NEW SERIES VII.

DOVE MARINE LABORATORY,

Cullercoats, Northumberland.

REPORT

For the year ending June 30th, 1918.

EDITED BY ALEXANDER MEEK,

PROFESSOR OF ZOOLOGY, ARMSTRONG COLLEGE, IN THE UNIVERSITY OF DURHAM,

AND

DIRECTOR OF THE DOVE MARINE LABORATORY.

Published by the Marine Laboratory Commiitee of Armstrong College on behalf of the Northumberland Sea Fisherics Committee and other contributing anthorities.

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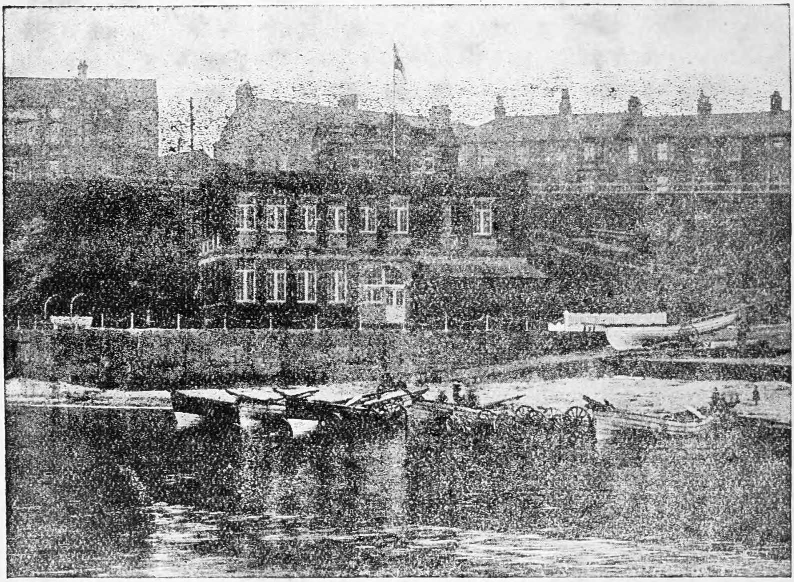

Dove Marine Laboratory, Cullercoats.

SUMMARY AND GENERAL REPORT.

During the year ending 30th June, 1918, in addition to general work connected with the coastal fisheries, a series of investigations were undertaken and are now reported upon.

Samples of herring were obtained from Berwick, Sea Houses and North Shields, altogether amounting to a total of 3,200 herring, and from the chart indicating the localities of capture it will be seen that the district was fairly completely covered. The samples again proved to be very similar in size and in age composition, thus evidencing that the Northumberland herring belong to one school. As in the previous season herrings with four winter rings were predominant; an interesting and noteworthy feature. Up to 1915 our investigations showed that the herring consisted for the most part of four year herring that is with three winter rings; in 1916 and 1917 the school has presented a majority of five year old herring (with four winter rings). It is fortunate that we have persevered with the herring investigation at this time for it may turn out that the advance in age composition is due to the restricted fishing. Reasons are given for the conclusion that spawning took place in the northern part of the district at the end of August and the beginning of September.

In 1918, as in 1917, the dry weather in the spring brought the Tyne at Newcastle into a serious state of pollution. Many kelts were poisoned, and in May the smolts, after hesitating above the tidal region, were tempted by a slight amount of rain to descend. Hundreds were killed opposite and below the gas works. It is not suggested that the gas works alone are responsible, nor that at present any particular effluent can be blamed. A collective plan of reducing the pollution will have to be adopted, but it cannot be urged that the present is a convenient time for undertaking it. Still, even now, the managers of works on the Tyne might be asked (and they have been asked by the

Tyne Salmon Conservancy) to do all they can to prevent poisonous effluents being poured into the river, and to see that poisonous products are not deposited on the banks.

An important step has been taken as to the formation of the mussel beds at Holy Island. Arrangements have been made for obtaining a lease of the area, and it is hoped that a beginning will be made in transplantation this season.

A paper on the Crustacea is meant to draw attention to the confusion which exists regarding larval nomenclature, and especially to bring together the knowledge we possess as to the growth and the age of various species, based mainly on the series obtained by G. Brook and Mr. Waddington. The statement shows that the Decapod Crustacea only reach maturity after about four to five years from hatching, and that the crab and lobster, for example, may reach an age which cannot be said to be less than 20 years.

Miss Olga M. Jorgensen, M.Sc., contributes a series of papers on the work she has been engaged in during the year. The first gives the results of an examination of the water of the tanks of the Cullercoats Laboratory, with a view to indicating the nature and the quantity of the micro-plankton of the water supply, and incidentally the changes in the micro-plankton of Cullercoats Bay. It is shown that the tanks and the sea undergo the spring and autumn increases so generally observed in the North Atlantic region, but it is plain that the maxima are intensified by the accumulation of plankton in the tanks between the periods of pumping. The results, therefore, do not give a true picture of the sea plankton, but they give an interesting and important indication of the monthly variation of the micro-plankton of the tanks and the lists of species will be found to be of great value.

Amphidinium operculatnm, which was recorded for the first time in 1913 and has appeared irregularly since, was found in 1917 and 1918 from November to May. It has thus, so to speak, become established at Cullercoats as Herdman has found it to have been at Port Erin.

Miss Jorgensen adds a note of importance to her account of the development of the common calcareous sponge *Grantia compressa.* The larva appears to be free for at least 24 hours, and is thus liable, like the larvae of so many other marine forms, to denatation. She also gives an account of the larval stages of the common shore crab ; and her drawings of the larvae of this and other species will be found in the paper on Crustacea referred to above.

Interesting records of the Euphausian, *Nematoscelis megalops* and of the parasitic copepod *Caligus curtus* with its parasites are given under Faunistic Notes.

A. MEEK.

25TH JULY, 1918.

HERRING INVESTIGATIONS, 1917.

BY A. MEEK AND DOROTHY STONE.

We were able during last season to examine thirteen samples from the Northumberland district, the total number of herring being 3,200. We have pleasure again in conveying our grateful thanks to all who were good enough to help us in the work; we would like particularly to thank Mr. Richard Dawson, of North Sunderland and North Shields, and the Messrs. Holmes, of Berwick.

The nature and origin of the samples are given in Table I., and the localities of capture are indicated in Chart 1. The North Shields samples were examined at North Shields fish quay, the Berwick samples in Messrs. Holmes' curing house at Berwick. The sample from Seahouses was sent to the Laboratory.

TABLE I

Sample.	No. in Sample.	Date.	Locality.
1 (North Shields) ...	250	5th July ...	20 miles N.E. by N. of Tyne.
2 " ...	250	20th July ...	24 miles N.E. by N. of Tyne.
3 " ...	250	29th August ...	20 miles E. by S. of Tyne.
4 " ...	250	12th September	18 miles E. of Tyne.
5 " ...	250	15th September	20 miles E. of Tyne.
A1 (Berwick) ...	250	7th July ...	15 miles N.E. of Berwick.
A2 " ...	250	27th July ...	15 miles S.E. of Berwick.
A3 " ...	250	9th August ...	15 miles E. of Berwick.
A4 " ...	250	10th August ...	15 miles E. of Berwick.
A5 " ...	250	5th September	20 miles E.S.E. of Berwick.
A6 " ...	250	6th September	20 miles E. by S. southerly of Berwick.
A7 " ...	250	7th September	23 miles E.S.E. of Berwick.
B1 (Seahouses) ...	200	8th September	15 miles E. of Seahouses.

Our purpose mainly is to put on record the measurements and the results of the examination of the scales. The details with reference to size and the number of winter rings are given

CHART 1.

The approximate positions from which the samples of herrings were obtained.

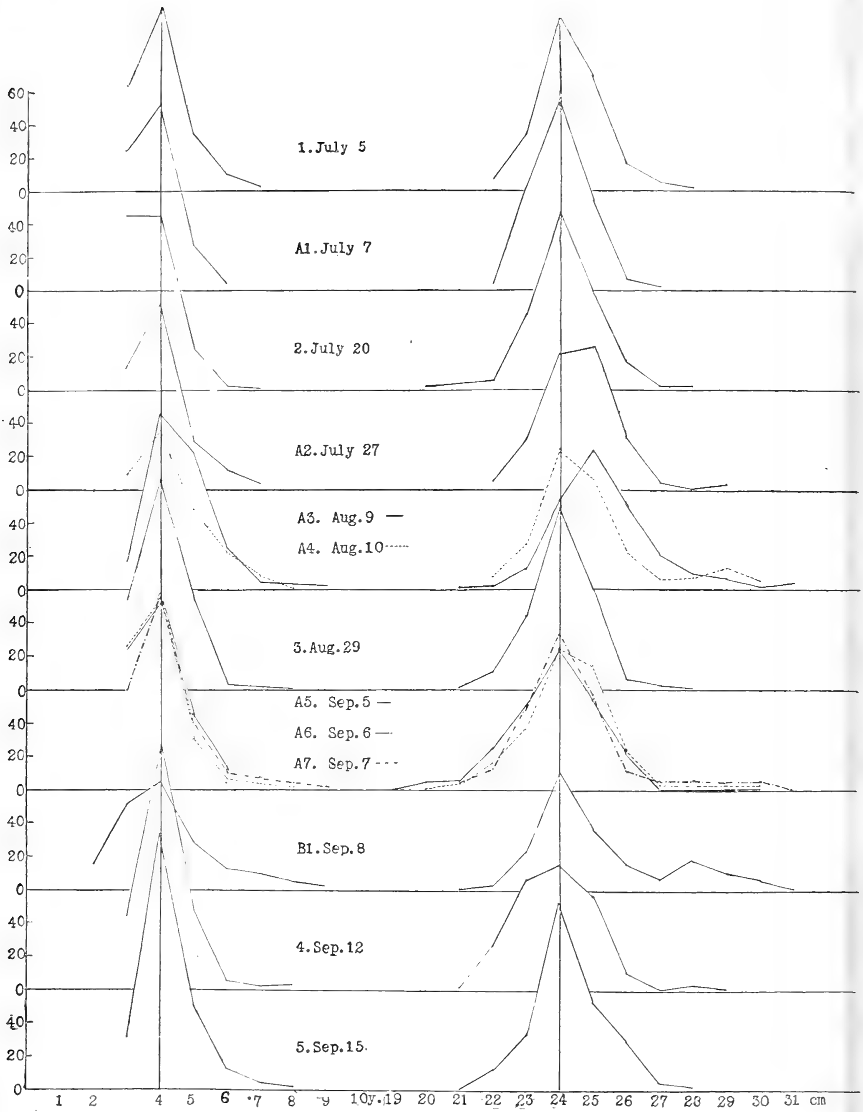

CHART 2.

The age in winter rings (on the left) and the size in cm. (on the right) of the samples arranged in chronological order.

in Table II. in the form in which they have been presented in previous reports. The results are presented graphically in Chart 2, which will be found to be interesting when compared with the chart published in the preceding report and the figures for past years. This year, as last year, the herrings with four winter rings were found to be predominant. The change which we recorded for 1916 in the age composition for the district is continued therefore in 1917. The shoals do not undergo a great deal of change during the season, but it will be noted that herrings with three winter rings were more common at the beginning of the season, especially in the southern part of the district, that these gave place to herrings with four winter rings which then characterised the district generally, and that in August in the northern part of the district herrings with five winter rings, together with still older stages became prominent. The older herring appear to have remained until early in September, after which period the shoals were found to consist of the same class of herring as were obtained in July. These general features will be found to be very similar to those which resulted from the investigation of the herring of 1916.

The change in the age-composition during the last two seasons is an interesting and significant feature, which may be and probably is associated with the present condition of the fishing.

TABLE II.—SIZE AND AGE.

CENTIMETRES.

Sample.	Winter Rings.	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
1	3	1	—	—	4	14	40	8	2	—	—	—	—	—	69
	4	—	—	—	5	21	55	36	8	1	1	—	—	—	127
	5	—	—	—	—	1	7	17	8	1	2	—	—	—	36
	6	—	—	—	—	—	2	5	1	2	—	—	—	—	10
	7	—	—	—	—	—	—	—	—	3	—	—	—	—	3
		1	—	—	9	36	104	66	19	7	3	—	—	—	245
2	3	—	1	—	5	22	55	22	5	—	—	—	—	—	110
	4	—	—	—	2	24	46	28	9	1	—	—	—	—	110
	5	—	—	—	—	1	7	8	4	3	1	—	—	—	24
	6	—	—	—	—	—	—	2	—	—	2	—	—	—	4
	7	—	—	—	—	—	—	—	1	—	1	—	—	—	2
		—	1	—	7	47	108	60	19	4	4	—	—	—	250
3	3	—	—	2	10	38	6	—	—	—	—	—	—	—	56
	4	—	—	—	—	8	107	13	—	—	—	—	—	—	128
	5	—	—	—	—	—	4	47	6	1	—	—	—	—	58
	6	—	—	—	—	—	—	2	1	1	—	—	—	—	4
	7	—	—	—	—	—	—	—	1	1	1	—	—	—	3
	8	—	—	—	—	—	—	—	—	1	—	—	—	—	1
		—	—	2	10	46	117	62	8	4	1	—	—	—	250
4	3	—	—	2	21	18	2	1	—	—	—	—	—	—	44
	4	—	—	—	7	49	69	20	1	—	—	—	—	—	146
	5	—	—	—	—	1	6	36	5	—	—	—	—	—	48
	6	—	—	—	—	—	—	1	5	1	—	—	—	—	7
	7	—	—	—	—	—	—	—	—	1	1	—	—	—	2
	8	—	—	—	—	—	—	—	—	—	2	1	—	—	3
		—	—	2	28	68	77	58	11	2	3	1	—	—	250
5	3	—	—	1	6	15	8	—	1	—	—	—	—	—	31
	4	—	—	—	7	19	100	22	5	—	—	—	—	—	153
	5	—	—	—	—	1	4	29	14	2	—	—	—	—	50
	6	—	—	—	—	—	—	2	9	—	1	—	—	—	12
	7	—	—	—	—	—	—	—	1	2	—	—	—	—	3
	8	—	—	—	—	—	—	—	—	1	—	—	—	—	1
		—	—	1	13	35	112	53	30	5	1	—	—	—	250

TABLE II.—SIZE AND AGE.

CENTIMETRES.

Sample.	Winter Rings.	19	20	21	22	23	24	25	26	27	28	29	30	31	Total
A1	3	—	—	—	3	23	44	11	2	1	—	—	—	—	84
	4	—	—	—	1	34	54	33	3	1	—	—	—	—	126
	5	—	—	—	1	1	12	11	2	—	—	—	—	—	27
	6	—	—	—	—	—	2	3	—	—	—	—	—	—	5
		—	—	—	5	58	112	58	7	2	—	—	—	—	242
A2	3	—	—	—	6	15	35	19	1	—	—	—	—	—	76
	4	—	—	—	—	12	41	50	14	5	—	—	—	—	122
	5	—	—	—	—	3	3	10	12	1	—	—	—	—	29
	6	—	—	—	—	—	1	3	5	—	2	1	—	—	12
	7	—	—	—	—	—	—	—	1	—	—	2	—	—	3
		—	—	—	6	30	80	82	33	6	2	3	—	—	242
A3	3	—	—	1	—	2	10	4	2	—	—	—	—	—	19
	4	—	—	—	2	6	32	46	20	4	4	—	—	—	114
	5	—	—	—	—	4	8	30	25	12	2	2	—	1	84
	6	—	—	—	—	1	6	4	4	3	3	4	—	—	25
	7	—	—	—	—	—	—	—	—	1	1	1	1	2	6
	9	—	—	—	—	—	—	—	—	—	—	1	—	—	1
		—	—	1	2	13	56	84	51	20	10	8	1	3	249
A4	3	—	—	—	6	15	29	18	2	—	—	—	—	—	70
	4	—	—	—	1	9	41	34	10	1	1	—	—	—	97
	5	—	—	1	1	4	11	14	7	6	3	1	1	—	49
	6	—	—	—	—	—	1	1	5	1	2	9	2	—	21
	7	—	—	—	—	—	—	1	—	—	1	3	4	—	9
	8	—	—	—	—	—	—	—	—	—	2	—	—	—	2
		—	—	1	8	28	82	68	24	8	9	13	7	—	248
A5	3	1	4	4	14	19	25	15	—	—	—	—	—	—	82
	4	—	1	2	9	24	43	23	10	—	—	—	—	—	112
	5	—	—	—	2	7	12	13	9	1	—	—	—	—	44
	6	—	—	—	—	1	4	4	2	—	—	—	1	—	12
		1	5	6	25	51	84	55	21	1	—	—	1	—	250

TABLE II.—SIZE AND AGE.

CENTIMETRES.

Sample.	Winter Rings.	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
A6	3	—	—	2	11	17	28	20	5	—	—	—	—	—	83
	4	—	1	2	6	20	43	42	10	—	—	—	—	—	124
	5	—	—	—	—	—	10	12	6	2	—	—	—	—	30
	6	—	—	—	—	—	2	2	—	1	—	1	1	—	7
	7	—	—	—	—	—	—	—	1	1	—	—	1	—	3
	8	—	—	—	—	—	—	—	—	—	—	1	—	—	1
		—	1	4	17	37	83	76	22	4	—	2	2	—	248
A7	3	—	—	5	12	16	18	9	—	—	—	—	—	—	60
	4	—	—	—	4	31	61	26	3	—	—	—	—	—	125
	5	—	—	—	—	—	14	18	5	1	1	—	—	—	39
	6	—	—	—	—	—	—	1	5	4	—	—	—	—	10
	7	—	—	—	—	—	—	—	—	1	3	2	1	—	7
	8	—	—	—	—	—	—	—	—	—	2	1	1	1	5
	9	—	—	—	—	—	—	—	—	—	—	—	1	—	1
		—	—	5	16	47	93	54	13	6	6	3	3	1	247
B1	2	—	—	1	4	12	—	—	—	—	—	—	—	—	17
	3	—	—	—	—	12	33	6	—	—	—	—	—	—	51
	4	—	—	—	—	—	32	22	12	—	—	—	—	—	66
	5	—	—	—	—	—	5	10	5	6	3	—	—	—	29
	6	—	—	—	—	—	—	—	—	2	11	1	—	—	14
	7	—	—	—	—	—	—	—	—	—	3	8	2	—	13
	8	—	—	—	—	—	—	—	—	—	1	2	3	1	7
	9	—	—	—	—	—	—	—	—	—	1	—	2	—	3
		—	—	1	4	24	70	38	17	8	19	11	7	1	200

We have no distinct record of the spawning of the herring last season, but notes were made as to the condition of the gonads of the samples, together with general notes as to the herrings landed at North Shields and Berwick. From these it is clear that during the early part of the season in July and the early part of August the herring were immature. In July the gonads were in the state of 1-2 and 2-3 towards the end of the month, and in August the Berwick samples indicated the presence also of herrings with gonads of 3-4. Towards the end of August and the beginning of September it was found that while the Shields samples remained immature full herring were being landed at Berwick and Seahouses. These were succeeded by spent herring, which penetrated throughout the whole district, being found not only in the northern part of the district but amongst the herrings landed at Shields as well. It is worth noting here also that on July 20th, when the sample of that date was examined at North Shields, three boats landed young herring measuring 16-19 cms., and it was stated that they were obtained further north than the position recorded for the sample.

The investigations of the Northumberland samples, which have now been made without interruption for a good many years, indicate that the herrings which annually visit the coast belong to one school, which for some reason or other during the last two years has advanced in age composition by one year. It is evident, however, that we cannot arrive at a full comprehension of the migrations of this interesting and important species until measures are taken to insure a full and comprehensive investigation on similar lines over a much wider area.

The facts given in Table II. are summarised in Tables III. and IV.

TABLE III.—SIZE.

CENTIMETRES.

Sample.		19	20	21	22	23	24	25	26	27	28	29	30	31
1	Nos. ...	—	—	—	9	37	106	69	19	7	3	—	—	—
	% ...	—	—	—	3·6	14·8	42·4	27·6	7·6	2·8	1·2	—	—	—
2	Nos. ...	—	1	—	7	47	108	60	19	4	4	—	—	—
	% ...	—	0·4	—	2·8	18·8	43·2	24·0	7·6	1·6	1·6	—	—	—
3	Nos. ...	—	—	2	10	46	117	62	8	4	1	—	—	—
	% ...	—	—	0·8	4·0	18·4	46·4	24·8	3·2	1·6	0·4	—	—	—
4	Nos. ...	—	—	2	28	68	77	58	11	2	3	1	—	—
	% ...	—	—	0·8	11·2	27·2	30·8	23·2	4·4	0·8	1·2	0·4	—	—
5	Nos. ...	—	—	1	13	35	112	53	30	5	1	—	—	—
	% ...	—	—	0·4	5·2	14·0	44·8	21·2	12·0	2·0	0·4	—	—	—
A1	Nos. ...	—	—	—	5	61	116	58	8	2	—	—	—	—
	% ...	—	—	—	2·0	24·4	46·4	23·2	3·2	0·8	—	—	—	—
A2	Nos. ...	—	—	—	7	31	82	86	33	6	2	3	—	—
	% ...	—	—	—	2·8	12·4	32·8	34·4	13·2	2·4	0·8	1·2	—	—
A3	Nos. ...	—	—	1	2	13	56	84	51	21	10	8	1	3
	% ...	—	—	0·4	0·8	5·2	22·4	33·6	20·4	8·4	4·0	3·2	0·4	1·2
A4	Nos. ...	—	—	1	8	28	84	68	24	8	9	13	7	—
	% ...	—	—	0·4	3·2	11·2	33·6	27·2	9·6	3·2	3·6	5·2	2·8	—
A5	Nos. ...	1	5	6	25	51	84	55	21	1	—	—	1	—
	% ...	0·4	2·0	2·4	10·0	20·4	33·6	22·0	8·4	0·4	—	—	0·4	—
A6	Nos. ...	—	1	4	17	38	84	76	22	4	—	2	2	—
	% ...	—	0·4	1·6	6·8	15·6	33·6	30·4	8·8	1·6	—	0·8	0·8	—
A7	Nos. ...	—	—	5	16	47	93	57	13	6	6	3	3	1
	% ...	—	—	2·0	6·4	18·8	37·2	22·8	5·2	2·4	2·4	1·2	1·2	0·4
B1	Nos. ...	—	—	1	4	24	70	38	17	8	19	11	7	1
	% ...	—	—	0·5	2·0	12·0	35·0	19·0	8·5	4·0	9·5	5·5	3·5	0·5

TABLE IV.—AGE.

WINTER RINGS.

Sample.		2	3	4	5	6	7	8	9
1	Nos. ...	—	68	127	36	10	3	—	—
	% ...	—	27·9	52·1	14·7	4·1	1·2	—	—
2	Nos. ...	—	110	110	24	4	2	—	—
	% ...	—	44·0	44·0	9·6	1·6	0·8	—	—
3	Nos. ...	—	56	128	58	4	3	1	—
	% ...	—	22·4	51·2	23·2	1·6	1·2	0·4	—
4	Nos.	—	44	146	48	7	2	3	—
	% ...	—	17·6	58·4	19·2	2·8	0·8	1·2	—
5	Nos. ...	—	31	153	50	12	3	1	—
	% ...	—	12·4	61·4	20·0	4·8	1·2	0·4	—
A1	Nos. ...	—	84	126	27	5	—	—	—
	% ...	—	34·8	52·1	11·2	2·1	—	—	—
A2	Nos. ...	—	76	122	29	12	3	—	—
	% ...	—	31·4	50·4	11·9	4·9	1·2	—	—
A3	Nos. ...	—	19	114	84	25	6	—	1
	% ...	—	7·6	45·7	33·7	10·0	2·4	—	0·4
A4	Nos. ...	—	70	97	49	21	9	2	—
	% ...	—	28·2	39·1	19·7	8·5	3·6	0·8	—
A5	Nos. ...	—	82	112	44	12	—	—	—
	% ...	—	32·8	44·8	17·6	4·8	—	—	—
A6	Nos. ...	—	83	124	30	7	3	1	—
	% ...	—	33·5	50·0	12·1	2·8	1·2	0·4	—
A7	Nos. ...	—	60	125	39	10	7	5	1
	% ...	—	24·3	50·6	15·8	4·0	2·8	2·0	0·4
B1	Nos. ...	17	51	66	29	14	13	7	3
	% ...	8·5	25·5	33·0	14·5	7·0	6·5	3·5	1·5

POLLUTION OF THE TYNE.

BY A. MEEK.

In the last report I drew attention to the effects of the pollution of the Tyne in the early summer of 1917. I have now to add to the record which I gave then a few particulars as to the destruction caused by the pollution this spring. Word was brought to me from time to time of kelts being taken out of the river, and on May 10th Mr. J. A. Williamson, Clerk to the Tyne Salmon Conservancy, wrote to me as follows :—

"During the last few days there has been about 5 inches of fresh water in the river Tyne, which, unfortunately, caused many smolts to take to the tidal water. Hundreds have been poisoned, and are being taken out of the river below the Team and Redheugh Bridge by children ; the gulls have had a rare feed too."

Mr. Williamson sent me six smolts taken on May 10th from the river, and at the meeting of the Conservancy next day, I obtained a further sample of thirteen, or nineteen in all. These were found to consist of fourteen salmon smolts, measuring 13·3 to 18·2 cm., and five trout smolts, meauring 16·0 to 20·8 cm., The scales were examined, and it was found that eight of the salmon had two winter areas, the rest having one winter area. The trout consisted of two which had spent two winters in fresh water, and three which had spent only one winter before migrating. The small sample indicated that the trout smolts of the Tyne are about 25 per cent. of the salmon smolts, and this is just about the proportion the fishermen catch of the older stages in the river and in the neighbourhood of the river, that is to say, in the Conservancy's district.

I hope on another occasion to have an opportunity of analysing the statistics of the salmon and trout fisheries, for they appear to show that the young stages of the trout especially are becoming steadily less numerous, and that both salmon and trout are sadly declining in numbers. In the meantime I must be content with recording the destruction of smolts particularly again this season, and to direct attention to what I stated in the last report as to taking steps to ameliorate a condition of things which is threatening to bring the Tyne to an end as a salmon river. I should like to urge that managers of works on the banks of the Tyne and its tributaries in the Newcastle area should endeavour to minimise the discharge of deleterious effluents and the deposition on the banks of poisonous products, such as gas lime, until the time arrives when some combined action can be made to restore the river to a cleaner condition.

It will be noted that the salmon and trout smolts exhibit a significant difference as regards size. The difference is borne out by detailed measurement and morphological detail.

PROPOSED MUSSEL BED AT HOLY ISLAND.

By A. Meek.

I intimated in the last report that the Northumberland Sea Fisheries Committee found it could not proceed with the formation of the mussel bed on the lines which were contemplated. They formed, however, a Mussel Committee, which, in association with the fishermen, has made much progress in the matter. We now see our way to make a start with the work of transplantation on a fairly large scale, without at the present time taking the fishermen away from their useful employment. It is obvious that under present conditions we cannot expect to start on the scale which was originally intended, but we hope nevertheless to transplant to the Scaup a fairly large quantity of mussels, and the progress of these will be watched with interest by the Mussel Committee as well as by the fishermen. I hope to be able to report that the preliminary work has been satisfactorily accomplished, and that in the near future we shall be able to supply the whole district with mussel bait.

ON THE CRUSTACEA.

By ALEXANDER MEEK.

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1.—LARVAL NOMENCLATURE.

The nomenclature of the larvae of Crustacea has got into a state of considerable confusion. At all events, no one appears to be able to say definitely what is meant by the terms *Protozoea* and *Zoea*. Even with reference to the Decapoda these names are indifferently applied to very different larvae and stages; protozoeæ may have seven, eight or thirteen appendages, and zoeæ seven, eight, twelve or thirteen pairs.

There is fortunately no trouble as to the nauplius. Whatever its shape, it is a larva with the three anterior pairs of appendages; and we apply the convenient term metanauplius to the immediately succeeding stages in which segmentation takes place, and the next few pairs of limbs make their appearance. We can refer therefore with precision to larvae which are hatched at the nauplius or at the metanauplius stage and to the metanauplius phases of the former.

At whatever stage the larva is liberated from the egg, whether at the nauplius or at some later phase, a series of ecdyses are passed through during which the remaining limbs are developed and grow. The limbs may all remain in a rudimentary condition until the number has been completed, or they may advance into a functional state in groups. My suggestion is that we can best define the stage at hatching and the subsequent stages by reference to the appendages which have been fully developed. To give point to my plea, I have prepared a chart (fig. 1) which indicates the nature of the development with reference to the appendages in the various groups. The nineteen appendages of the Malacostraca are arranged in vertical columns, and their names as applied to the Decapoda are also indicated. The horizontal lines opposite the names of the groups indicate the stage at which hatching takes place, and the successive ecdyses by the step-like breaks in the line. All the appendages to the left of the steps in each case have reached a functional condition, or, in other words, the steps refer to the ecdyses during which the appendages to the right are completing their development.

It is usually assumed that the development of the Penaeidea exhibits best the typical condition, and it will be convenient to describe it now as serving to define the stages. The eggs of the pelagic Penaeus are loosely attached to the posterior pereiopods, and are hatched in the course of a day or so. The larva is a simple nauplius bearing three pairs of unsegmented limbs. An ecdysis converts this into a metanauplius, in which the carapace is indicated and rudiments of the succeeding four pairs of limbs. These latter attain full development at the next ecdysis, and the larva now becomes a protozoea. The next four ecdyses and instars complete the segmentation of the thorax and abdomen, and mark the appearance and growth of limbs 8-12, as well as the uropods which appear precociously early in Penaeus as in several other Malacostraca. The posterior pairs of thoracic limbs have not much room for development, and in this group the last or the two last may not appear, or in the case of the penultimate pair may have only a temporary existence. This is the stage which may be called the zoea. During the next three ecdyses the pleopoda are completed, and the larva attains its adult quota of limbs. This may be called the megalopa, and gives place with further ecdyses to the adult form when the limbs do not undergo any further marked modification.

These stages will be sufficiently plain from the chart. It is still convenient in the case of the Sergestidae to define the successive stages of the elaborately spinulated larvae by such names as elaphocaris, acanthosoma and mastigopus, but it is not necessary to consider them here.

The Brachyura (fig. 2) are liberated in the condition which in the Penaeidea has been styled the protozoea, that is to say, the limbs are present up to and including the second maxilliped, and the larva is called by the name protozoea by authors. At

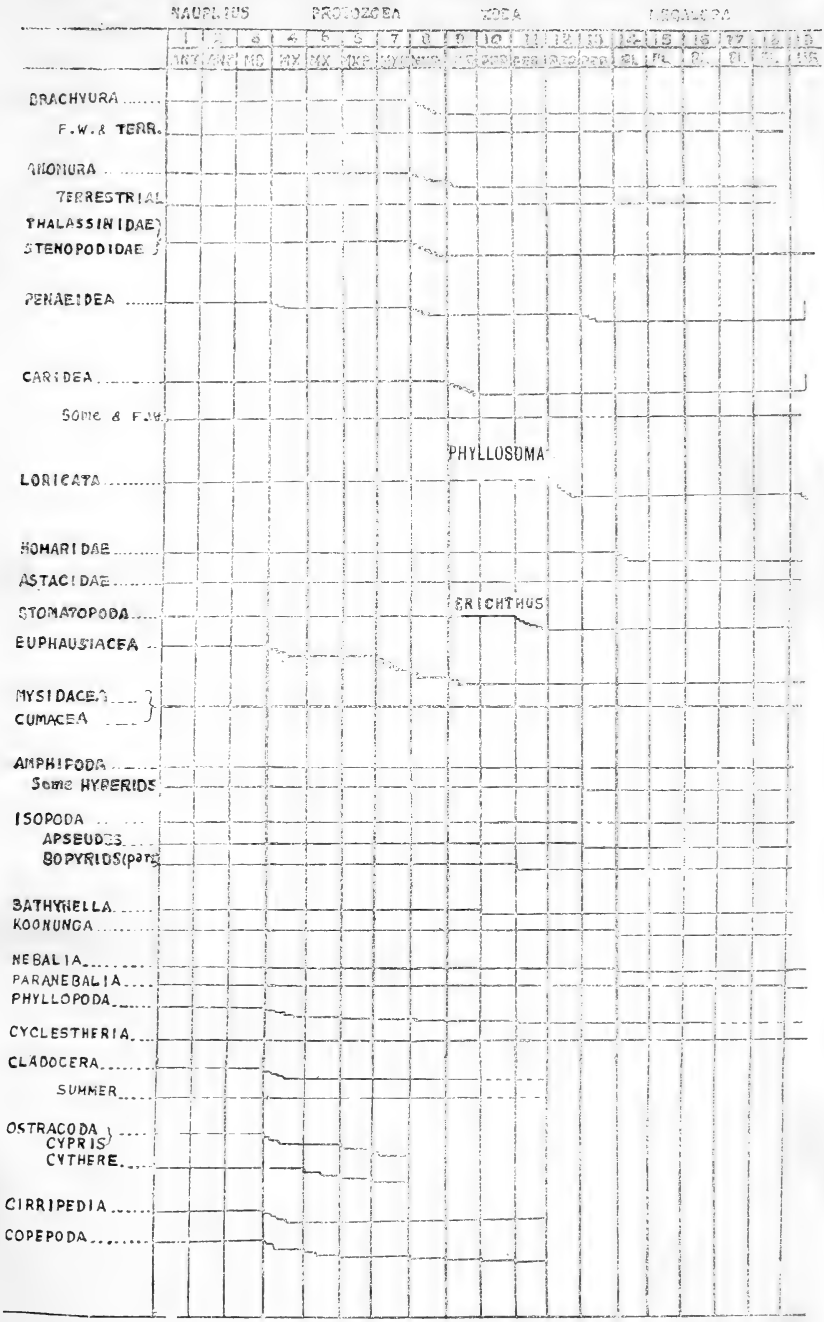

NAUPLIUS
PROTOZOEA
ZOEA
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
BRACHYURA
F.W. & TERR.
ANOMURA
TERRESTRIAL
THALASSINIDAE
STENOPODIDAE
PENAEIDEA
CARIDEA
Some & F.W.
PHYLLOSOMA
LORICATA
HOMARIDAE
ASTACIDAE
ERICHTHUS
STOMATOPODA
EUPHAUSIACEA
MYSIDACEA
CUMACEA
AMPHIPODA
Some HYPERIDS
ISOPODA
APSEUDES
BOPYRIDS(part)
BATHYNELLA
KOONUNGA
NEBALIA
PARANEBALIA
PHYLLOPODA
CYCLESTHERIA
CLADOCERA
SUMMER
OSTRACODA
CYPRIS
CYTHERE
CIRRIPEDIA
COPEPODA

FIGURE 1.

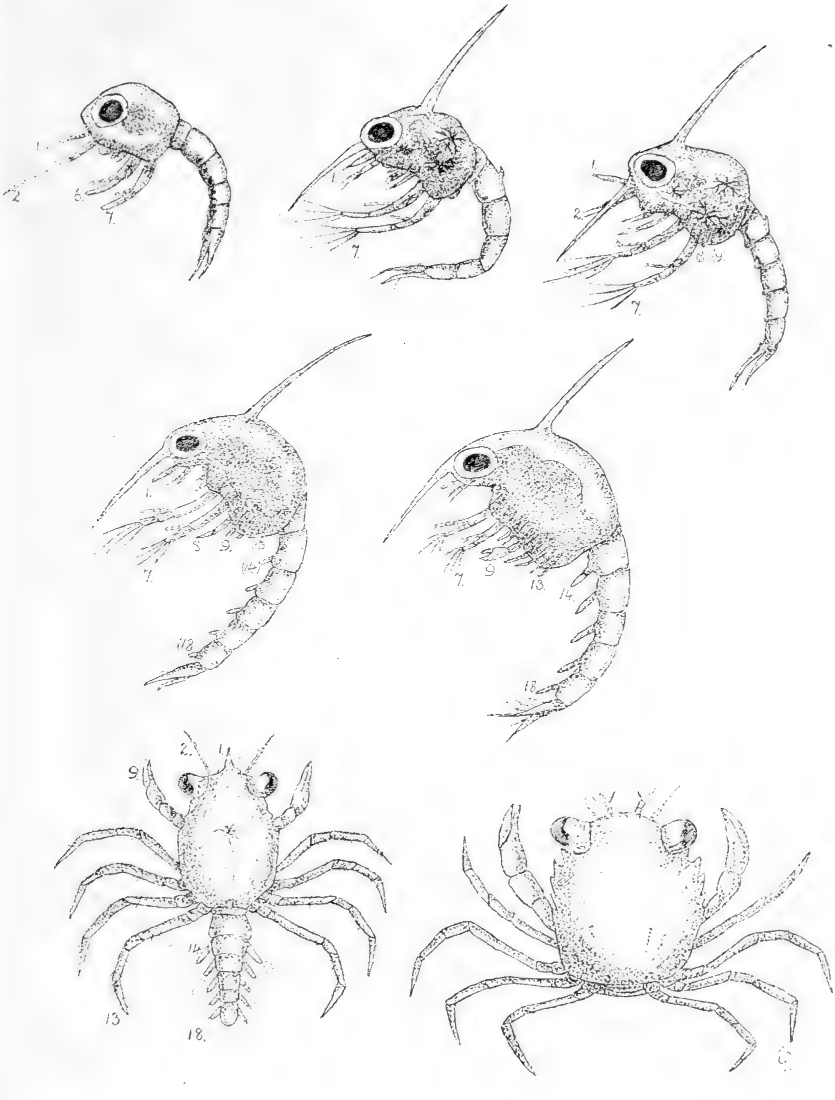


FIGURE 2.

Carcinus maenas, the later larval stages (in the middle), after Williamson ; the megalopa and young stage, after Brook.

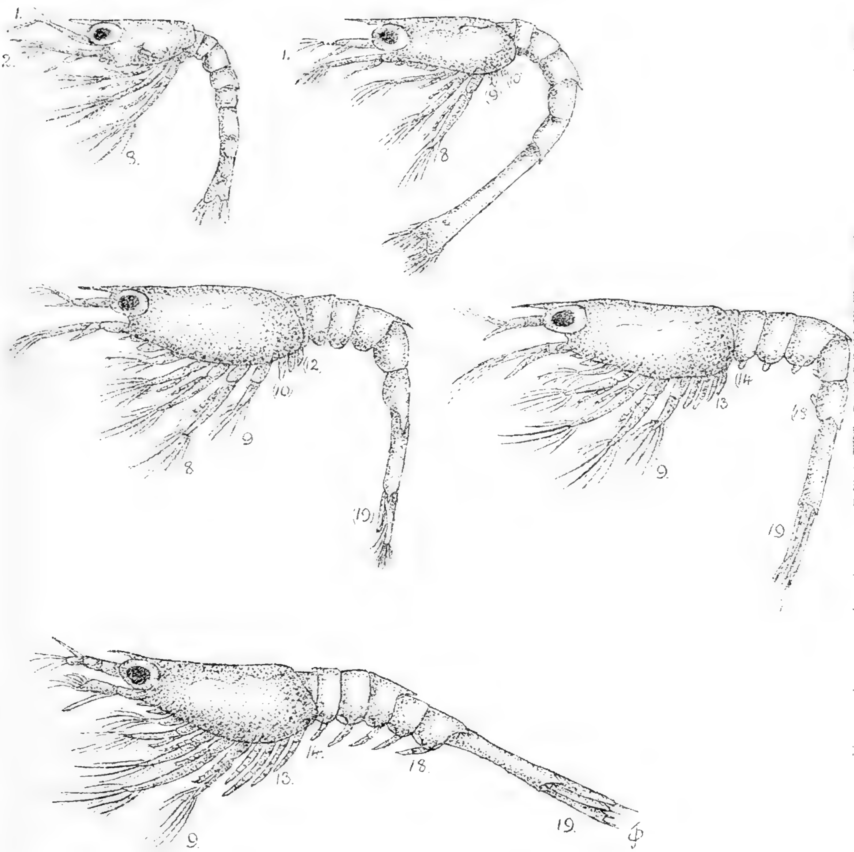


FIGURE 3.

Crangon vulgaris, after Williamson.

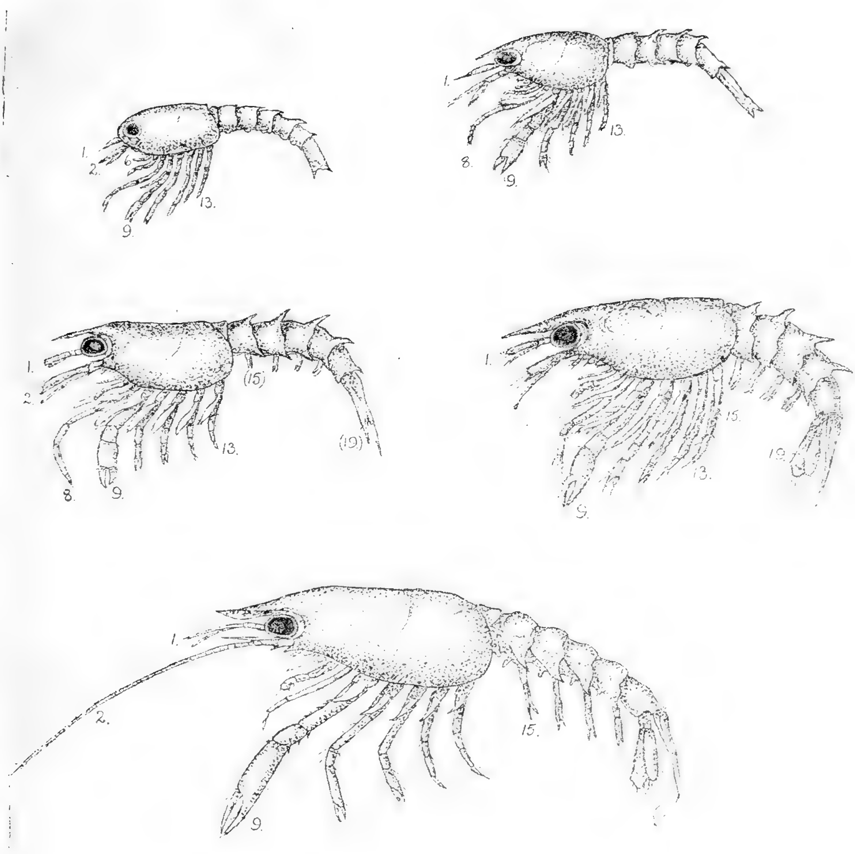


Figure 4.

Homarus valgaris, the first larva, after Fullarton.

the next ecdysis the limbs undergo practically no change, but the larva acquires its characteristic spines. It is now called a zoea. During the so-called zoea stages the posterior limbs are growing, but typically remain rudimentary until the ecdysis which reduces or obliterates the thoracic spines and broadens the carapace in the formation of the megalopa. In these respects the Brachyura are in agreement with the Thalassinidae and the Stenopodidae, and some of the Anomura only differ in that after the first few ecdyses the third pair of maxillipeds attain development, becoming, like the first two pairs of maxillipeds, swimming legs. It is in this state, also, that is to say, with eight pairs of limbs, that the Caridea are hatched typically. In all these cases it may be suggested that the name protozoea should be given to all the pre-megalopa stages, in other words, there is no zoea stage.

As has been noted in the case of the Penaeidea, the physiological difficulties in the formation of the last two pairs of limbs of the thorax, that is just where the abdomen commences, leads to a hesitation in the development, resulting sometimes in the suppression of the limbs. The effect is seen in other groups. The zoea stage may be thus defined as larvae with pereiopods or with all the segments and limbs complete to the tenth, eleventh, twelfth or thirteenth. We may thus include the phyllosoma stages of the Loricata with eleven pairs of appendages, still retaining for convenience, however, the name phyllosoma, the erichthus larva of the Stomatopoda, with ten pairs of appendages, as well as the larvae of the Homaridae, which are typically freed with all the limbs to the thirteenth fully formed. Even the first stage of the lobster although it possesses thirteen pairs of limbs has been styled a protozoea.

The successive stages give time for the appendages not developed at hatching to grow, and as has been apparent, it is convenient to define the stages in succession when groups of the limbs attain a functional condition. The nauplius has three pairs of limbs, and during the metanauplius ecdyses, while the nauplius limbs retain their prominence, the next four or five limbs are gradually reaching their full development. As soon as this has been accomplished the larva may be called a protozoea. A further series of ecdyses give time for the thoracic limbs behind those already developed to become prominent, and when the whole of these or such part of them as are to be developed at this period are completed the larva is a zoea. A physiological precocious appearance and growth of the uropods may take place in the later protozoea stages. When the pleopods in turn have become fully developed the larva is a megalopa. Although the limbs at this stage are complete, several ecdyses are necessary before the limbs attain the adult character.

The pelagic Euphausiacea (fig. 5), like the pelagic Penaeidea, are hatched at the nauplius stage, but they attain the megalopa condition through stages which are far from being parallel. The metanauplius stages lead to the calyptopis, which possesses six pairs of limbs. A further series of ecdyses brings about the addition of the seventh limb, and also the uropods. This stage has been styled the furcilia. It is a typical protozoea. One or two more ecdyses convert this into the cyrtopia, which has eight pairs of appendages, and two other ecdyses bring about the complete development of the limbs, and the megalopa, which in this case is not very different from the adult, is established. The calyptopis is peculiar, but it is followed by stages which are typical protozoea, and a zoea phase may be said to be absent.

The Mysids, Amphipods, Isopods and their allies undergo development in brood chambers, and are usually liberated in the megalopa condition, but in some cases as zoeae. The eggs hatch in some in the pouch as nauplii, in others at a more advanced stage, but even in these latter the nauplius stage is indicated.

Nebalia is reared under the protection of the bivalve carapace. A nauplius stage is passed through in the egg which is hatched as a zoea with all the thoracic limbs completed, and the larva is liberated in the megalopa state.

With the exception of Cyclestheria of the Phyllopoda and the Cladocera, which have parthenogenetically produced young in the summer, the Entomostraca are liberated as nauplii. The ecdyses bring about increase in size and a gradual appearance of the limbs in the usual order.

The sum of my plea here is that I consider the stages in Crustacean development can be best defined by the number of appendages, which in the successive stages have reached a functional condition. I venture to propose therefore the following stages :—

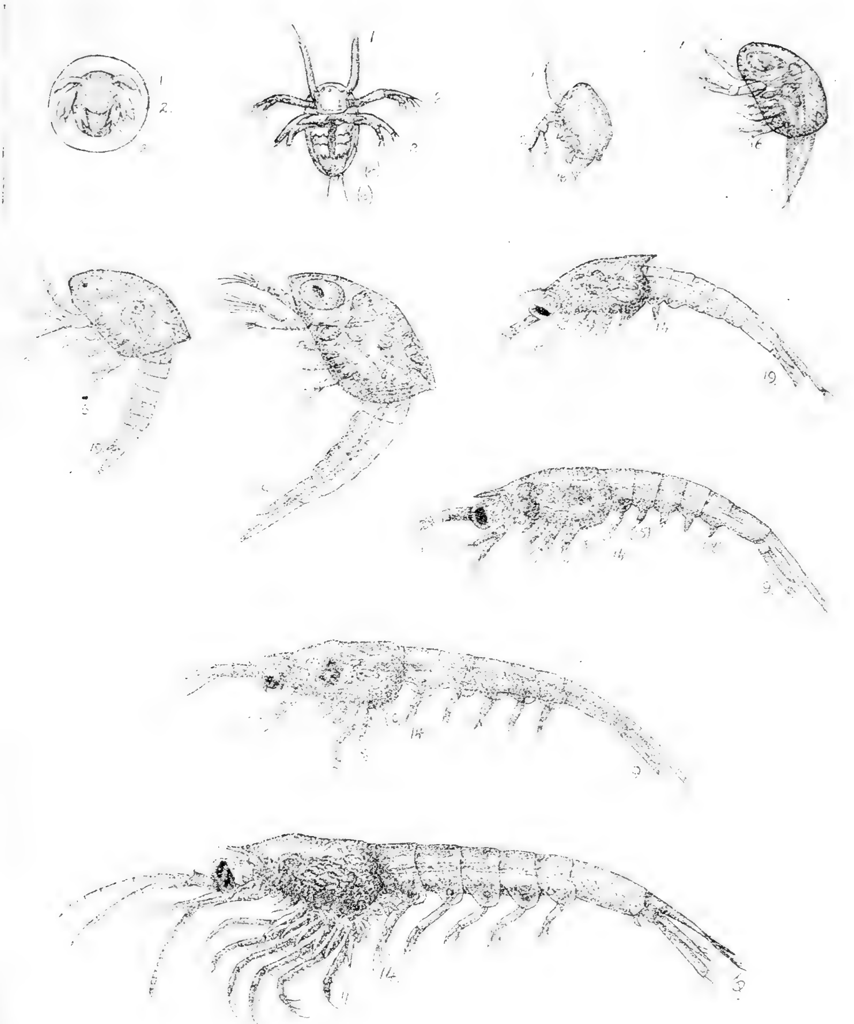


FIGURE 5.

Euphausia, after Sars.

Nauplius, three pairs of appendages.

Protozoea, more than three pairs but not more than eight pairs of appendages.

Zoea, more than eight but not more than thirteen pairs of appendages.

An obvious objection to the scheme is that Euphausia, for example, is bound to pass through a zoea stage to reach a megalopa condition. But I have chosen to define the stages with reference to a state of full development, for the reason that if we take into consideration the appearance of all the appendages we should want to define not four stages but some sixteen. I hope at least in drawing attention to the problem I have paved the way to a solution, and that writers on the subject will cease from calling by the same name such obviously different stages as the newly hatched larvae of the crab and the lobster.

2.—GROWTH.

The preceding section will serve to explain the modification of the nomenclature which is employed here to distinguish the larvae. The larvae, as has been seen, are hatched with a certain number of appendages, and a series of ecdyses allow of the development and the growth of the remaining limbs. This is accompanied by an increase in size. After the larval stages have been completed, the subsequent advances in growth are brought about by further ecdyses. These as a whole gradually become separated by longer intervals of time, but the intervals are also subject to some degree of variation by season, the ecdyses tending to be more numerous in the warmer months. A sudden increase in growth takes place usually at each ecdysis, but a continuation of growth may take place during a short period after the ecdysis has occurred. It might therefore be more accurate to express the increase in graphs such as those which have been made to illustrate this section by steep curves, but as the growth which succeeds the ecdysis is small compared with that which is the result of the process and the time with reference to the instar is short the growth is expressed as accomplished at the ecdysis.

Brachyura.—The growth of the shore crab, *Carcinus maenas*, can be stated with an approach to accuracy for G. Brook and Mr.

H. J. Waddington, of Bournemouth, have managed to rear many examples in a state of confinement through a large number of ecdyses. When these experiments are analysed and brought together, it is at once apparent that the successive advances in growth and the periods of the instars are intimately related. The information with reference to the majority of the series has been given in full by Williamson (1903), and it is restated in Table I. For convenience of reference the series are distinguished by the figures and numbers employed by Williamson and by the letters given by Brook. It will at once be plain that in the table I have arranged as well as I was able the respective series with reference to the ecdyses with a view to obtaining mean results, and these were afterwards smoothed. In each case the size is given and the number of days occupied during the instar of that size. By this means the results of season are eliminated, and it is possible by this method to eliminate also the influence of sex. But the sexes exhibit an interesting difference in growth, and in this case the results for each are shown in detail, for the point is important enough to warrant its being emphasised. The smoothed results are expressed in the form of a chart in fig. 6.

As has been stated already in the previous section, the crab is liberated from the egg in the protozoea condition. The seven pairs of limbs are practically fully developed. The first ecdysis yields the first of the so-called zoea stages, but it only differs from its predecessor by having the spines so characteristic of the larvae of this group. During the four stages the remaining limbs appear and grow, but they do not reach a functional state until the ecdysis which produces the megalopa. Each successive larva employs the first two pairs of maxillipeds as natatory organs, the limbs posterior to these are not brought into use. The larval spines do not constitute a zoea, and I venture to submit therefore that all the larval stages preceding the megalopa are or should be styled protozoea.

The fifth ecdysis gives rise to the megalopa. The dorsal spine in the case of the shore crab is not developed at this stage, and as a rule it is rudimentary in Brachyuran megalopa. The carapace is broad and flattened, thus approaching the adult condition, but the abdomen is still directed posteriorly. The limbs are now fully developed and adult-like in appearance, situation and in function. They still present certain spines, which, like those of the preceding stages, are employed to assist in ecdysis.

The protozoeae are pelagic, and the megalopa is still to a large extent pelagic, but it is beginning to take an interest in demersal conditions. The protozoea stages may be said to last about a month, and thus for a period of a month or six weeks the shore crab is undergoing a denatant migration along the coast. At the end of this denatation in the megalopa and the first young stages it is showered in immense numbers on the bottom for the most part between and just beyond tide-marks.

Ecdyses succeed one another rapidly during the first year of life, as is apparent from Table I. and fig. 6, but these take place in the sheltered condition afforded at the bottom. During the instars moreover the young crab is advancing into shallow water.

TABLE I.—SEX NOT STATED.

1 = G. Brook. 2 = H. J. Waddington. W = Williamson.

		Ecdyses.	A[1]		B[1].		Z[1].		3[2].		7[2].		Mean.	
			Size.	Days.	Size.	Days.	Size.	Days.	Size.	Days.	Size.	Days.	Size.	Days.
			mm.		mm.		mm.		mm.		mm.		mm.	
Protozoea	1	0	—	—	—	—	—	—	—	—	—	—	—	—
	2	1	—	—	—	—	—	—	—	—	—	—	—	—
	3	2	—	—	—	—	—	—	—	—	—	—	—	—
	4	3	—	—	—	—	—	—	—	—	—	—	—	—
	5	4	—	—	—	—	—	—	—	—	—	—	—	—
Megalopa	...	5	0·93	—	0·93	—	—	—	—	—	1·15	W	1·0	—
Crab	1	6	1·52	10	1·6	18	—	—	—	—	1·7	W	1·6	14
	2	7	2·3	15	2·32	26	2·28	—	—	—	2·4	W	2·3	20
	3	8	3·02	26	3·09	21	2·96	14	—	—	3·2	W	3·1	20
	4	9	3·72	59	4·19	89	4·14	—	—	—	4·0	W	4·0	74
	5	10	4·48	84	5·2	84	—	—	—	—	—	—	4·9	84
	6	11	5·07	—	6·7	44	—	—	6·25	—	—	—	6·0	44
	7	12	—	—	8·9	33	—	—	8·25	24	—	—	8·5	29
	8	13	—	—	11·6	24	—	—	9·75	41	—	—	10·7	32
	9	14	—	—	13·5	—	—	—	12·5	65	—	—	13·0	65
	10	15	—	—	—	—	—	—	15·75	67	16·5	—	16·1	67
	11	16	—	—	—	—	—	—	21·0	109	19·25	30	20·1	69
	12	17	—	—	—	—	—	—	24·5	49	24·0	34	24·2	41
	13	18	—	—	—	—	—	—	30·75	48	30·0	51	30·4	49
	14	19	—	—	—	—	—	—	36·0	—	37·0	64	36·5	64
	15	20	—	—	—	—	—	—	—	—	46·5	103	46·5	103
	16	21	—	—	—	—	—	—	—	—	62·0	nearly 2 years	62·0	2 years
	17	22	—	—	—	—	—	—	—	—	62·0	—	62·0	—

TABLE I.—FEMALE.

1 = G. Brook. 2 = H. J. Waddington. W = Williamson.

		Ecdyses.	4^2.		6^2.		9^2 (B).		10^2 (C).		P^1.		B^{11}.		D^1.		Mean.		Smoothed.		Age.
			Size.	Days	Size.	Days.	Size.	Days.	Size.	Days.	Size.	Days.	Size.	Days.	Size.	Days.	Size.	Days.	Size.	Days.	
			mm.		mm.		mm.		mm.		mm.		mm.		mm.		mm.		mm.		
Protozoea	1	0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0·3	0	0
	2	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0·4	8	8
	3	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0·5	9	17
	4	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0·6	10	27
	5	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0·7	11	38
Megalopa	...	5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0·95	12	50
Crab	1	6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1·6	14	64
	2	7	2·5	—	—	—	—	—	—	—	—	—	—	—	—	—	2·5	14	2·3	14	78
	3	8	3·0	14	—	—	—	—	—	—	—	—	—	—	—	—	3·0	14	3·0	15	93
	4	9	3·7	41	—	—	—	—	—	—	—	—	—	—	—	—	3·7	41	3·7	26	119
	5	10	5·0	24	—	—	—	—	—	—	—	—	—	—	—	—	5·0	24	5·0	36	155
	6	11	6·0	43	6·5	—	—	—	—	—	6·0	—	—	—	—	—	6·2	43	6·3	35	190
	7	12	7·5	57	8·2	40	—	—	—	—	7·5	18	—	—	—	—	7·7	38	7·8	39	229
	8	13	9·5	73	9·5	39	—	—	9·0	—	10·0	24	—	—	—	—	9·5	45	9·9	54	283
	9	14	12·7	86	12·0	38	12·5	—	12·0	44	14·0	144	—	—	—	—	12·6	78	12·7	61	344
	10	15	15·5	32	15·0	72	16·5	43	14·0	52	19·5	104	—	—	16·0	—	16·1	61	16·6	69	413
	11	16	19·7	30	19·0	138	21·0	81	18·5	41	26·5	—	—	—	22·0	49	21·1	68	21·2	61	474
	12	17	25·5	46	23·7	37	29·5	87	25·0	52	—	—	26·0	—	28·0	—	26·3	55	26·9	62	536
	13	18	32·0	48	29·0	62	37·0	110	33·0	49	—	—	35·0	51	—	—	33·2	64	33·6	75	611
	14	19	39·0	178	36·0	70	46·5	69	42·5	—	—	—	42·0	—	—	—	41·2	106	42·0	131	742
	15	20	48·0	157	48·5	292	58·5	—	—	—	—	—	—	—	—	—	51·7	224	49·3	224	966
	16	21	55·0	—	55·0	—	—	—	—	—	—	—	—	—	—	—	55·0	—	58·0	—	—
	17	22	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

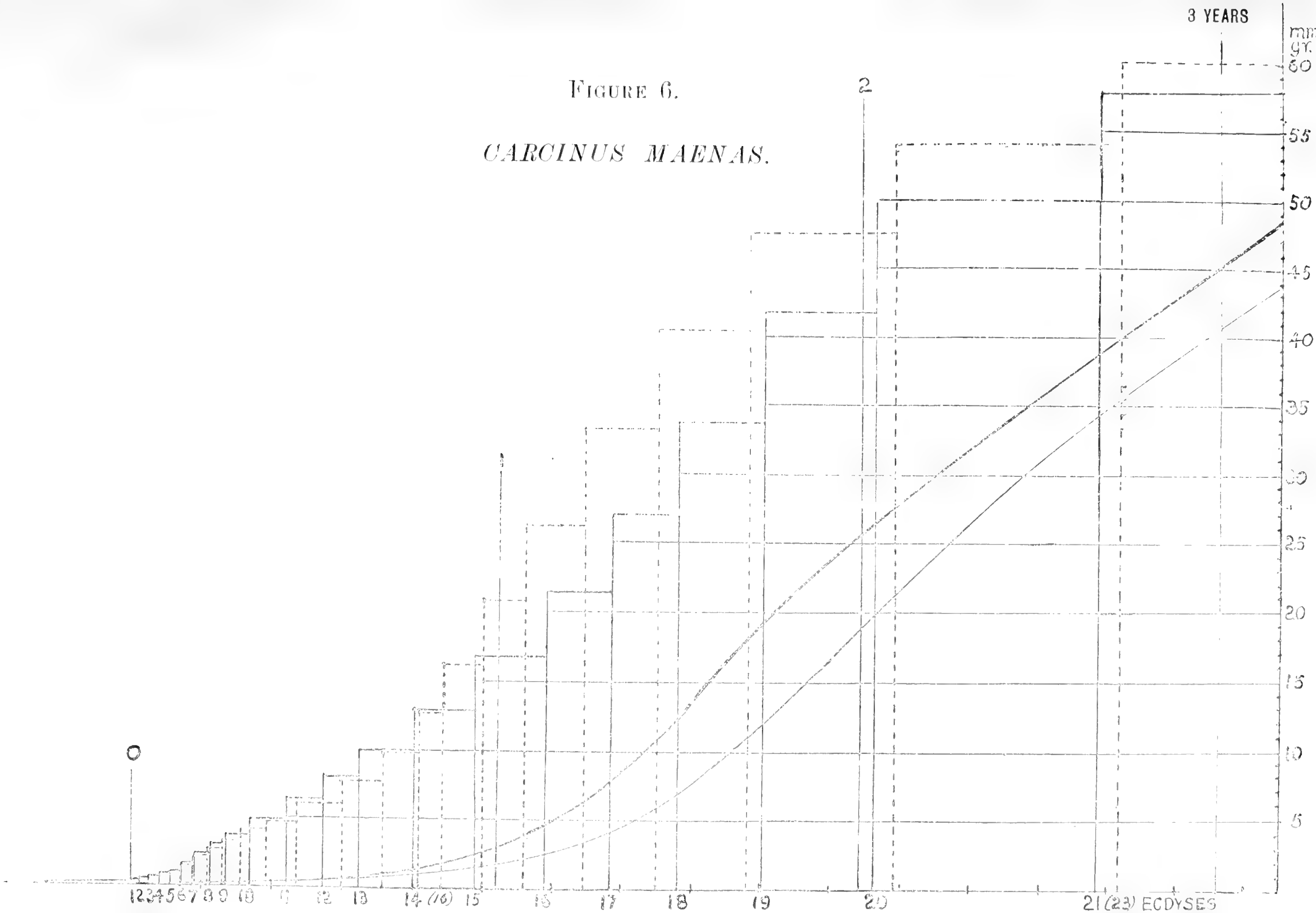
TABLE I.—MALE.

1=G. Brook. 2=H. J. Waddington. W=Williamson.

		Ecdyses.	5^2.		1^2.		2^2.		8^2 (A).		11^2.		N^1.		Y^1.		M^1.		Mean.		Smoothed.		Age.
			Size.	Days.	Size.	Days.	Size.	Days.	Size.	Days.	Size.	Days.	Size.	Days.	Size.	Days.	Size.	Days.	Size.	Days.	Size.	Days.	
			mm.		mm.		mm.		mm.		mm		mm.		mm.		mm.		mm.		mm.		
Protozoea	1	0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0·3	0	0
	2	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0·4	8	8
	3	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0·5	9	17
	4	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0·6	10	27
	5	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0·7	11	38
Megalopa	...	5	—	—	0·9	—	—	—	—	—	—	—	—	—	—	—	—	—	0·9	—	0·95	12	50
Crab	1	6	—	—	1·1	13	—	—	—	—	—	—	—	—	—	—	—	—	1·1	13	1·5	13	63
	2	7	2·5	—	1·6	13	—	—	—	—	2·0	12	—	—	—	—	—	—	2·0	13	2·0	13	76
	3	8	3·0	15	1·8	14	—	—	—	—	3·0	15	—	—	—	—	—	—	2·6	15	2·6	15	91
	4	9	3·5	26	2·5	12	—	—	3·0	—	4·0	13	—	—	—	—	—	—	3·3	17	3·2	17	108
	5	10	4·0	31	3·2	15	—	—	3·5	12	4·5	14	—	—	—	—	—	—	3·8	18	3·9	24	132
	6	11	4·7	64	4·2	14	4·7	—	4·0	44	5·0	24	—	—	—	—	—	—	4·5	36	4·7	32	164
	7	12	6·2	53	5·7	19	5·7	27	5·5	86	6·0	29	—	—	—	—	—	—	5·8	43	5·9	43	207
	8	13	7·5	95	7·5	29	7·0	18	8·0	86	6·5	18	—	—	—	—	—	—	7·3	49	7·6	42	249
	9	14	8·0	58	10·0	35	9·2	18	10·0	28	9·5	25	—	—	—	—	—	—	9·3	33	9·6	38	287
	10	15	10·0	29	13·5	34	12·0	37	13·0	35	12·5	29	—	—	—	—	13·0	—	12·3	33	12·5	31	318
	11	16	12·5	23	18·0	—	16·0	19	17·0	36	16·5	31	15·5	—	14·5	—	17·5	31	15·9	28	16·1	33	351
	12	17	15·5	35	—	—	20·0	—	22·0	34	22·0	77	18·5	16	20·0	31	23·0	34	20·1	38	20·8	42	393
	13	18	19·0	30	—	—	—	—	28·0	48	28·5	47	23·0	126	29·0	54	31·0	—	26·4	61	26·2	58	451
	14	19	24·5	31	—	—	—	—	—	—	35·5	74	29·0	105	39·0	92	—	—	32·0	75	33·2	74	525
	15	20	33·0	48	—	—	—	—	—	—	43·5	110	37·0	82	51·0	108	—	—	41·1	87	40·5	89	614
	16	21	41·0	104	—	—	—	—	—	—	52·0	—	45·0	—	56·0	—	—	—	48·5	104	47·5	116	730
	17	22	53·0	156	—	—	—	—	—	—	—	—	—	—	—	—	—	—	53·0	156	53·7	250	980
	18	23	59·5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	59·5	—	60·0	—	—

Figure 6.

CARCINUS MAENAS.



In fig. 6 the upright lines represent the successive ecdyses, the horizontal lines in step-like succession the instars; the whole lines refer to the female and the dotted lines to the male. The numbers below indicate the numbers of ecdyses, and along the margin at the right to the length in mm. and the weight in gr. The upright lines numbered 0, 1, 2 and 3 refer to the age in years from the time of hatching. The curved lines express the weight in grammes, the upper being that of the male.

It is quite plain remembering that the chart has been prepared with a close approximation to the observed facts, (1) that the periods of the instars are gradually lengthened, (2) that in the first year there are fifteen ecdyses in the case of the female and seventeen in that of the male. The male thus obtains a start in growth which it does not afterwards lose. Another point incidentally evidenced is that although the crab remains during the instar of the same size it is constantly increasing in weight.

A summary of the facts brought out in the chart is given in Table II.

TABLE II.—GROWTH OF *CARCINUS MAENAS.*

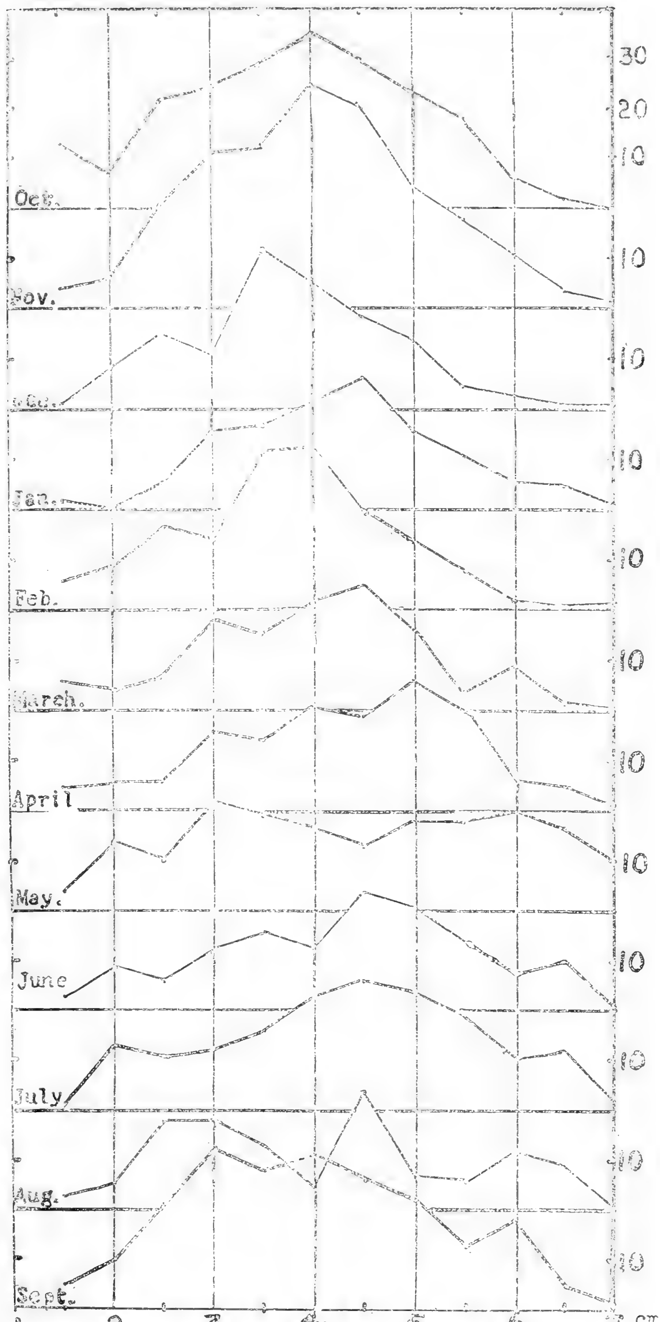
Year.	Number of Ecdyses.		Size in mm.		Weight in gr.	
	Female.	Male.	Female.	Male.	Female.	Male.
1	15	17	16·6	20·8	1·5	2·8
2	4	4	42·0	47·5	18·7	25·6
3	2	2	58·0	60·0	40·8	45·2

This gives the mean results based on the available material. There is a great deal of variation, due especially to the long spawning and hatching seasons, but it is evident from the experiments in rearing which have been made that the effect of season on growth in the case of the late hatched " 0 " group is compensated for by an acceleration in the " 1 " group. With this in mind we can say with some degree of reason that maturity in the female takes place at about the twenty-first ecdysis. At the time of the ecdysis, when pairing occurs, the ova are in an undeveloped state, and time must elapse before they are ready for extrusion. The period of incubation does not appear to be a long one, but as I stated in 1902, it is not likely shorter than four months. It is probable therefore that a year is taken up at least in these processes, that, in other words, the next ecdysis after that in which pairing occurs for the first time will be at the end of a year. It will be noted, however, that at about the period of the twenty-first ecdysis a long interval is bound to occur, for growth would not warrant an earlier ecdysis. These and other correlated points will gain in clearness by a consideration of the growth of the edible crab.

We do not yet possess full information as to the larval history of the edible crab, *Cancer pagurus*, but so far as we know it appears to be precisely similar to that of the shore crab. The protozoeae have seven pairs of functional appendages, and the pelagic stages which lead to the megalopa are completed in about a month or a little more. The megalopa gives place to the first young stages, and we have to thank Cunningham for drawing attention to their remarkable likeness to Atelecyclus. The evidence upon which an estimate of the growth is based was presented by Williamson in 1904 and by me in 1905. It consists of three series of stages reared by Mr. H. J. Waddington at Bournemouth, two of which refer to females, the third with the sex not determined, Williamson's careful records of the crabs collected in the region of Dunbar, and the observations made at Cullercoats.

From the Waddington series we can see that a female may attain a size of 30-35 mm. in a year after hatching, and 46-56·5 mm. in two years. From Williamson's measurements of the crabs of the beach at Dunbar (fig. 7) it may be seen that during the summer, from May to July, crabs of about 20 mm. appear between tide marks, that they reach a size of about 30 mm. in August and September, and 40 mm. in October and November. We see some evidence also that the larger of these leave the inshore during the succeeding winter months, reappearing, however, to some extent in the spring and summer.

Taking these observations together we have the means of fixing the general growth during the first two years, and we can see also that there is a wide range of variation. The later stages



30
20
10
Oct.
10
Nov.
10
Dec.
10
Jan.
10
Feb.
10
March.
10
April
10
May.
10
June
10
July
10
Aug.
10
Sept.
1
2
3
4
5
6
7 cm.

FIGURE 7.

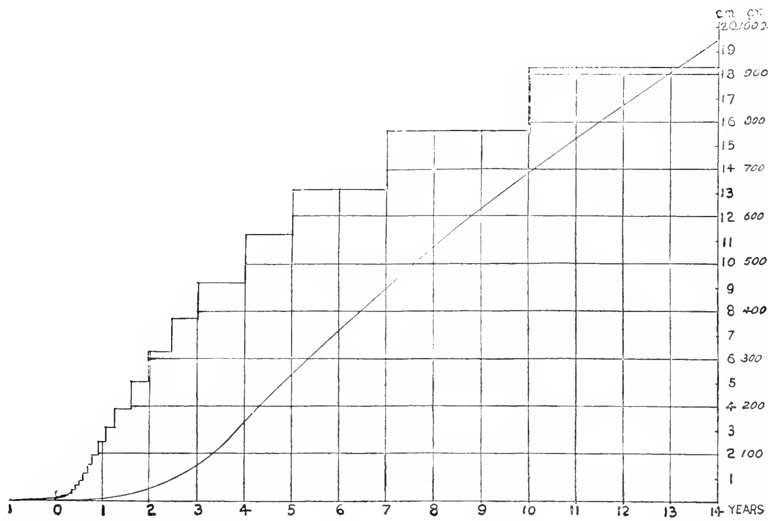


FIGURE 8.

CANCER PAGURUS.

have been determined by the observations on larger crabs watched for periods long enough to allow of at least one ecdysis taking place, and by the results of marking experiments.

The chart of growth (fig. 8) which is submitted here to indicate the mean growth of the female of this species may not be absolutely accurate, but I do not think it is far from being so. It is almost precisely the same as that given in 1905. In this case I have ventured to picture growth over a large number of years, so as to permit of the discussion of several points of interest connected with this species and Crustacea in general.

The spawning season of the crab appears to be practically the same all round the British Islands. It may be said to last from November to February, only varying in different regions by being a little earlier or a little later. This at all events is true of the Cornwall region according to Cunningham, of the east coast of Scotland and the north-east coast of England from the information derived by Williamson and by me. Hatching takes place from July to October. From this it may be gathered that the incubation is one of about eight months, and experiments made on the Northumberland coast have demonstrated that this is about the length of the period.

After hatching, the protozoeae are subject to a drift along the coast for about a month or six weeks, and as has already been stated, the megalopa and the young stages which follow it reach the bottom, not usually inshore but in moderate depths outside. They gain the inshore region for the most part during the second year. After November of the second year they leave the tide region, and some return to the shore in the following summer. A few may return in the next one or two summers, but the majority do not again venture between tide marks. Outside, however, they repeat on a larger scale the inward and outward migrations. The population of crabs as a whole migrates offshore in winter and inshore in summer, as is well-known to the fishermen. As a result of marking experiments it has been proved that the mature female crab migrates before coming into berry, that is to say, before spawning, in a contranatant direction. The Northumberland crabs, for example, migrate for the most part to the southern side of the Firth of Forth, but some reach the north side, or a part of the coast still further north ; two have been recaptured on the southern shore of the Moray Firth, at Banff.

This is the only Invertebrate of which we have actual knowledge of such a migration taking place, but it is probable that some of the other and at all events the larger Crustacea and the Cephalopod Mollusca have the same power.

A summary may now be given of the growth of the crab, as presented in fig. 8.

TABLE III.—*CANCER PAGURUS* (FEMALE).

Year.	Number of Ecdyses.	Size.	Weight.	Gain in Weight.
		Mm.	Gr.	Gr.
1	14	25	4	4
2	4	63	25	21
3	2	92	75	50
4	1	112	170	95
5	1	131	270	100
6	0	131	365	95
7	1	156	455	90
8	0	156	540	85
9	0	156	620	80
10	1	183	695	75
11	0	183	767	72
12	0	183	837	70
13	0	183	905	68
14	1	210	971	66

The chart and the table may be and they are not intended to be more than approximately correct, but even so what they demonstrate is of importance with reference to a species of considerable economic importance, for when all is said it is the mainstay of the inshore fisherman.

According to the scheme set forth in both the table and chart a female crab bears berries three times between its fifth and its fourteenth year. Apart from theoretical considerations relating to growth we have facts to prove that such intervals actually occur. It is well-known that the two-year period characterises the smaller crabs. The evidence for this has been given in previous reports; the results of observations of crabs in confinement and of marking experiments. Even theoretically apart from such facts it is plain that the annual spawning which has been assumed to take place is impossible. At the period of casting, which in the years immediately preceding maturity takes place in the autumn and continues at and after maturity at the same season, the ova are in an undeveloped condition and remain in this state practically during the period of hardening, a period of some months. The crab therefore cannot spawn at the next spawning season, that is to say, about the end of the year. It is postponed until the spawning season of the following year, a period of some fifteen months after the ecdysis at which pairing occurred. In consequence of this hatching will take place in the summer of the second year, and casting immediately thereafter; thus at the end of a period of about two years. It was tempting to say without the material we are now considering that in this case growth had to wait on reproduction, but it is evident that at the stage of first maturity growth is in adjustment with the needs of maturity.

There is proof likewise from our marking experiments that a female crab after an ecdysis may remain for a period of over two years before spawning, *vide* Report (new series IV., p. 40) for an account of a specimen returned from Dunbar, measuring 15·2 cm. Similarly in the Report (new series V., p. 7) the record is given of a female which after an absence of three years and five months was in March berried. This specimen measured 18 cm. We have the proof therefore that spawning may be postponed over the periods demanded by the chart. It may be said that we have no proof that in these cases spawning may not have taken place, that during this period of years there may have been two spawnings. This is a possibility which must not be overlooked. In the case of, let us say, a female casting at seven years old spawning could take place about January, after she attains eight years, and again about January after she is nine years. Williamson offers some considerations to indicate that such an event takes place. He has shown, for example, that the spermathecae are not entirely emptied of their contents in the berried female, and that a second lot of ova could be fertilised after the first had been hatched. That this takes place sometimes even if rarely is of considerable interest for it indicates that the periodicity of reproduction tends to be maintained.

On the other hand we have evidence to show that it is not common, that as a rule spawning only takes place once during the instar. In the Report (new series III., p. 74) referring to the results of marking experiments it was pointed out that in the female crabs which had not migrated the ova were small in size, whereas in the females which had migrated the ova were approaching the size of maturity. This tended to prove (1) that the migration was due to the development of the ova, and (2) that the condition cf the ova in the non-migratory females pointed to a postponement of the spawning season. Besides in our experience no matter how large the crab hatching almost invariably is succeeded by an ecdysis.

If this latter aspect of the condition in question be found to be the general one it is evident that the ripening of the gonads does not take place in such cases until the approach of the spawning season, that is to say, according to the conditions given in the chart until in the one when nearly nine and in the other approaching thirteen years. Furthermore it is clear that not merely the rate of growth is slowing down but in association therewith the ripening of the ova takes place at a longer interval of time. It is admitted that in some cases reproduction may take place as has been stated twice during the instar when the instar is a long enough one to permit it, but it is manifest that the periodicity of the ripening is controlled by somatic growth, or rather that ripening is slowing down in association with the decline in growth. It may yet be shown that subsequent to the age considered four years may elapse before spawning takes place. Even if it be said that two spawnings may occur in the instar, it is evident that the sperms have a much longer period of life in the spermatheca than has been in this and similar cases considered.

We have thus an interesting correlation between growth, ecdysis, reproduction and migration. With reference to the last it is not necessary to state after the work which has been reported upon before, that it only affects the females.

There is one further point relating to the migrations which may be touched upon here although it is not the intention to dwell on this aspect of the subject. The question has been asked, is there a return migration of the females? It is not at all likely to be general if it occur at all, for if the above considerations be accepted, it is apparent that after migrating contranatantly and spawning and hatching, the female will cast in the new situation. The evidence goes to show that until she gets the impulse to move on again she remains where the ecdysis took place, and further when she migrates again it is still further in the same direction.

The fact that spawning in general with reference to this and other groups is an annual event has led naturally to the conclusion that all the mature individuals spawn every year. But it is becoming plain that this is often more apparent than real.

Further information with regard to the crab will be found in Williamson's papers in the 18th, 21st and 22nd Annual Reports of the Fishery Board for Scotland and in the reports of the Cullercoats Laboratory for many of the years between 1898 and 1916.

Mr. Waddington kindly drew my attention to a series of a male *Mamaia* (*Maia*) *squinado* which he presented to the College of Surgeons. The first stage was found on August 18th, 1902, the first moult took place on October 21st, and the subsequent history according to the table I now give. I have to thank R. H. Burne, of the College of Surgeons, for the measurements :—

TABLE IV.

1902.	mm.	Days.
Aug. 18	3·25	—
Oct. 21	4·0	144
1903.		
Mar. 14	5·0	64
May 17	6·5	169
Nov. 2	9·0	64
1904.		
Jan. 5	11·0	66
Mar. 11	16·0	241
Nov. 7	19·0	113
1905.		
Feb. 28	24·0	—
May 13	Died	—

It is a tropical species common throughout the Mediterranean and the neighbouring Atlantic, and reaches the southern coasts of Britain. How far, and from what point, the larva had been drifted which yielded the specimen found by Mr. Waddington at Bournemouth we cannot tell. But it is evident from the irregularity of the instars that the conditions are not favourable at the northern limit of its range. No doubt the instars would be shorter in warmer southern waters, but even so it is worth noting that the spider crabs, as evidenced by this example, do not reach maturity until after the lapse of several years.

ANOMURA.—A Waddington series of the common hermit crab, *Eupagurus bernhardus*, is preserved in the British Museum.

It has not been found possible to measure the stages, but the record is interesting in that it shows that the Anomura may also take several years to reach a mature condition. Calman in a letter stated that the last stage of the series is still small in size. The dates of the successive ecdyses are :—

TABLE V.

1903.	Instar Days.	1904.	Instar Days.	1905.	Instar Days.
June 30...	32	Jan. 31	48	Mar. 7	74
Aug. 1...	31	Mar. 19	61	May 20	—
Sept. 1...	50	May 19	88	May 30	Died
Oct. 21...	28	(Aug. 15)	54		
Nov 18...	35	Oct. 8	58		
Dec. 23...	39	Dec. 5	92		

The stage enclosed in brackets for August, 1904, was lost and the date is not given, but to complete the series it has been assumed to have taken place on August 15th.

MACRURA.—The preceding example belonging to the Anomura gives evidence that ecdyses may be numerous and size apparently only slightly increased thereby. There is a Waddington series of *Leander* (*fabricii*) *adspersus* in the British Museum which appears to indicate that ecdyses may take place in rapid succession year after year without any appreciable increase in size taking place. The particulars are given in Table VI. The measurements given are the length of the carapace from the posterior wall of the orbit to the posterior margin. The total length was measured in the case of Nos. 5 and 38, and was found to be 42 and 49 mm. respectively. The measurements of the carapace as furnished by Mr. Storrow are given with reference to time in diagrammatic form in fig. 9. From this it will be seen more plainly that there has nevertheless been a gradual increase in size. The upright lines refer to the ecdyses when the increase was noted to have taken place, and the intervening dots indicate the ecdyses when no increase in the size of the carapace apparently occurred. If there was an increase at other periods than those stated it was not apparent, for Mr. Storrow wrote with reference to the series that

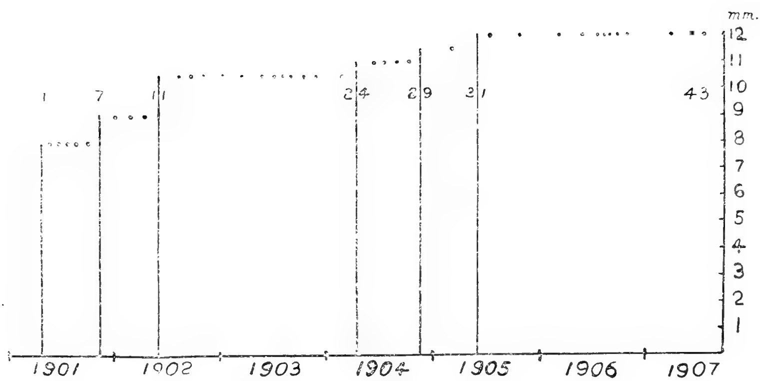

mm.
12
11
10
9
8
7
6
5
4
3
2
1
1
7
11
24
29
31
43
1901
1902
1903
1904
1905
1906
1907

FIGURE 9.

Nos. 11 to 23 showed no alteration in size of the carapace, and this was found to be the case also for Nos. 31 to 42, " the whole of which were measured and were found to be 12 mm. by Dr. Calman and myself."

TABLE VI.—*LEANDER (FABRICII) ADSPERSUS.*

Number.	Date.		Instar Days.	Size.	Number.	Date.		Instar Days.	Size.
	1901.			mm.		1904.			mm.
1	April	26	24	8	23	Feb.	20	53	—
2	May	20	37	—	24	April	13	63	11
3	June	26	71	—	25	June	15	36	—
4	Missing				26	July	21	44	—
5	Sept.	5	38	—	27	Sept.	3	37	—
6	Oct.	13	31	—	28	Oct.	10	31	—
7	Nov.	13	61	9	29	Nov.	10	120	11·5
	1902.					1905.			
8	Jan.	13	55	—	30	March	10	85	—
9	March	9	45	—	31	June	3	48	12·0
10	April	23	45	—	32	July	21	98	—
11	June	7	60	10·5	33	Oct.	27	134	—
12	Aug.	6	42	—		1906.			
13	Sept.	17	45	—	34	March	10	91	—
14	Nov.	1	71	—	35	June	9	39	—
	1903.				36	July	18	30	—
15	Jan.	10	75	—	37	Aug.	18	21	—
16	March	26	66	—	38	Sept.	8	25	—
17	May	31	39	—	39	Oct.	3	37	—
18	July	9	30	—	40	Nov.	9	145	—
19	Aug.	8	28	—		1907.			
20	Sept.	5	44	—	41	April	3	72	—
21	Oct.	19	37	—	42	June	14	40	—
22	Nov.	25	88	—	43	July	24	—	—
					Died.	July	26	—	—

During a period of six years and three months this example only increased in length from about 42 mm. to about 49 mm., and had cast its cuticle forty-three times. The series evidences that in certain cases moulting takes place quite independently of growth. It will be noted that while the ecdyses occurred without interruption during the long period they were particularly numerous in 1901, 1903 and in 1906, that on the whole they were diminishing in frequency. If the cuticle is shed so frequently in this and probably in similar Macrurous Decapods without reference to growth except incidentally, and probably also without there being a necessity for freeing the body from external growth, it is difficult to explain. It is a problem which may be recommended to the physiologist.

It is evident from the table and the diagram that this specimen when captured was not a product of the year of capture. It is probable, indeed, that it was then not less than two years old, and we have again therefore a valuable instance of the long life of even the smaller types of Decapods.

An attempt may now be made to present the growth of the lobster, *Homarus vulgaris*. The spawning season may be said to be July to September, and the hatching season, June to August, but occasional cases are obtained of hatching taking place as late as October. When hatched the larva possesses all the appendages fully developed to the last thoracic, and the abdomen is segmented, the telson being prolonged into forks, and the dorsal walls of the abdominal segments into spines. A larva with this structure cannot be called a protozoea; it is a zoea. It moults almost at once, giving a zoea in which the pleopods 2-5 are developed. At the next ecdysis the uropods are added. The limbs are practically completed at the fourth stage, but as a more conspicuous change takes place at the next ecdysis, and a change of habit leading from the pelagic to a more demersal life the term megalopa is more conveniently reserved for that stage which here and in America is now generally distinguished as the lobsterling. Still further ecdyses take place before the last vestiges of the exopods disappear from the pereiopods.

The four zoea stages last from about three weeks to a month or longer according to temperature. The lobsterling is still to some extent pelagic, but it periodically comes to rest at the bottom, taking advantage of the shelter provided.

The lobsterlings measure from 1·6 to 1·9 cm., and have been found in our tank experiments at Cullercoats from about the end of July to September. A size of 3·5 cm. may be reached by the end of September, and of 5 cm. in November. On the other hand, we have examples which in the following July were only 5·4 to 6·6 cm. With this as an introduction the material upon which an estimate of the growth is based may be presented. (Table VII.).

TABLE VII.—LOBSTER.

Male (W).				Female (C).			Female (C).		
Date.	Carapace.	Total Length.	Instar Days.	Date	Total Length.	Instar Days.	Date.	Total Length.	Instar Days.
		mm.			mm.			mm.	
	Zoea 1	9·0	7		9·0	7			
	2	11·0	8		11·0	9			
	3	13·0	12		13·0	12			
	4	16·0	14		16·0	14			
1906.	Megalopa	18·0	14		18·0	14			
Aug. 21	10·0	21·0	16		21·0	16			
Sept. 14	12·0	24·5	24		25·0	18			
Oct. 9	14·0	28·5	25	1911.	29·0	20	1911.		
Nov. 23	15·5	32·5	45	Sept. 27	35·0	44	Nov.	50·0	231
1907.				1912.			1912.		
Mar. 14	17·0	37·0	111	Mar. 16	40·0	117	May 5	55·0	71
May 5	19·5	41·0	52	July 11	54·0	46	July 15	66·0	—
							1913.		
July 14	21·0	44·0	70	Aug. 26	73·0	337	May 16	Killed accidentally	
				1913.					
Aug. 24	23·5	49·0	41	July 1	84·0	70			
Oct. 26	26·0	55·5	63						
				Sept. 9	98·0	293			
1908.				1914.					
Feb. 17	29·5	63·0	114	June 29	115·0	95			
May 12	34·0	74·0	85	Sept. 21	130·0	276			
				1915.					
Aug. 16	38·5	84·0	96	June 26	150·0	Died			
Dec. 9	41·5	90·5	115						
1909.									
June 8	47·0	104·0	181						
1904.									
Sept. 16	51·0	110·5	—						
1905.									
Mar. 29	56·0	121·5	168						
Sept. 7	64·0	140·0	162						
1906.					Male B.			Male B.	
April 21	69·0	151·0	226						
Nov. 19	78·0	171·5	212		176·0				
1907.				1883.					
July 30	87 0	191·0	253	July	182·0	—		190·0	—
1908.							1883.		
April 17	90·0	196·0	285	Dec.	203·0	—	May	202 0	—
1909.				1884.			Sept.	227·0	—
April 8	100·0	216·5	356	June	225·0	—	1884.		
July 31	107·0	222·5	Died	Nov.	238·0	—	May	238·0	—
							Oct.	248·0	—

The table only refers to such examples as have been kept over a period. There are besides many records of the sizes of the early stages, and of the results of ecdyses at late stages. These, however, do not help us to understand the facts of the tables, which will come as a surprise to all interested in the growth of Crustacea, even after the presentation of the preceding examples. The stages are two Waddington series (W) in the British Museum. The first is probably a male (1906-1909), the second (1904-1909) is a male; two Brook's series (B) of males; and two females reared at Cullercoats (C) from the eggs. The one lost on May 10th, 1913, undermined the stones under which it lay, and one of the stones fell and crushed it. The other after reaching a size of 150 mm. was lost in some such similar manner, but the exact cause of death was not apparent. The Norwegian series of Appelloff referred to by Williamson (1905) show the same growth as those recorded above, 2 years 3¼ ins. (8·25 cm.), 3 years 4½ ins. (11·4 cm.). A second specimen got measuring 4¾ ins (12 cm.) after casting twice in the next year reached 7 ins. (17·8 cm.), and after another cast in the second year 8⅛ ins. (20·6 cm.). The facts may be broadly summarised (Table VIII.) to indicate the size at the end of the respective calendar years of lobsters reared in aquarium conditions.

TABLE VIII.

	Male. mm.	Female. mm.
1st year	32·5	35 to 50
2nd ,,	55·5	66 to 73
3rd ,,	90·5	98
4th ,,	110·5	130
5th ,,	140	—
6th ,,	171·5 to 176	—
7th ,,	191	—
8th ,,	196 to 227	—
9th ,,	222·5 to 248	—

The facts of Table VII. have been used to make the diagram reproduced herewith (fig. 10). In this case no attempt has been made to smooth the results. The figure shows that the early stages reared at Cullercoats and the two males reared by Mr. Waddington follow the same general trend of growth, and the older stages (B) of Brook's fit into the record as well. But it is manifest that if we are to accept these facts as exhibiting truly the growth of the lobster, maturity is not reached until about

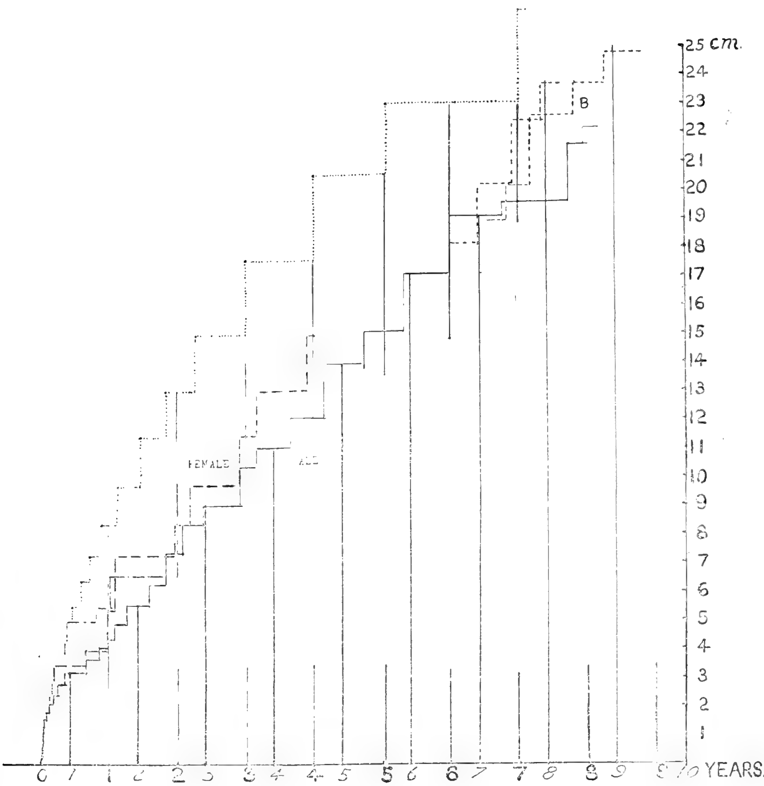


FIGURE 10.

seven or eight years. It is probable therefore that in this case growth is not accurately indicated by the experimental method. The growth of the Waddington specimens appears in the winter of the first year to be deflected from the normal path, and the same feature is true of the Cullercoats specimens, which may be said to have suffered during the first and more distinctly in the second winter. We have then to choose between explaining this as being due to season or as the result of tank conditions.

Two considerations help us to conclude that the confinement is the cause of the slow growth. The first is that in the rearing experiments on a large scale at Rhode Island, Professor Mead and his colleagues found that the American species, which is so like our own, reaches in a year a size of 5·5 to 7·3 cm., and in two years 11·43 cm. It will be noted that the Cullercoats females in the first year were growing just at about that rate. The other point is that when maturity is attained in the case of the female a period of two years must elapse between the ecdyses. The incubation period is one of about eleven months. After casting and pairing the female requires a year before spawning, and the ecdysis takes place immediately after hatching.

It is seldom that berried lobsters under 9 ins. are seen. They appear to be from 9 to 10 ins., say 21 to 24 cm., as a rule when they come to maturity. This will mark, as we have seen it to mark in these and other cases, the point of inflexion of the curve of growth where the change to a more horizontal phase occurs. It would be possible with all this in mind to construct an ideal curve, fitting into it the ecdyses shown by experiment but neglecting the instars. This, it will be seen, I have ventured to do, and that there may be no confusion I had better state now that the idealised scheme of the growth with reference to the female is shown by the line of small dots, the actual growth of the Cullercoats females by broken lines, and the actual growth of the Waddington males by the continuous line. Brook's series are added to the latter, and indicated by dotted lines and marked "B." The upright figures below refer to the years after hatching, and the sloping figures to the calendar years. The results may now be summarised (Table IX.):—

TABLE IX.—LOBSTER.

Year.	Male.		Female.		Probable Correction (Female).	
	Size.	Ecdyses.	Size.	Ecdyses.	Size.	Ecdyses.
	Cm.		Cm.		Cm.	
1	4·4	12	5·4-6·6	11	8·4	13
2	7·4	4	8·4	2	13·0	3
3	10 4	3	11·5	2	17·6	2
4	12·1	2	15·0	?	20·6	1
5	15·1	2	—	—	23·0	1
6	19·1	2	—	—	23·0	0
7	22·5	2	—	—	26·2	1
8	23·8	2	—	—	26·2	0

The male evidently casts more frequently, but during the years of actual experiment it does not gain thereby an increase in size over the female. The later stages of the female are known from actual observation to have instars of several years. And in this case it has been observed that a female may come into berry twice in the same instar. It has not happened in our experience, although we have for many years kept berried females until hatching took place, and in the majority of cases until the ecdysis. But Cunningham and Andrew Scott have recorded cases. It may occur therefore during the later stages when more than two years intervene between ecdyses.

Some information as to the growth of the Norway lobster, *Nephrops norvegicus*, may be derived from Storrow's account in the Report for 1911 (new series I.) Females with newly spawned eggs were got mostly from July to October, the largest number in September. Hatching was found to take place from May to September, but for the most part in June. This points, as Storrow states, to an incubation of about nine months. The four zoea stages are similar to those of the lobster.

Females become mature at a size of 8 cm., more at 11-14 cm., and are caught to a size of 17 cm.; males mature at 10 cm., and are found to a size of 22 cm. or slightly more. Males were found to be mature all the year, but the obvious signs of active maturity were mostly evident in August. This, or say July-October, is probably the time of casting and pairing in the case of the females. The males cast usually in February, March and April.

The tables which Storrow prepared of the measurements of large numbers each month show on analysis sizes which stand out prominently. These have been taken to represent stages in growth. The results of the analysis are given in the following table, which may be taken as a tentative attempt to indicate the growth of this species.

TABLE X.—NORWAY LOBSTER.

Year.	Male. cm.	Female. cm.
1	3	2·5
2	8·5	7 5
3	13·0	10·0
4	16·0	12·0
5	18·0	13·5
5	19·5	15·2
7	21·0	15·2

The population of males centre about 16 cm., and of the females about 12 cm., and they are then apparently about four years old. It is about this period also that maturity may be said to be reached in the average condition.

The foregoing examples show that the Decapoda have a long period of development and growth. Maturity is not reached in some of them until they are five years old, and life may be prolonged for many years afterwards. It will be apparent, for example, that a lobster of say 12 ins. (30·5 cm.) is about ten years, and of about 16 ins. (40 cm.) at least about fifteen years old: one was caught at Marske-on-Sea which measured 29 ins. and weighed 15½ lbs. Crabs also may be reckoned to reach as great an age. A male crab was found in June this year (1918) to measure 23·2 cm. (9 ins.) across the carapace and to weigh 2,500 gr. (5·5 lbs.) A crab caught at Brixham, now in the Hull Museum, weighed 12 lbs. Such large examples cannot be less than twenty years old.

In complete contrast to the Decapoda and the Stomatopoda the lower Malacostraca and the Entomostraca grow to full size in a short period of time. Some have an annual phase, and others produce several broods in the year, all of which may become mature in the one season.

In most cases it has already been plain the larval passes without break into the adult condition. This feature is particularly evident in the Entomostraca, which remaining small preserve many larval features. Even the Cirripedia may be looked upon as large babies.

As conditions are at present, I must content myself with referring to one example. Dr. Marie Lebour has recently described the early history of *Calanus finmarchicus* from the stages prepared by Mr. Crawshay at Plymouth, and she has been good enough to send me the following measurements :—

Nauplius Stages.						Copepod Stages.					
1	2	3	4	5	6	7	8	9	10	11	12
0·21	0·27	0·42	0·48	0·51	[0·67]	0·8	1·2	1·5	1·8	2·3	[2·9]

At the twelfth stage the young Calanus is fully developed, all the limbs being completely formed. One or two more ecdyses appear to be necessary before the adult size is attained. The larval stages were found to be passed through in about two months.

If the development was equally rapid all the year a maximum of six broods could be said to be produced. But we know from the results of plankton investigations that this species and Copepoda generally increase enormously in numbers in summer, and the increase of the young and the nauplii is particularly noticeable about May and June, and again is observed about September. Reproduction then undergoes a special intensity in spring and autumn, and this periodicity appears to be referable to the period of growth in the summer, and points to a diminution both in reproduction and growth in the winter.

It must not be forgotten, however, that this and the other pelagic Copepoda are holoplanktonic, and that the double wave of Copepoda observed in the Irish Sea, at Plymouth and at Cullercoats is a general one affecting the whole of the North Atlantic. It is the inshore manifestation of a change which is oceanic in its scope. Gran sees reason for believing that this species at least only reproduces once a year, that there is an annual spawning season, but the facts appear to point to the event happening at least twice, the annual phase being a short summer followed by a long winter generation. In tropical waters the generations are probably still more frequent, and it is from the tropical Atlantic that the North Atlantic obtains its annual supplies.

Although growth takes place by a series of saltations it is evident that it is similar to that of other groups of which we have knowledge. 1. There is a steady diminution of the rate of growth from the beginning of development. 2. Growth is not uniform; it is subject to external and internal conditions. It is well known from experiment that changes in temperature are of great importance in varying development and growth, and the effects have to some extent been illustrated in the above analyses. In the case of a species spread from the Mediterranean to the north of Norway the life-history both in respect to development and growth is liable to a gradual change from the tropical to the more Arctic limit of the distribution. In one or two cases I have attempted to depict the ideal growth apart from external circumstances. But it is clear that the environment is always bringing about variation. The ideal, in other words, may not ever be reached, circumstances are always at work to produce change. For the North Atlantic region generally we can predicate a summer of rapid growth and a winter of slower growth, and we have evidence to prove that in many cases the result is not always ideal or even average, that there is an actual slowing in growth which leads to the reflexion that one of two things must happen, either the size is stunted or life is prolonged.

In concluding this section it is a pleasure to record, in addition to that already acknowledged, the help I have received from Dr. Calman, of the British Museum of Natural History, and from Mr. Storrow who devoted a day from duty to measure many of the series utilised in the foregoing presentation. But above all, I might be allowed to say how much we all owe to George Brook, and especially to Mr. Waddington, for the series of preparations they have made showing the history of many examples of Crustacea for periods extending as will be noted, often for several years. Miss O. M. Jorgensen, M.Sc., kindly made the drawings (figs. 2-5) of the larvae of various Crustaceans for this paper.

PLANKTON OF THE SUPPLY TANKS OF THE DOVE MARINE LABORATORY.

By OLGA M. JORGENSEN.

An investigation of the contents of the supply tanks was made from May, 1917, to May, 1918, in the hope that it would yield a satisfactory indication, both quantitatively and qualitatively, of the micro-plankton of the sea at Cullercoats, but as the method has been found to have many disadvantages, and owing to too little time being available for the work, only a very general account can be given.

At first the water to be examined was drawn from the Laboratory taps, and a certain amount, usually 1,000 cc., filtered. The contents of the filter paper were washed in a known quantity of filtered sea-water, and either examined straight away or centrifuged first. This was found to be tedious and unsatisfactory, after which the centrifuge only was used, the method employed by Dr. Marie Lebour at Plymouth being adopted.*

Samples of sea-water were obtained by lowering a large can into the supply tank until it dipped just sufficiently below the surface to become filled. The water was then well stirred before being drawn off with a pipette and run into the centrifuge tube. Samples were taken and examined once a week whenever possible, the temperature, height of water in the tank, and the weather conditions being noted. No samples were taken during the month of December.

The samples were found to consist almost entirely of Diatoms, Peridiniales and Protozoa, with an odd Nemertine, Copepod or Pygnogon appearing occasionally.

DIATOMS.

On the whole, the average number of diatoms for each month gives a curve similar to that recorded for Plymouth* and the Irish Sea,† that is to say, there is a smaller autumn maximum and a considerably higher spring one (*see* fig. 1). The autumn

* "The Microplankton of Plymouth Sound." By Marie V. Lebour, D.Sc.

† Herdman in "Lanc. Sea Fish. Lab. Reps." for years 1907-1917.

maximum occurred early, viz., in August and the spring one in April. Although the general shape of the curve corresponds to Dr. Lebour's, we find that the actual numbers of diatoms vary very considerably. At Plymouth, the number of diatoms in 50 cc. of water at the autumn maximum was below 900, ours being slightly in advance of this (1,100 in 50 cc.), but while at the spring maximum only 2,000 diatoms per 50 cc. were obtained at Plymouth, our average was 8,000 per 50 cc. The number may, of course, represent the numbers to be obtained in the sea at this time, but it is possible the number in the tanks is higher than it ought to be at this time as a result of resting spores formed in autumn settling in the mud on the tank bottom and giving rise to numbers of new diatoms in the spring. No attempt has been made to prove this, but it seems reasonable in the case of *Nitzschia closterium* at least, as quantities of small specimens were obtained in April and May. Also, it must be remembered that the tanks are not entirely emptied each day, so that a certain number of diatoms will always be present from previous pumpings, together with those pumped in each day.

Another disadvantage of using the tank water for this investigation is that large diatoms like *Biddulphia spp.* and those occurring in tangled masses, *e.g.*, *Chaetoceras spp.* evidently fail to get into the tanks in anything like representative numbers, as these two genera occurred at rare intervals, and then only in small numbers. This is evidently the case with other genera also, for though the actual number of diatoms present in the samples is high, the number of genera and species recorded is much lower than those in the Plymouth samples or in Cleve's work.*

A list of the species of diatoms which occurred in the samples is included in the present paper (Table I.) with the months in which they are present, and a note as to whether they appear as solitary individuals (×), are rare (r), in fair numbers (f), common (c), or very common (cc), and in addition to this the monthly averages are given for the commonest and most frequently appearing genera (Table II.), together with a number of others which occur at odd times in fair numbers, or which are present in greater or less quantity throughout the year.

* P. T. Cleve's "Plankton Researches," Kongl. Svenska Vetenskaps-Akademiens Handlinger, Bander 36, No. 8.

TABEL I.—SHOWING THE RELATIVE QUANTITIES OF EACH SPECIES OBTAINED FROM THE SUPPLY TANKS DURING EACH MONTH.

Species.	1917.						1918.				
	June.	July.	Aug.	Sept.	Oct.	Nov.	Jan.	Feb.	Mar.	April.	May
Diatomaceæ—											
Melosira jurgensii Ag.	f	r	r	r	r	—	—	—	r	f	f
„ borreri Grev.	—	r	—	—	—	—	—	—	—	—	—
„ nummuloides Ag. ...	—	f	r	—	—	—	—	—	×	r	r
Paralia sulcata (Ehr.) ...	r	×	c	f	c	c	c	—	c	f	c
Skeletonema costatum (Grev.)	r	f	r	×	f	—	—	—	f	ccc	ccc
Thalossiosira hyalina (Grun.) ...	—	—	—	r	—	—	—	—	—	—	—
„ decipiens (Grun.) ...	×	—	×	—	r	—	—	—	—	×	r
Leptocylindrus danicus (Cleve)	—	—	—	r	f	—	—	r	r	—	×
Hyalodiscus stelliger Bail. ...	×	—	—	—	—	—	—	—	×	—	—
Coscinodiscus radiatus Ehr. ...	r	×	×	r	r	r	r	r	r	f	r
„ excentricus Ehr.	—	—	—	—	—	—	r	—	×	—	—
„ lineatus Ehr. ...	—	—	—	—	—	—	×	—	—	—	—
Actinoptychus undulatus (Bail)	r	—	—	—	×	—	r	—	—	—	—
Rhizosolenia setigera (Brightw.)	—	—	—	—	×	—	—	×	—	—	—
„ shrubsolei Cleve ...	—	r	r	×	r	×	×	—	—	—	—
„ calcar avis Schultze	—	—	×	—	—	—	—	—	—	—	—
Chaetoceras sociale Lauder ...	f	—	c	—	—	—	—	—	—	×	—
„ gracile Schütt ...	—	×	—	—	—	—	—	—	—	—	—
„ radians Schütt ...	×	—	×	—	—	—	—	—	—	—	r
Eucampia zoodiacus Ehr. ...	—	—	c	4	r	×	—	—	—	f	—
Biddulphia sinensis Grev. ...	—	—	—	—	—	×	×	—	—	×	—
„ mobiliensis (Bail.)	—	—	—	—	—	—	×	×	—	—	—
„ aurita Bréb. ...	—	—	—	—	—	—	—	×	—	×	—
Fragilaria striatula Lyngb. ...	f	cc	cc	r	f	f	r	f	f	f	f
„ cylindrus Grun. ...	×	—	—	—	—	—	r	—	—	—	r
Thalassiothrix curvata Castr. ...	—	—	—	×	r	—	×	—	—	—	—
„ frauenfeldii Grun. ...	×	×	—	—	—	—	—	×	—	—	r
„ nitzschioides Grun. ...	—	—	—	—	—	—	—	—	×	—	×
Asterionella bleakeleyi W. Sm.	—	f	r	—	r	—	—	—	—	—	—
Grammatophora serpentina Fuhr.	f	—	—	—	—	—	—	—	—	—	—
Navicula fusiformis Grun. ...	r	—	f	—	r	r	r	—	r	f	r
„ sphærophora Kütz. ...	—	—	—	—	—	—	×	—	—	—	×
„ binodis Ehr.	c	—	×	×	—	×	f	—	r	r	r
Pleurosigma acutum Norm. ...	×	r	×	×	×	×	×	×	r	c	c
„ angulatum W. Sm.	—	r	—	—	—	—	—	—	—	—	—
Amphiprora alata Kütz. ...	×	—	—	—	—	—	—	—	—	—	—
„ obscura A. S. ...	—	—	—	×	—	—	—	—	—	—	—
„ obtusa A. S. ...	—	r	—	—	—	—	—	—	×	—	—
„ paludosa W. Sm.	—	—	×	—	—	—	r	—	×	×	×
„ maxima Greg. ...	—	×	r	—	—	—	—	—	—	—	—
Amphora spectabilis Greg. ...	—	×	r	r	×	×	r	r	r	c	c
„ arenicola Grun. ...	—	—	—	×	—	×	—	—	—	—	—
Nitzschia closterium W. Sm.	r	c	cc	f	f	r	—	r	r	ccc	cc
„ seriata Cleve... ...	—	—	r	—	r	—	—	—	—	—	×
„ delicatissima Grev. ...	—	—	×	—	—	—	—	—	—	—	—

TABLE I.—*Continued.*

Species.	1917.						1918.				
	June.	July.	Aug.	Sept.	Oct.	Nov.	Jan.	Feb.	Mar.	April.	May.
Synedra pulchella Kütz. ...	—	r	×	r	r	r	—	—	—	c	f
Surirella spiralis Kütz.... ...	—	—	—	—	—	—	—	×	—	×	—
Isthmia nervosa Kütz. ...	r	—	—	—	—	—	—	—	—	—	—
Rhabdonema adriaticus Kütz.	—	r	—	—	—	—	—	—	—	×	—
Cymbella cymbiformis Ehr. ...	—	—	—	—	—	×	—	—	—	—	r
'eridiniales—											
Ceratium tripos (O. F. Müll.) ...	—	—	—	—	—	—	—	—	—	r	r
„ furca Ehr.	—	—	—	c	—	r	—	—	—	—	—
„ fusus Ehr.	—	r	r	r	—	—	—	—	—	—	—
„ longipes Gran. ...	—	—	—	—	—	—	r	—	—	—	—
Amphidinium operculatum C. and L.	f	f	c	r	r	r	cc	—	r	—	r
„ rotundatum Lohm.	—	×	r	—	×	—	—	c	r	—	—
„ crassum Lohm.	—	×	—	—	—	r	×	—	—	—	—
Peridinium pedunculatum Schütt.	—	—	—	c	r	r	—	—	—	—	—
„ oceanicum Vanh. ...	—	—	—	—	—	—	—	—	—	—	r
„ thorianum Pauls. ...	r	cc	r	cc	f	r	f	f	—	cc	cc
„ conicum (Gran.) ...	—	r	—	—	—	—	—	—	—	r	f
„ pellucidum (Bergh.)	—	—	r	c	—	—	r	f	r	f	r
„ orbiculare Pauls. ...	r	f	r	c	c	f	f	c	r	r	c
„ pallidum Ostf. ...	—	—	—	—	—	r	—	—	—	—	—
Spirodinium fissum Levander ...	—	×	f	r	r	×	×	—	—	r	f
Glenodinium gymnodinium Pénard	—	cc	cc	—	—	—	—	—	—	r	f
Gymnodinium vestifici Schütt.	—	r	—	—	×	r	r	c	r	cc	f
„ æruginosum Stein	—	f	—	—	—	—	—	—	—	r	r
Oxytoxum reticulum Bütsch. ...	—	—	—	f	—	—	—	—	—	r	—
Dinophysis schuetti Murr. and Whit.	—	×	—	—	—	—	—	—	—	—	—
„ acuminata Cl. and L.	—	—	—	r	—	—	—	—	—	×	—
lorophyceæ—											
nkistrodesmus falcatus Ralfs.	—	r	—	—	—	×	—	r	—	f	f
rotococcus sp.	—	—	r	×	—	—	—	—	—	—	f
icrospora sp.	r	—	r	—	—	r	—	—	—	—	c
nophyceae—											
scillatoria sp.	—	r	—	—	—	—	—	×	—	—	—
gellatæ—											
inobryon sertularia	—	r	—	—	—	—	—	—	—	—	—
arteria sp.	—	—	—	—	—	—	—	—	—	—	r
icoflagellatae—											
istephanus speculum (Ehrenb.)	—	r	—	×	—	—	—	—	—	×	×
usoria—											
trombidium sp.	—	—	—	×	—	r	r	—	—	—	×
uplotes sp. (probably E. charon Müll.)	—	c	r	r	×	r	×	—	r	—	×
idinum nasutum Müll. ...	×	—	—	—	—	—	—	—	—	—	—

TABLE II.—SHOWING THE ACTUAL NUMBERS PER 50 CC OF THE CHIEF GENERA OF DIATOMS IN THE PLANKTON SAMPLES.

Species.	1917.						1918.				
	June.	July.	Aug.	Sept.	Oct.	Nov.	Jan.	Feb.	Mar.	April.	May.
Nitzschia	8	144	553	30	53	25	1	5	15	1345	400
Skeletonema	14	19	13	1	20	—	—	—	20	5375	4833
Melosira	40	7	13	6	11	—	—	—	5	—	34
Pleurosigma	1	3	1	1	1	1	—	1	5	420	288
Amphora	—	1	6	6	1	1	6	10	5	640	73
Paralia	6	1	82	25	75	52	120	—	95	40	73
Fragilaria	36	245	238	9	41	31	8	22	19	25	26
Coscinodiscus	2	1	1	4	2	3	7	2	12	20	10
Synedra	—	1	1	1	1	1	—	—	—	78	11
Rhizosolenia	—	1	17	1	3	1	2	—	—	—	—
Chætoceras	1	1	210	—	—	—	—	—	—	—	—
Eucampia	—	—	47	3	4	1	—	—	—	10	—
Asterionella	—	19	6	—	2	—	—	—	—	—	—
Thalassiothrix	3	11	3	2	11	3	—	—	—	—	14
Navicula	—	7	17	3	4	13	3	2	—	8	23

An analysis of this table gives the following particulars of these genera :—

Nitzschia.—This genus is represented chiefly by *N. closterium* and a few *N. seriata* at odd times. *N. delicatissima* appeared very rarely. *N. closterium* is present throughout the year, but is very scarce in January and February. It attains its maximum in April, when numbers of the short form with straight ends occur amongst the ordinary long form. (*See* * p. 152.) This is the commonest diatom in the samples, and shows a striking difference from the Plymouth records, where it occurs throughout the year, but never in large numbers unless entangled in masses of other diatoms. Here it was very rarely found entangled, and the individuals were in the great majority of cases entirely separated. Occasionally two were found together but never more.

Skeletonema.—*S. costatum* was present all the year, except from November to February inclusive. A great increase in its numbers occurred suddenly in April and May, and it is to this species, together with *Nitzschia closterium*, that the spring maximum is due. The chains of *S. costatum* were very short, the majority containing only four to six cells. A fair number were, however, ten to twelve cells long.

S. costatum is recorded as being very plentiful at Plymouth, and as appearing in enormous numbers at Kiel. It has periods of total disappearance at these places also.

Melosira.—Two species of *Melosira* appeared in the samples *M. jurgensii* being the chief one, whilst *M. nummuloides* occurred at rare intervals. At no time was this diatom common, and it was absent from November to February and in April. It reached its maximum in May and June.

Pleurosigma.—*P. acutum* was one of the larger species which was evidently able to find its way into the tanks easily, as it occurred practically all the year round. From June to February it was represented only very poorly by single specimens here and there, though at no time was it entirely absent, except during January. In March there was a slight increase in quantity, and in April and May a very considerable rise in numbers of this species. During these two months the individual diatoms varied greatly in size.

P. angulatum also appeared occasionally.

Amphora.—This genus was represented almost entirely by one species, namely, *A. spectabilis,* which, like *Pleurosigma,* occurred in small numbers all the year round, and showed a sudden increase in April and May. *A. arenicola* was very rarely present.

Paralia.—*P. sulcata* was present in fair numbers throughout the period, with the exception of July, when it was very rare, and February when it was not recorded at all. A sudden rise in the quantity of this diatom took place in August, and it reached a maximum number in January. The chains in this case were usually much longer than those of Skeletonema. *P. sulcata* appears to be present in this region all through the year without any marked fluctuations in quantity. This agrees with Dr. Lebour's account of the species as it occurs almost all the year round at Plymouth, but is essentially a winter species with a maximum in November from which the numbers dwindle but pick up again in August.

Fragilaria.—*F. striatula* is another species which is to be found at Cullercoats at all seasons. It was almost as common in the samples as *Nitzschia closterium,* but reached a maximum height at a different time, viz., in July and August. During the remaining months it occurred in fair numbers with great regularity. At no time was it absent from the samples. It is to this species, together with *N. closterium,* that the August maximum of the diatom population is due. *F. cylindrus* also occurs, but much less frequently.

Fragilaria sp. is mentioned in the Plymouth list, but is marked " rare " on every occasion.

Coscinodiscus.—This genus was represented by *C. radiatus* chiefly, together with *C. excentricus* and *C. lineatus* in smaller numbers. It was present throughout the year, but never in great quantities. It appeared rather more frequently during March and April. At Plymouth it is a winter form.

Navicula.—*N. fusiformis, N. binodis* and *N. sphaerophora,* together with small and unidentified species, occurred in small numbers during almost every month, and were rather more common in May.

The following diatoms are on the whole rare, but are interesting in that they appeared in the samples only during certain periods.

Syredra pulchella.—Present from April to November. Rare, except in April.

Rhizosolenia shrubsolei, R. setigera and *R. calcar avis.*—Present from August to January. Very rare, but rather more in August. The genus is represented by six species at Plymouth, with a maximum number in June.

Chaetoceras sociale and *C. radians.*—Occurred very rarely in June, and rather more commonly in August. The genus is a common one in the Plymouth records, and is represented by more than sixteen species.

Eucampia zoodiacus made its appearance suddenly in August, when it was quite common, and remained until November. It occurred only once more, in March. *E. zoodiacus* is present occasionally at Plymouth from May to October.

Asterionella bleakeleyi occurred during three months, July, August and October, and was fairly common in July. At Plymouth it is recorded only twice, in November and December.

Thalassiothrix curvata (with some *T. frauenfeldii*) was present from May to November in fair numbers.

Other diatoms occurring still more rarely or at irregular intervals are included in the general list of species given in Table I. A few still remain unidentified.

Two of the species recorded, namely, *Surirella spiralis* and *Cymbella cymbiformis* are fresh water forms.

PERIDINIALES.

Members of this group appear in the tank samples in numbers which give a curve very similar to the Plymouth one, the greatest numbers being present in July and September here, and in May and July at Plymouth. The increase takes place with great suddenness at both places. (Fig. I.)

Here again, as in the case of the diatoms, we have to record a much larger number of individuals, namely, 5,000 per 50 cc. at the maximum, as against 1,000 per 1,000 cc. at Plymouth, and, again, I consider that the number in our samples is abnormal. This feature is noticeable during the whole period, and would seem to be due to the numbers of Peridinians remaining in the tanks between successive pumpings and reproducing repeatedly in the confined space. Their quantity, too, is not depleted by their forming food for higher organisms, so that, together with the numbers regularly pumped in from the sea, this gives us an extraordinarily high proportion of these forms in the tanks.

From July to September the numbers ranged from 1,000 to 5,000 per 50 cc. In February and April they touched the 500 line, and rose to 900 in May, but during the remainder of the time the numbers of Peridiniales present was never above 200 per 50 cc. Even when least plentiful the numbers are considerably in advance of those given by Dr. Lebour for the corresponding months. From her curve we find that at no time between October and May do these forms reach the 100 line per 1,000 cc. Evidently the tanks are always a most unreliable source of supply for the estimation of the Dinoflagellate population of the sea.

An analysis of the records shows the commonest species of Peridiniales in the tanks to be *Peridinium orbiculare* and *P. thorianum*, which occur in greater or smaller numbers all the year round. The former appears with greatest frequency from September to January, and the latter in April, May, July and September. *P. pellucidum* is common between September and January, and appears in small quantities during most of the remaining months. It is by these three species chiefly that the September maximum is caused.

Other species which occur fairly regularly are *Glenodinium gymnodinium*, *Spirodinium fissum* and *Amphidinium operculatum.* Further details of the occurrence of the last-named species are given in another paper (page 57). *A. crassum* and *A. rotundatum* also occurred less frequently.

The remainder of the species of *Peridiniales* recorded appeared in and disappeared from the samples spasmodically.

PROTOZOA.

The extreme smallness of some of these forms and the consequent difficulty in identifying them have made it necessary to leave many of them unidentified. Exceptions were made in the case of a few very distinctive or commonly occurring species.

The numbers of Protozoa in the samples almost reach the 500 line per 50 cc. in July, at other times varying between 25 and 125 per 50 cc. These numbers, too, are no doubt abnormal. The appearance of the chief species is recorded in Table I. They belong for the most part to the *Infusoria.* A single *Silicoflagellate, Distephanus speculum* appeared from time to time, and a Flagellate, *Dinobryon sertularia,* occurred very rarely.

ALGAE.

The *Chrorophyceae* were represented most frequently by *Ankistrodesmus falcatus,* which appeared in small numbers at irregular intervals, and rather more frequently in May.

Protococcus sp. occurred rarely, as did a species of filamentous green alga, possibly *Microspora sp.*

The *Cyanophyceae* were represented on two or three occasions by short chains of *Oscillatoria sp.*

METAZOA.

It is evident that almost the whole of the Metazoan portion of the plankton is prevented from entering the tanks, as only odd specimens appear here and there in the records.

Conclusion.—It will be apparent from the foregoing account that an investigation of this kind cannot be carried on satisfactorily by the use of the supply tanks of the Laboratory as a source of the samples, but will have to be done by means of water samples or tow-nettings from the open sea, or preferably by both methods used simultaneously. Large species fail to gain admittance to the tanks, Dinoflagellates are able to multiply too rapidly in the tanks throughout the year, and Diatoms evidently succeed in reproducing too copiously during the early part of the year to give a fair idea of the numbers present outside; but the results give a fairly satisfactory idea of the relative quantities of the species which get into the tanks, as the curves correspond in general shape to those of other investigators. The numbers they represent are too high, however, although such a condition is very desirable for the purposes for which the tank water is used ordinarily.

The method used could no doubt be adapted satisfactorily for determining the depths at which various species of diatoms occur normally when undisturbed by storms, and far enough from the shore to be unaffected by breakers.

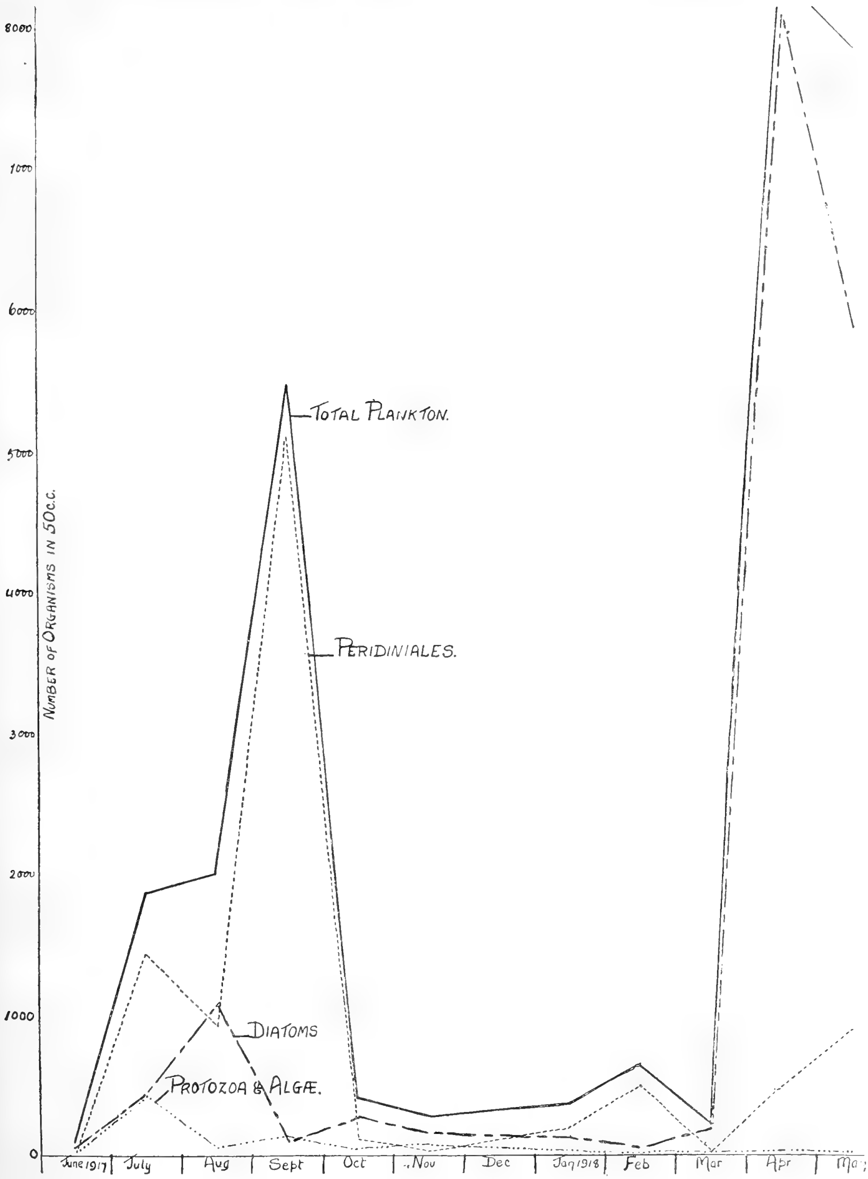


FIGURE 1.

Plankton of Laboratory Tanks. 1917-18.

OCCURRENCE OF *AMPHIDINIUM OPERCULATUM* AT CULLERCOATS.

By OLGA M. JORGENSEN.

Previous to the autumn of 1917 this form was recorded from Cullercoats Bay on only two occasions. The first time it was noted was on May 25th, 1913, when Mr. Storrow * observed small patches of sand coloured by *Amphidinium operculatum* at the north side of the bay. It remained for several days. It was not noted again until the next year when Mr. T. Whitehead † gave a short account of his observations. *A. operculatum* occurred on the foreshore in much larger numbers than last year in two patches N.E. and E. of the Laboratory, and a few feet below high water mark. These patches proved to be an almost pure culture of the species, and consisted chiefly of encysted forms. These patches persisted until the end of September. (When they were first observed is not stated.)

Although I had noted the occurrence of *Amphidinium* in the plankton samples which I examined from time to time, my attention was not particularly attracted to it until September, 1917, when a sample was brought into the Laboratory from the north end of the bay, where it occurred in patches on the wet sand.

From this time the characteristic brown patches were looked for at frequent intervals, but not until November 29th did they appear again, when wet stretches of sand below the Laboratory were covered with faint brown markings. On the following day a tour of the foreshore was made from the north side of the Laboratory to the south end of the bay, when immense quantities of *Amphidinium* were found to be present throughout the tidal zone, wherever water remained on the surface of the sand. A number of sandy pools among the rocks at the high tide mark showed still larger quantities, lying in deep brown patches on the sand. There did not appear to be any in the water. The examination of a sample showed that these forms were very active.

* "Report of the Dove Marine Laboratory, Cullercoats," 1913.
† "Report of the Dove Marine Laboratory, Cullercoats," 1914.

The drier portions of the beach were free from the brown patches, but from one of these a scraping of sand was taken about $1\frac{1}{2}$ inches deep, brought into the Laboratory and covered with filtered sea water. Next morning the surface of the sand was covered with *Amphidinium*.

During the same day, December 1st, a thorough examination of the beach was made again. The sand in the pools was now more thickly covered with the brown films, which were becoming buoyed up in the water and leaving the sand altogether in many cases. The patches were still as prevalent on the beach from end to end of Cullercoats Bay, but there was no sign of the *Amphidinium* on the Tynemouth sands or beyond the northern breakwater.

These and further observations continued up to the time of writing (May, 1918) are not in accord with Whitehead's explanation that the *Amphidinia* sink into the sand when covered with water—in fact, the reverse is the case, for whenever water was present on the surface the brown patches occurred, while they were entirely absent from the drier regions. That the *Amphidinia* sink into the sand when it becomes dry is shown from the result of moistening the scrapings of drier sand.

On December 2nd, the *Amphidinium* had diminished somewhat in quantity, and on the 3rd had vanished entirely. The total disappearance may have been due to some extent to a heavy gale which occurred during the night.

From December, 1917, until May, 1918, the records of the occurrence of *A. operculatum* in Cullercoats Bay are as follows :—

Dec. 1st.—Plentiful on wet sand ; thick film in pools.
,, 2nd.—Decreased in quantity.
,, 3rd.—Disappeared.
,, 6th.—Present in small quantities.
,, 8th.—Disappeared.
,, 13th.—Plentiful on sands and in pools (spring tides).
,, 14th.—More plentiful.
,, 15th.—Heavy films in pools ; disappeared from sands, present in scrapings.
Jan. 5th.—None visible.
,, 21st.—None visible
,, 23rd.—None visible. } Very severe weather; entirely absent from scrapings and water samples.
Feb. 9th.—None visible.
,, 14th.—None visible ; very scarce in samples.
,, 20th.—None visible ; rather more plentiful in samples.
,, 21st.—None visible ; rather more plentiful in samples.
,, 25th —None visible ; none from examination of samples ; two individuals obtained by centrifuging 8 ccs. of water.
,, 26th.—None visible ; very few in sample.
,, 28th.—None visible ; very few in sample.

Mar. 2nd.—None visible ; very few in sample.
,, 20th.—None visible ; very few in sample.
,, 23rd.—Faint traces in pools.
,, 24th.—Patches smaller and fewer but deeper in colour.
,, 25th.—Only two faint patches in pools.
,, 26th.—None visible ; fairly plentiful in sample.
,, 27th.—A few small patches.
,, 30th.—None visible ; fairly plentiful in sample.
April 3rd.—None visible ; fairly plentiful in sample.
,, 27th.—Patches very few and faint.
May 2nd.—None visible ; in fair numbers in samples.

From the above records it appears that during the last six months at least, *Amphidinium* has been present on the foreshore at Cullercoats continuously, its entire absence being noted on January 21st and 23rd only, although it has appeared in sufficient quantities to make it conspicuous on only four occasions. Further observations will probably show results similar to those made at Port Erin. Professor Herdman, to whom I wrote on the subject, says, " *Amphidinium* has appeared off and on in abundance during the last ten years, and is scarcely (if ever) altogether absent. . . . . We have now stopped recording it at Port Erin as it seems to be permanently established on the beach."

Though we are not yet in a position to make definite statements as to the causes of the apparently erratic appearance and disappearance of *A. operculatum* here, it may be of interest to note that on the four occasions on which it is recorded as being visible to the naked eye there have been spring tides ; this is exactly the reverse of Professor Herdman's observations * in 1912, when he found that *Amphidinium* was most plentiful at the neaps. Mr. Storrow, too, in noting its occurrence in 1913 states that it "gradually disappeared with the advent of the spring tides."

I have not observed any alternation of *Amphidinium* and Diatoms here (*see* *), but in one case where a sample of sand and water was kept in the Laboratory for some three weeks, the former, which was visible as a film in the water, sank down after a time and the *Amphidinium* was found to have been replaced almost entirely by diatoms. It was present, however, at the edge of the jar about ¼ inch below the surface of the sand.

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* "26th Annual Report of the Liverpool Marine Biological Committee," 1912.

NOTE ON THE LARVAE OF *GRANTIA COMPRESSA*.

By OLGA M. JORGENSEN.

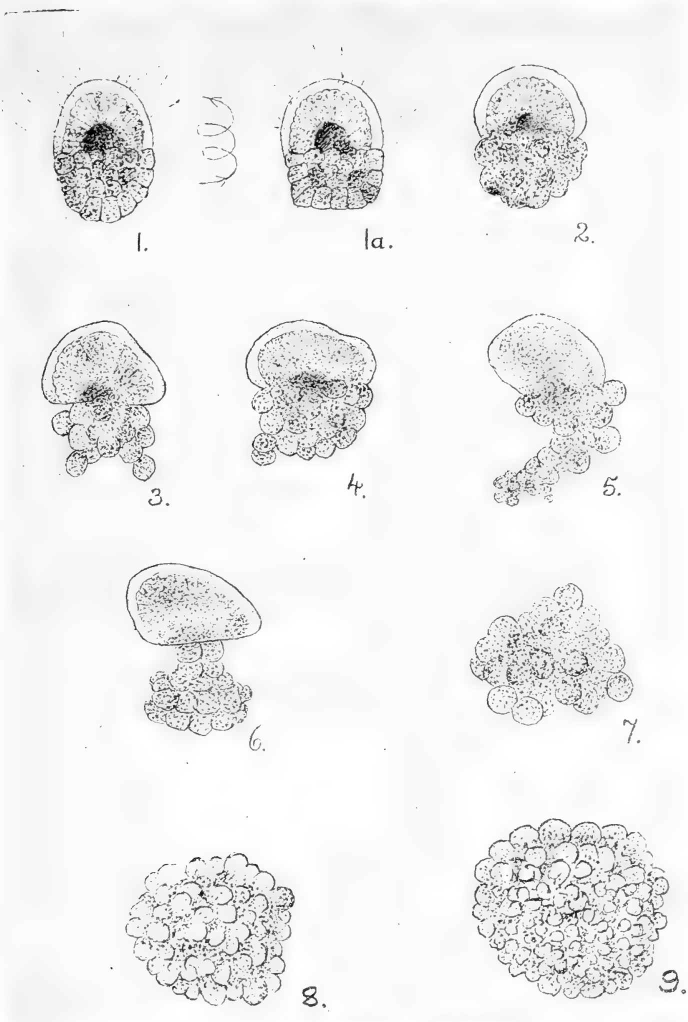
At the beginning of September, 1917, specimens of *Grantia compressa* were obtained containing embryos ready for hatching. The free swimming stages were secured from these both naturally and by the use of the centrifuge, and the following observations made.

On September 3rd, a few of the sponges were attached to a wire fixed in the mouth of the centrifuge tube, which was then filled with filtered sea-water, and centrifuged for ten minutes. A number of actively swimming amphiblastulae were thus collected. They appeared as shown in fig. 1. Next day (nineteen hours later), some of these were still active, but a greater number had ceased to swim about, and the larger granular cells had begun to multiply. A few appeared to be developing normally (fig. 2), but the majority had evidently been affected by the centrifuging and were growing irregularly. These took various forms, some of which are indicated in figs. 3-6. Ten hours later all had ceased to be active.

On September 5th, all the larvae were dead except two which had settled down—the granular cells having overgrown the columnar ones. (Fig. 7.) Two days later they appeared as in fig. 8. They were apparently unchanged next day when they were probably dead, as on September 10th they had disappeared entirely.

When the first batch of material was centrifuged, a number of other specimens were placed in filtered sea-water and left overnight, when naturally hatched larvae were obtained.

Many of these were identical in form with those hatched previously (fig. 1) ,while others showed a decided flattening of the posterior pole (fig. 1A). These larvae were more active than those got by centrifuging—showing a quicker forward movement,



GRANTIA COMPRESSA.

FIGS. 1-1A.—Side view of newly hatched amphiblastula.
FIG. 2.—Same, slightly older. Posterior granular cells beginning to overgrow columnar cells.
FIGS. 3-6.—Side view of abnormal amphiblastulae, showing irregular growth of granular cells after centrifuging.
FIG. 7.—Fixed larva seen from above.
FIGS. 8-9.—Same a day older. Large granular cells dividing to form epithelium.

together with a rapid rotation. They developed quickly into the form shown in fig. 2, but still remained active.

After twenty-four hours some were still moving slowly, whilst a few appeared ready to become fixed. Two had not changed in form. On September 8th a small number appeared to have settled down as fixed forms, but on the 10th all were dead.

Further batches of material were kept and examined from time to time, from which it would appear that the larvae remain active for about twenty-four hours, after which a further two days gives a complete change from the amphiblastula form to that in which the overgrowth of the granular cells is complete and fixation is taking place (figs. 8 and 9).

Some of those in the last-mentioned stage appeared nearly twice as large in diameter (viewed from above) as the newly hatched ones.

The freshly hatched larvae swim at the surface of the water except when disturbed, when they seek the lower layers for a time, but as proliferation of the granular cells increases the larvae sink to the bottom, while still retaining their motile character for a short time.

In one of the earliest samples an embryo was found to have hatched prematurely, being still in the typical pseudogastrula stage. It had not been subjected to centrifuging.

The latest batches examined (September 10th) indicated that the period of hatching was drawing to a close, as in one case eight sponges were centrifuged, and gave only about half-a-dozen larvae.

An attempt was made to rear the larvae, and to obtain the fixed stage by keeping them in vessels coated internally with celloidin, but without success. Probably the vessels were too small and shallow, and the water too still to be favourable to their growth. The amphiblastulae remained active in the vessels for twenty-four hours, and it is not likely that this period would be either much longer or shorter under natural conditions, as it will be regulated more by the amount of reserve food material stored within the creature than by small differences in the external conditions—so that this gives the young sponge time to drift a considerable distance from the parent before it becomes permanently fixed.

NOTES ON THE DEVELOPMENT OF *CARCINUS MAENAS.*

By OLGA M. JORGENSEN.

A number of berried hens of the common shore crab were collected from time to time between November and April, and kept in the Laboratory tanks, and the eggs examined at intervals. Early in December, some recently spawned eggs were examined. They were orange coloured throughout, and the cells showed as yet no differentiation. On January 30th, the same batch of eggs showed the large black eyes of the embryo to have developed sufficiently to be seen with the naked eye. An examination of the egg at this stage showed the orange coloured portion to occupy only two-thirds to three-quarters of the sphere. The disposition of the embryo within the egg can be seen clearly at this stage, as the chromatophores characteristic of the Zoeae have been laid down already. Those of the abdomen form a chain running across the middle line of the thoracic region, showing the "tail" to be curled round the body. Unfortunately, it is impossible to give any further account of this batch of eggs, as the crab escaped from the tank.

Another crab examined on April 26th had eggs apparently almost ready to hatch. It was isolated in a small glass tank, through which compressed air was bubbled, and on May 1st a number of larvae were found. These were carried round and round in the current induced by the compressed air, and when removed into a Petri dish some were found to propel themselves fairly actively, whilst others lay on their side, the only movement being a spasmodic jerking of the limbs.

Two separate batches of larvae were kept in this way in the hope that some might be reared through all the larval stages, and some definite records of the length of each stage arrived at, but when two moults had taken place the laboratory attendant shut off the compressed air, with the result that the larvae sank to the bottom of the jars, and next day most of them were found to be dead, and some were covered with a thick growth of *Vorti-*

cellae. The experiment was repeated with the same unfortunate result. Attempts were made to feed the larvae by adding cultures of diatoms and *Amphidinium* to the water. At the time of writing the experiment has been set going a third time.

The three stages obtained—the Protozoea, and 1st and second Zoeae of Williamson *—are represented in figs. 1 to 3 of Fig. II. (page 20), and the time taken between the moults when the larvae were in these stages is given below for the first two batches of material.

FIRST BATCH.

May 1st (afternoon ...	... Protozoea found, beginning to hatch.
May 2nd (morning) ...	... A number of protozoeae isolated, only one had moulted in the afternoon.
May 3rd (afternoon) ...	... Some protozoeae still present, many moulted, and now in first zoea stage.
May 5th (morning) ...	... About equal numbers of first and second zoeae present, no protozoeae found.

SECOND BATCH.

May 5th (morning) ...	... Protozoeae isolated.
May 6th (morning) ...	... A number of protozoeae present. First zoea stage chiefly, with a few second zoeae.
May 7th (morning) ...	... Only one living protozoea found. First and second zoea stages in about equal numbers.
May 8th (morning) ...	... Some first zoeae still present, chiefly second zoeae. No protozoeae found.
May 9th (morning) ...	... Only second zoeae found.

This makes the length of the first larval stage (protozoea) between twenty and thirty hours, and in one case as long as forty-four hours approximately. The second stage or first Zoea appears to last from forty-eight hours to seventy-two hours (a few longer than this.)

These observations are strikingly different from Williamson's. He states that the protozoea stage is of very short duration, and that on leaving the egg-capsule the larva casts *immediately*. He continues, "I have not noticed the Protozoea stage in cases where the larvae have been hatched out in a tank, but it may be got by washing the egg-mass of a female during the time the young are hatching."

I think that very possibly Williamson's statement as to the very short duration of this stage may be due to the fact that it

* "21st Ann Rep of Fish. Bd. for Scotland," p. 136.

is much less active than the following stage, and that unless the vessel containing the larvae is arranged so that there is a continual current sufficient to keep them suspended they will sink to the bottom of the tank, and most probably be lost in any sand or mud there, though, no doubt, there is a good deal of variation in the length of time during which this stage may persist.

As regards the length of the first Zoea stage our observations at Cullercoats are again divergent from Williamson's, but in the opposite direction—that is to say, that while we find a longer protozoea stage, the period during which our larvae remained as first Zoeae is considerably shorter than his, viz., forty-eight hours to seventy-two hours here, whilst he states that "Zoeae of the first stage which hatched on May 15th moulted into the second Zoea stage between the 24th and 27th, that is, after not more than twelve days." This difference is interesting, as it shows a considerable variation in the duration of the second stage too, and, no doubt, the same is the case in the subsequent stages.

In completing the series of figures of the later larval stages, modifications of Williamson's* and Faxon's† figures have been used, and an attempt made to indicate the relative size. Williamson gives us no actual measurements of the first four stages, but takes the distance between the points of the dorsal and rostral spines as the basis from which to indicate the relative sizes of these stages in his drawings, but this gives no indication of the relation between the size of the last Zoea and the Megalops, the size of which he gives as 2·5 mm. broad and 2·7 mm. long (Brook's‡ figures for this stage are much smaller, viz., ·93 mm. and ·43 mm.)

My own measurements for the first three stages are as follows:—

Protozoea	...	...	1·7 mm. long (average of seven specimens).
First Zoea	...	...	1·95 mm. long (average of seven specimens).
Second Zoea	...	...	2·1 mm. long (average of seven specimens).

This shows an increase in size smaller than that suggested by Williamson's drawings, but supposing the larvae to increase at about the same rate in moulting into the third and fourth Zoea stages, this fits in very well with the size given by him for the Megalops, and it is on these figures that the relative sizes of my drawings are based. The last two figures are taken from those given by Brook.

† "Bull. Mus. Compar. Zoology, Harvard," Vol. VI., p. 159.
‡ "Ann. and Mag. Nat. Hist," S. 5, Vol. 14, p. 202.

FAUNISTIC NOTES.

Nematoscelis megalops, Sars.—On March 23rd, 1918, large numbers of Schizopods were found dead in the sandy pools at the high water mark in Cullercoats Bay, and on the next day they were observed in even greater quantity on the beach between Monkseaton and St. Mary's Island. On March 25th the same forms were still present, but had been carried higher by the tide, and were fewer in numbers than on the previous day.

An examination of the least damaged specimens showed the creature to be *Nematoscelis megalops*, Sars., which is an oceanic form occurring in the North and South Atlantic. It is recorded also from the Indian Ocean, the Mediterranean, off the Labrador and Nova Scotia coasts, and in the Irish Sea.* This appears to be the first record of the occurrence of the species on this coast.

Sars gives the greatest length of *N. megalops* as 26 mm. The largest obtained here was 20 mm. long (fig. 1). This species is characterised by the great length of the first pair of legs, which terminate in a group of bristles. The tail also corresponds exactly to that figured by Sars, as does the arrangement of the gills (figs. 2-4).

Amongst the *N. megalops* collected at Monkseaton a number of *Euthemisto compressa*, Goës, were found.† These were evidently the large form of the species, the average length being 13 mm.

This species occurred much more sparingly on the beach than did the *Nematoscelis*, and was not observed at Cullercoats.

Sars mentions *E. compressa* as occurring off the Norwegian coast, in the Arctic Ocean and Davis Straits, and near the east coast of Greenland. The large variety is found in the North Sea irregularly, but its occurrence as recorded in previous reports is interesting. The small variety appears every season.

O. M. JORGENSEN.

* "Nordisches Plankton," VI., Schizopoden, and "Report of the H.M.S. 'Challenger,'" XII., p. 131.

† Sars' "Crustacea of Norway," I., pp 12-15.

Caligus curtus, Müller.—On October 30th, 1917, two codling, about 18 inches long, were brought into the Laboratory, and from their heads eight specimens of *Caligus* were removed. Seven of these were females, with an average length of 8·1 mm. Five of them bore complete egg-strings, which averaged 9·6 mm. long. The remaining individual measured 11 mm. in length, and was a male. The copepods were quite active after removal from their host, and were observed to bear large numbers of white leech-like creatures round the edge of the carapace, and large bunches of club-shaped objects at the end of the body on the ventral surface.

In colour they were pale yellow and profusely patterned with dark red irregular-shaped chromatophores, especially along the edges of the carapace. None of the specimens showed any blood in the alimentary canal.

It was not without some difficulty that the species was finally decided upon, as the creatures bore considerable resemblance to both *C. rapax* and *C. curtus*. In the general form of the body the females correspond very closely to that of *C. rapax*, while the greater size, and the length and general character of the egg strings are decidedly those of *C. curtus*. Also the male exceeds the female in size—another characteristic of *C. curtus*—but does not do so to such a marked extent as stated by C. B. Wilson.*

Working from Wilson's descriptions and arranging the characters of our specimens in two columns according to their likeness to one or other of his species, we get the following :—

C. curtus.	*C. rapax.*
	Carapace longer than wide.
	Anterior margin only slightly rounded.
	Lunules large, orbicular, widely separate and projecting.
Eyes small, situated forward.	
Setae and spines present on first antennae.	First antennae large, tips nearly equal extreme width of carapace.
Length of female = 8·1 mm. (8-12 mm.)*	
Length of egg strings = 9·6 mm. (14 mm.)*	
Length of male = 11 mm. (13-20 mm.)*	

* The numbers in brackets denote Wilson's measurements for *C. curtus*.

From the table it is evident that these individuals had affinities with both the above-mentioned species, but I have decided to

* Chas. Branch Wilson. "Parasitic Copepods of North America."

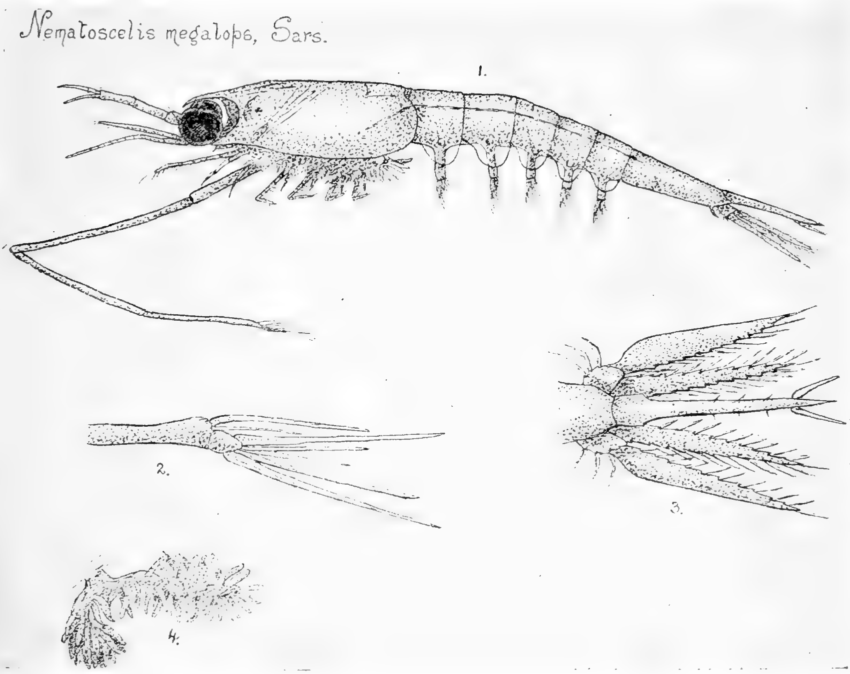


FIGURE 1.

relegate them to the species *curtus* as, other points being fairly equally divided, the most outstanding feature, the relatively large size of the male, marks them out as being nearer to *C. curtus*, as it is the only species of *Caligus* in which this is the case. It would appear, then, that we cannot draw a hard and fast line between the two species as we get such forms as these occupying, an intermediate position, and, considering that the two species occur on a number of hosts, amongst which *Gadus morrhua* is given for each species, it would be only reasonable to suppose that the two species—if they are actually separate species—are sufficiently closely allied to breed one with the other, while it is possible that a further investigation of the matter might show that according to varying conditions of the host, and to differences in its surroundings the parasites approach either the *curtus* form or the *rapax* form, or that they may occupy an intermediate position between these two extremes.

The parasites infesting the carapace of this *Caligus* proved to be the trematode *Udonella pollachii*, Nob,† the largest of which measured 4 mm. when fully extended. They remained attached to the edge of the carapace by the anal sucker, while alternately contracting and extending the body, and twisting from side to side very actively. The eggs of the trematode clustered beneath the body of the *Caligus* are each club-shaped and suspended on a short stalk.

Masses of a *Vorticella* were also found attached to the carapace of the *Caligus*, and in one case a small number had attached themselves to a trematode.

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EXPLANATION OF PLATE.

Fig. 1.—Dorsal surface of female *Caligus* showing markings and egg-strings.
Fig. 2.—Same from ventral surface showing numbers of *Udonella* (Ud.) attached to edge of carapace and to egg-strings, also clusters of eggs of the trematode.
Fig. 3.—Two chromatophores.
Fig. 4.—*Udonella pollachii*.
Fig. 5.—Eggs of same.

† Van Beneden, "Recherches sur les Bdellodes on Hirudinées et les Trématodes Marins."