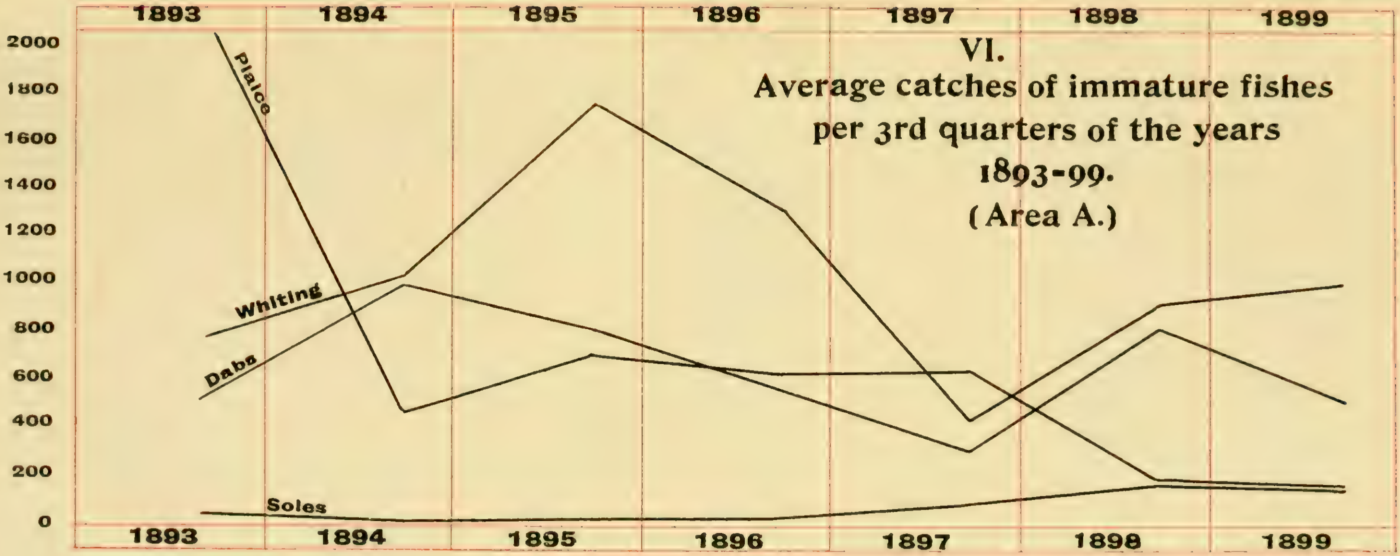
HATCHING APPARATUS.

PLATE B.



JAN. FEB. MAR. APRIL. MAY. JUNE. JULY. AUG. SEPT. OCT. NOV. DEC.
I.
Average monthly catches of
WHITING,
1893-99.
Area A
Area B
II.
Average monthly catches of
PLAICE,
1893-99.
Area B
Area A
III.
Average monthly catches of
DABS,
1893-99.
Area A
Area B
IV.
Average monthly catches of
SOLES,
1893-99.
Area A
Area B
V.
Average monthly catches of
SHRIMPS, (IN QUARTS)
1893-99.
Area A
Area B

PLATE C.


VI.
Average catches of immature fishes
per 3rd quarters of the years
1893-99.
(Area A.)
1893
1894
1895
1896
1897
1898
1899
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Plaice
Whiting
Dabs
Soles

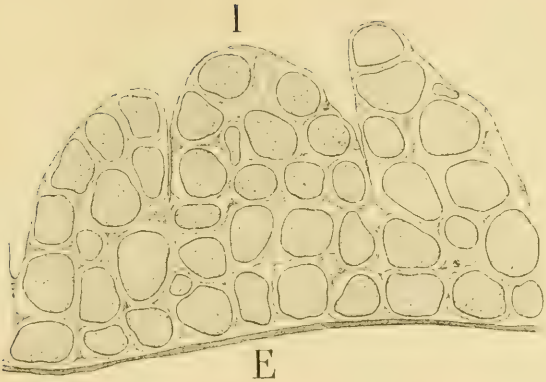


FIG. 2.

FIG 1.

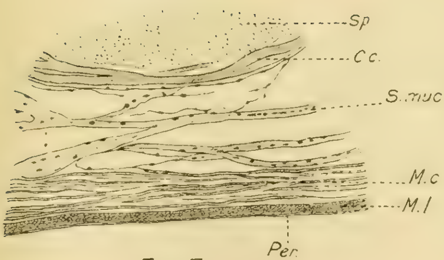


FIG 3

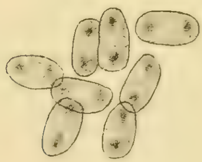
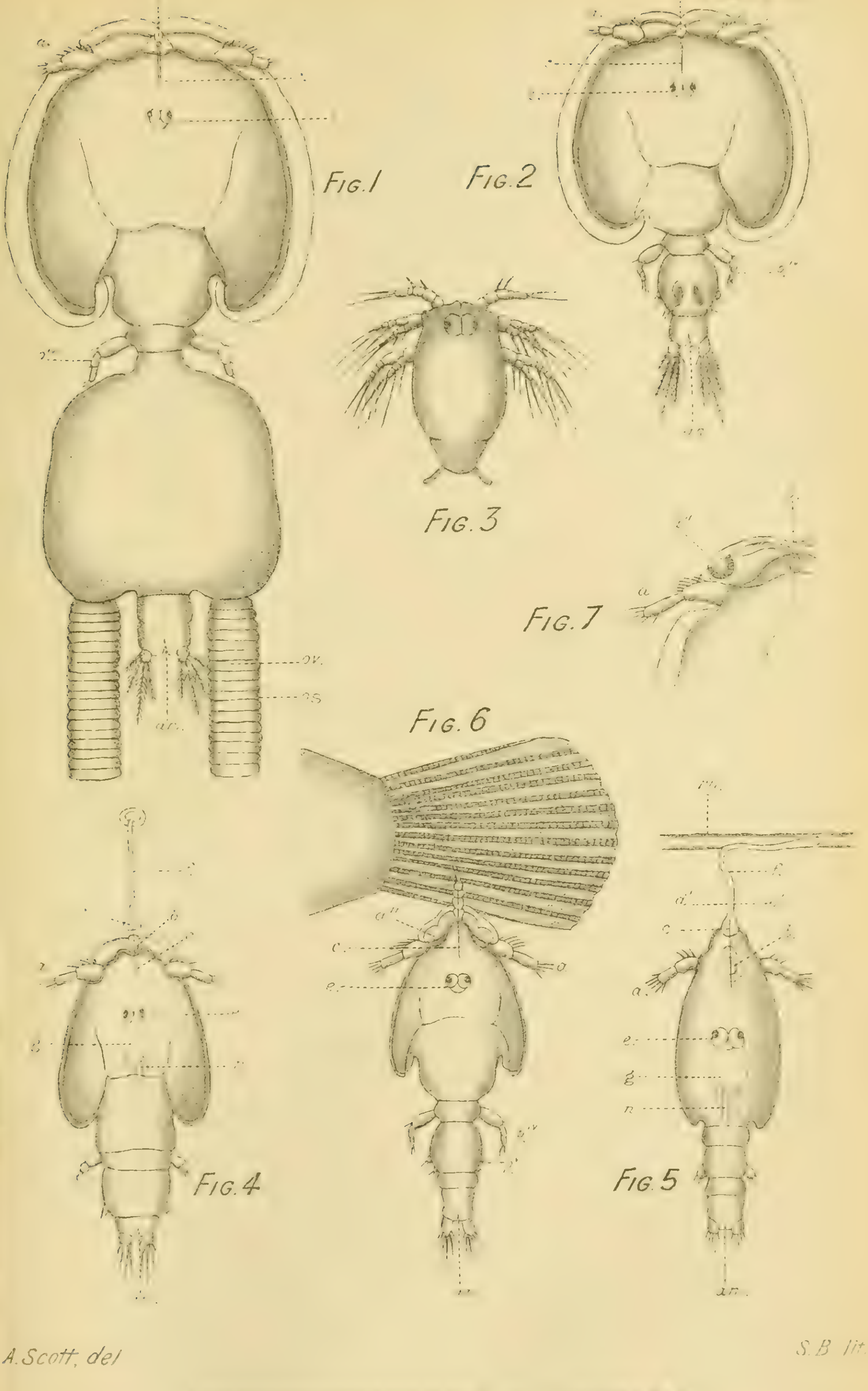


FIG. 4.

J.J. del. *S.B. lith.*

SPOROZOON FROM PLAICE.

PLATE I.

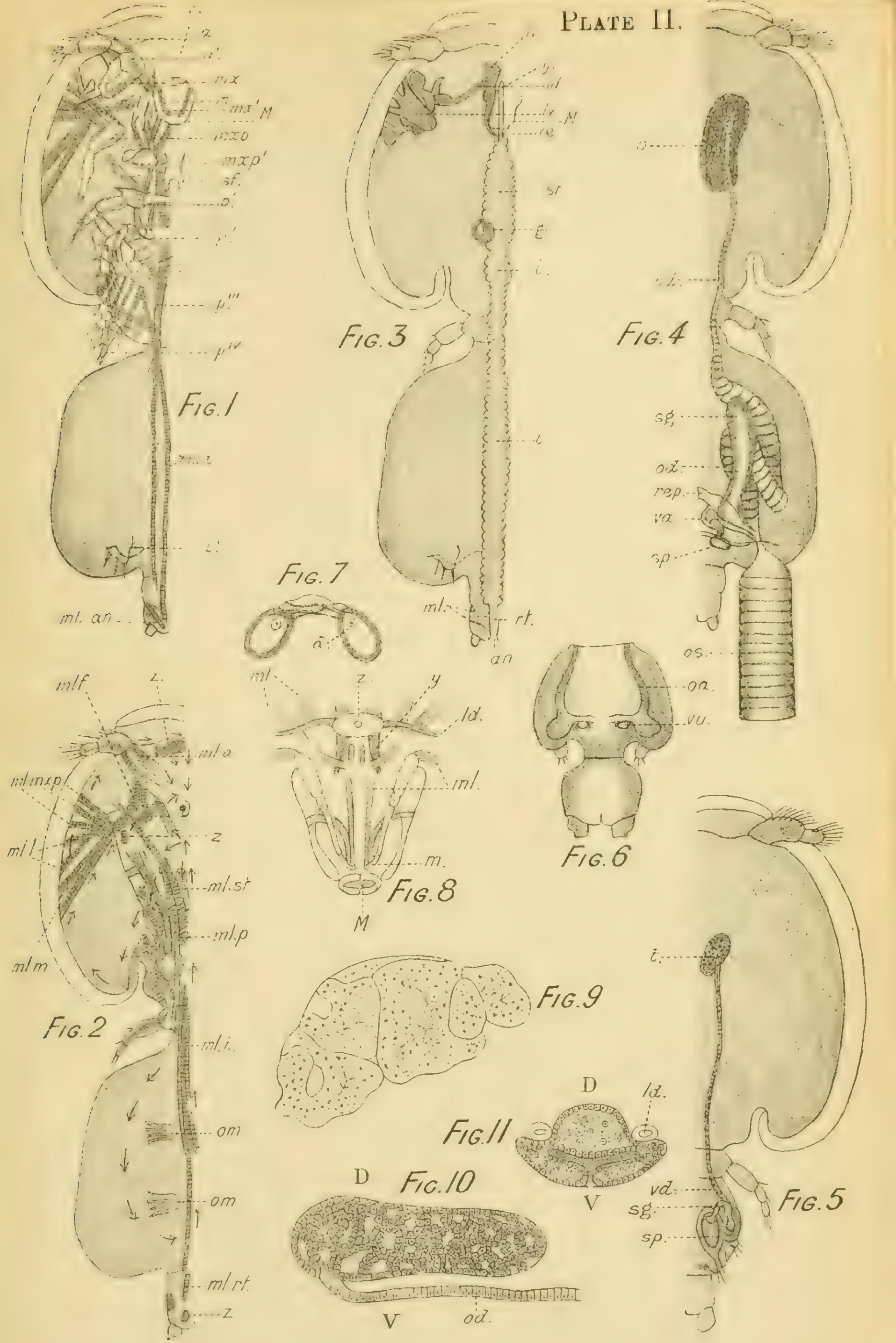


A. Scott, del

S. B. lit.

LEPEOPHTHEIRUS & LERNÆA.

PLATE II.

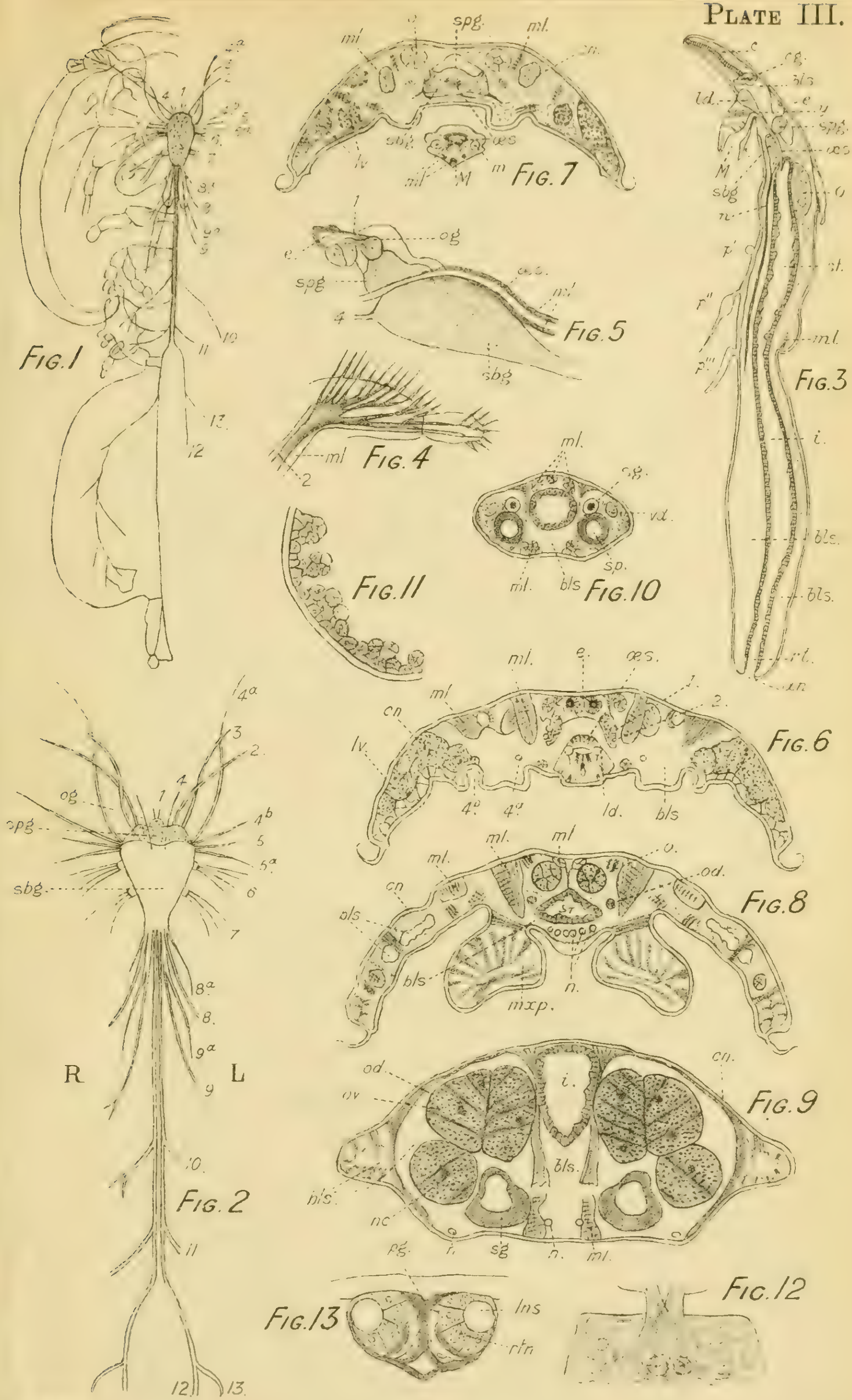


A. Scott, del.

S.B. lith.

LEPEOPHTHEIRUS & LERNÆA.

PLATE III.

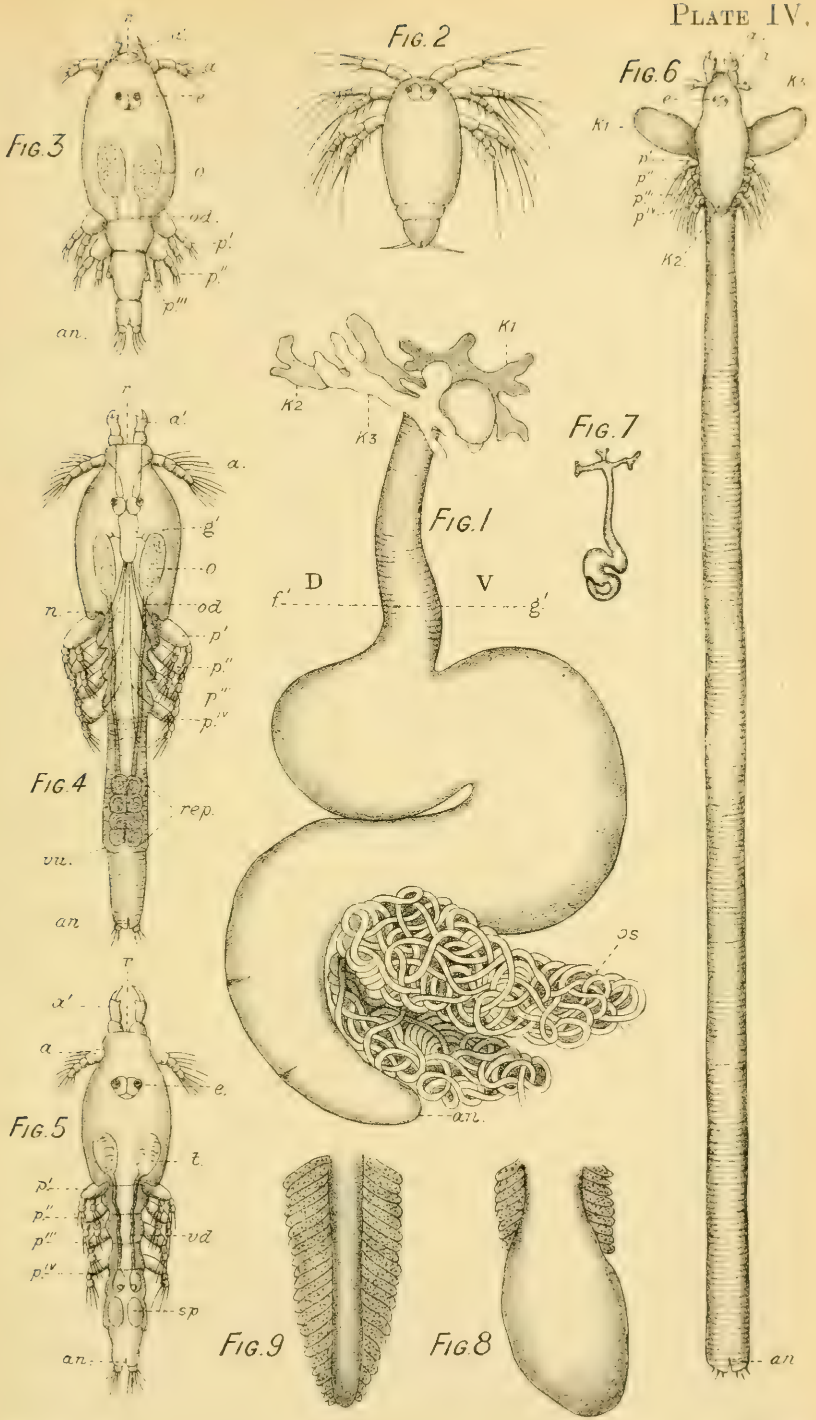


A. Scott del.

S. B. lith.

LEPEOPHTHEIRUS & LERNÆA.

PLATE IV.

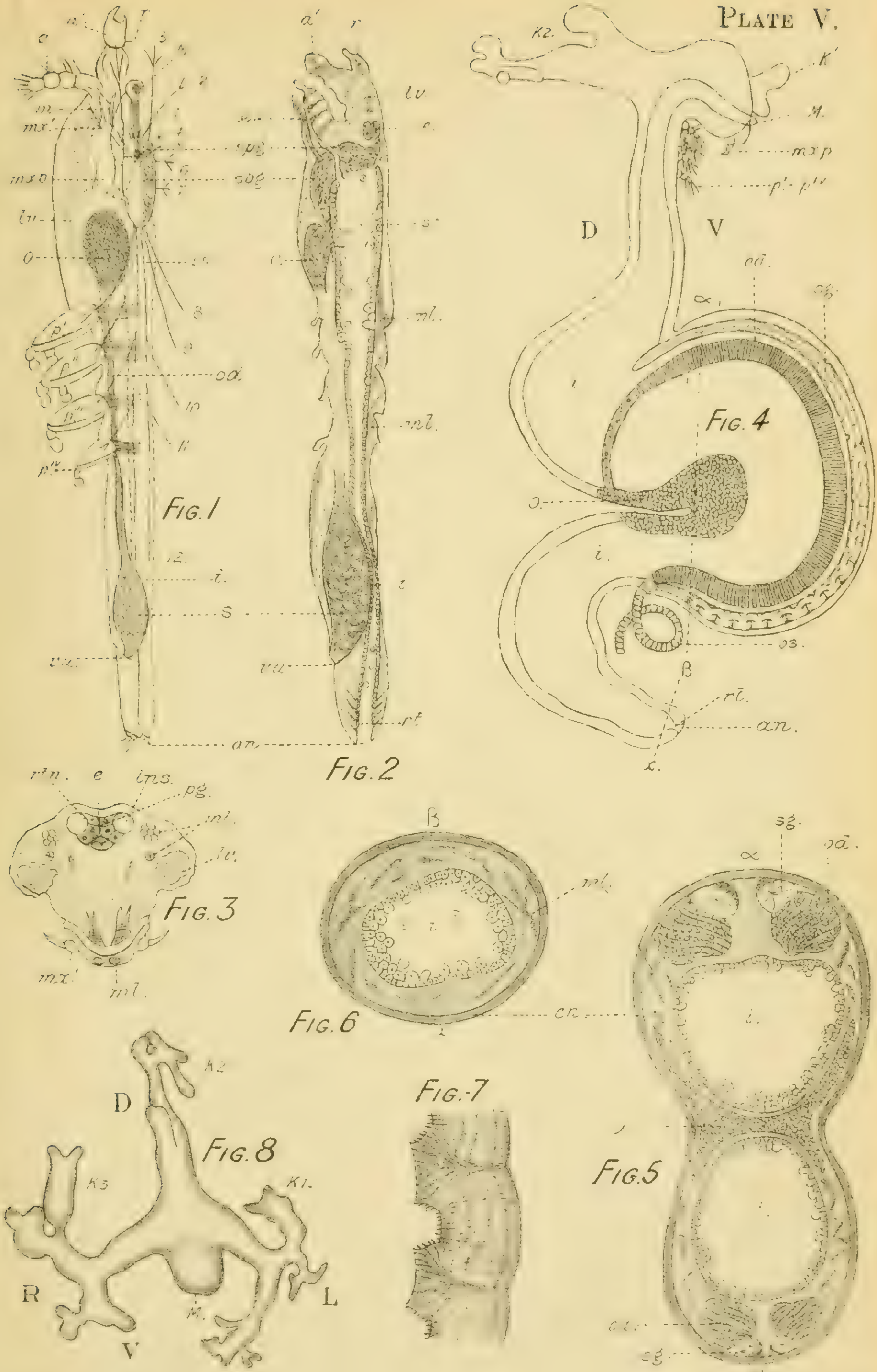


A. Scott del.

S.B. lith.

LEPEOPHTHEIRUS & LERNÆA.

PLATE V.



LEPEOPHTHEIRUS & LERNÆA.