MINISTRY OF COMMERCE AND INDUSTRY, EGYPT

Fisheries Research Directorate

NOTES AND MEMOIRS No. 14

THE TOW-NET PLANKTON OF LAKE QARUN, EGYPT

DECEMBER 1930 TO DECEMBER 1931

BY

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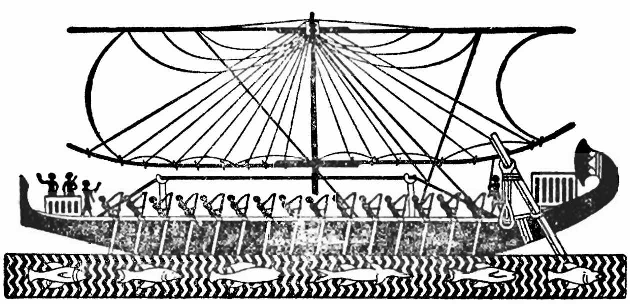

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Introduction

During a visit to Lake Qarun in February 1928, it was found that the whole of the lake investigated carried a very heavy copepod plankton. The copepods found were all of one species—*Diaptomus salinus* Daday—and were sufficiently numerous in places to give the water a reddish appearance.

One of the two reasons of this work was, therefore, the investigation of the zooplankton caught in a coarse silk tow-net from one station throughout an annual period with regard to the specific composition and quantity.

The second reason was to determine the variations in the fat content of the presumed sole species in the catch with special reference to the probable differences in the ratio of Na, K and Mg to Ca. It was thought likely that such differences might occur in view of the fact that the lake draws its water supply from the Nile, and that contributary sources of the Nile water vary in their relation and origin throughout the year.

The significance of the ratio Ca : Mg, Na and K has been emphasised by Clowes (1) as a result of laboratory experiments and theoretical considerations. According to Clowes the protoplasmic membrane of the cell-wall in a living organism is either an emulsion of aqueous droplets in an oily phase, or an emulsion of oily droplets in an aquous phase. An excess of Ca in the medium surrounding the protoplasmic membrane promotes the oily phase, as this element forms insoluble soaps with fatty acids presumed to be present in the protoplasmic membrane. An excess of Mg, Na and K would, on the other hand, promote an aqueous phase, as these elements form soluble soaps.

For the reasons mentioned above, then, it was thought that the conditions in Lake Qarun might afford some confirmation of Clowe's theory from " field " observations. While the results will be shown in the proper place, it may be said here and now that they suggest an inverse relation between Ca and the fat content of the zooplankton and not a direct one.

For the rest, there emerges an interesting sequence of species both in number and in kind, and, perhaps most strikingly, a diminution in size for two of the most important species as the season progresses. These data are dealt with in Part I. In Part II there are figured and shortly described the stages of *Leander squilla elegans* which it has been necessary to differentiate in connection with the treatment of the question of size for stage in Part I.

R.S.W.

E.T.

PART 1

POSITIONS, METHODS AND DETAILS OF HAULS

The observations were made at a position one kilometre east of Geziret Qoullieh, where the water was usually four metres deep. This position is one of five from which quarterly observations of temperature and salinity have been taken by the Coastguards and Fisheries Service for a number of years ; it is shown in the charlt opposite by a cross.

The net used for the plankton collections was the Internationa type described by Ostenfeld and Jespersen (2) ; it was furnished with bolting silk having 58 meshes to the linear inch and fished for ten minutes at the surface as horizontal tow-net. In towing the net a rowing boat was used except on a few occasions on which it was only possible for a motor boat to visit the station. On all occasions the speed of the boat aimed at was such that the upper lip of the net was a few inches submerged, whilst the cone was under just sufficient tension to make it stretch out parallel to the surface of the water.

When the plankton catch was of sufficient bulk two tows were made, one being preserved in weak formalin for making the specific estimate and the other dried in the sun prior to further drying and ether extraction at the laboratory in Alexandria. In December 1930, January 1931 and at times when the catch was light only the first tow was made.

The temperature of the water was taken at most hauls, and except that of May 3, 1931, estimates of Mg, Ca and Na plus K were made for all surface samples taken between March 1, 1931 and October 5, 1931 by Mr. E. Titterington of H.M. Laboratory of Applied Biology. On a few occasions water samples for Chlorine and Oxygen content were collected ; these were estimated in the one case by the Knudsen (3) and in the other by the Winkler (4) methods. The work is in debt to Dr. Abou Samra of the Marine Fisheries Laboratory, Alexandria, for the carrying out of these latter determinations, and also to Dr. Hussein Faouzi for making several of the hauls during the summer. The determination of *Moina salinarum* is due to Mr. R. Gurney and in that of *Leander squilla* valuable assistance was received from Dr. I. Gordon and Mr. Gurney. Finally, in the appendix designed to explain simply the statistical test used in this paper, considerable help was received from Mr. H. J. Buchanan Wollaston of the Fisheries Laboratory, Lowestoft.

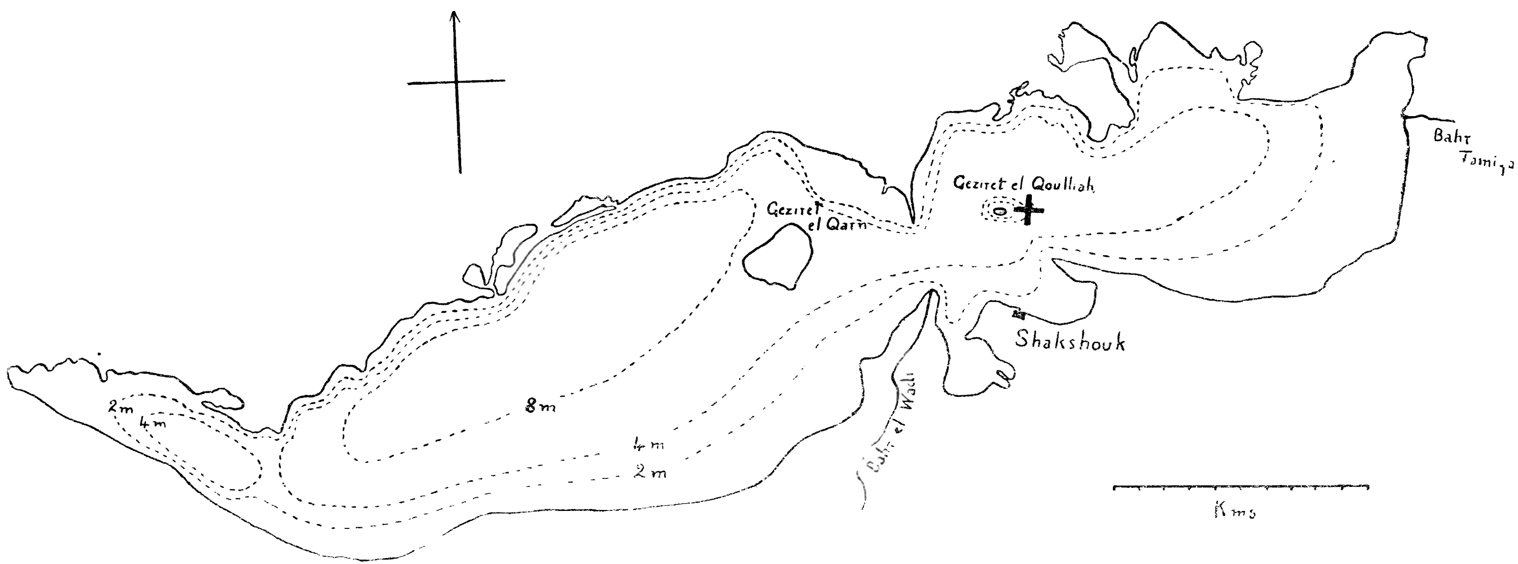

FIGURE 1

Chart showing the Position of the Station in Lake Qarun by a Cross.

Table I

TABLE

Serial Number of Sample	Date	Time (E.T.)	Remarks	Temperature (Cent.)
1	1-12-1930	1000-1010	—	—
2	1- 1-1931	1500-1510	—	—
3	15- 2-1931	0940-0950	Lake calm, masses of algæ on surface...	12.7
4	1- 3-1931	0830-0840	Light N.W. wind	16.5
5	15- 3-1931	0859-0909	Calm	20.5
6	1- 4-1931	1000-1010	Almost glass calm. Patches of foam	18.85
7	16- 4-1931	0915-0925	Fresh wind, lake choppy	18.6
8	3- 5-1931	0914-0924	Fresh wind, rather choppy	19.8
9	15- 5-1931	0915-0925	Very light North wind, lake rippled	21.1
10	28- 5-1931	0924-0934	Light N.E. wind lake rippled ...	23.8
11	15- 6-1931	0921-0931	Wind light to fresh, lake choppy to calm	24.4
12	30- 6-1931	0838-0848	Wind N.W. light, rising	25.0
13	16- 7-1931	1027-1037	Strong N.E. wind...	25.5
14	4- 8-1931	0932-0942	Wind N. light, lake rippled ...	25.75
15	16- 8-1931	0917-0927	Very light N.E. wind	26.5
16	3- 9-1931	1300-1310	Very light N.E. wind	25.5
17	17- 9-1931	0924-0934	Wind light N.N.W., lake rippled	25.6
18	5-10-1931	0904-0914	Wind N.E. light, lake rippled	21.9
19	17-10-1931	0930-0940	Fresh N.E. wind, very rough...	19.9
20	1-11-1931	0922-0932	Fresh N.E. wind, lake rough...	20.8
21	17-11-1931	0940-0950	Fresh N.E. wind, very rough ..	17.6
—	1-11-1934	—	—	—

1

Chlorine (gms. per litre)	Oxygen (ccs. per litre)	K + Na (gms. per litre)	Mg + Ca (gms. per litre)	Volume of Plankton	Colour of Plankton	% Ether Soluble Matter
—	—	—	—	250 ccs.	—	—
—	—	—	—	265 ccs.	—	—
—	—	—	—	146 ccs.	Faint pink	13.3
—	—	14.81	1.30+.53	250 ccs.	Good brick red	33.8
—	—	15.01	1.29+.52	138 ccs.	Faint pink	34·7
—	—	15.07	1.33+.56	62 ccs.	Grey	13.0
—	—	14.93	1.32+.58	495 ccs.	Dark green in life	18.0
—	—	—	—	260 ccs.	Preserved Leander pale pink	11.4
—	6.05	15.11	1.30+.58	40 ccs.	Grey	7.8
11.19	4.47	15.00	1.32+.59	1.2 ccs.	,,	—
11.79	—	15.13	1.29+.61	1.2 ccs.	,,	11.4
12.25	4.62	14.99	1.34+.59	3.0 ccs.	,,	14.3
—	—	15.10	1.39+.60	2.0 ccs.	,,	—
13.45	—	15.12	1.36+.62	1.75 ccs.	,,	—
14.10	3.33	15.10	1.37+.62	7.5 ccs.	,,	—
13.80	3.98	14.98	1.38+.64	2.0 ccs.	,,	—
13.35	3.92	—	1.39+.63	3.4 ccs.	,,	—
13.16	—	—	1.36+.64	.5 ccs.	,,	—
12.59	—	—	—	3.0 ccs.	,,	—
13.25	—	—	—	.6 ccs.	,,	—
12.96	—	—	—	2.0 ccs.	,,	—
—	—	—	1.36+.61	—	—	—

The dates and times of the 21 visits to the station and an abstract of the principal observations are shown in the table on page 6, 7.

The preserved plankton was estimated by taking a Stempel pipette sub-sample from a given volume in a whirling flask such as was first used by Hensen and his collaborators. The sub-sample was counted on a glass slide ruled in two millimetre squares.

Samples of dry plankton were powdered at the Alexandria Laboratory and dried at about 60°C until their weight varied by 4 milligrams or less in 24 hours. This took approximately a week. The dried powders were then placed in narrow weighed glass tubes whose lower and slightly restricted ends were stopped with glass wool. The powder in its glass extraction thimble was then extracted with ether in a soxhlet apparatus for five hours and then dried and weighed under the same conditions as before. The ether soluble matter or "fat" weight was then obtained by difference.

R.S.W.

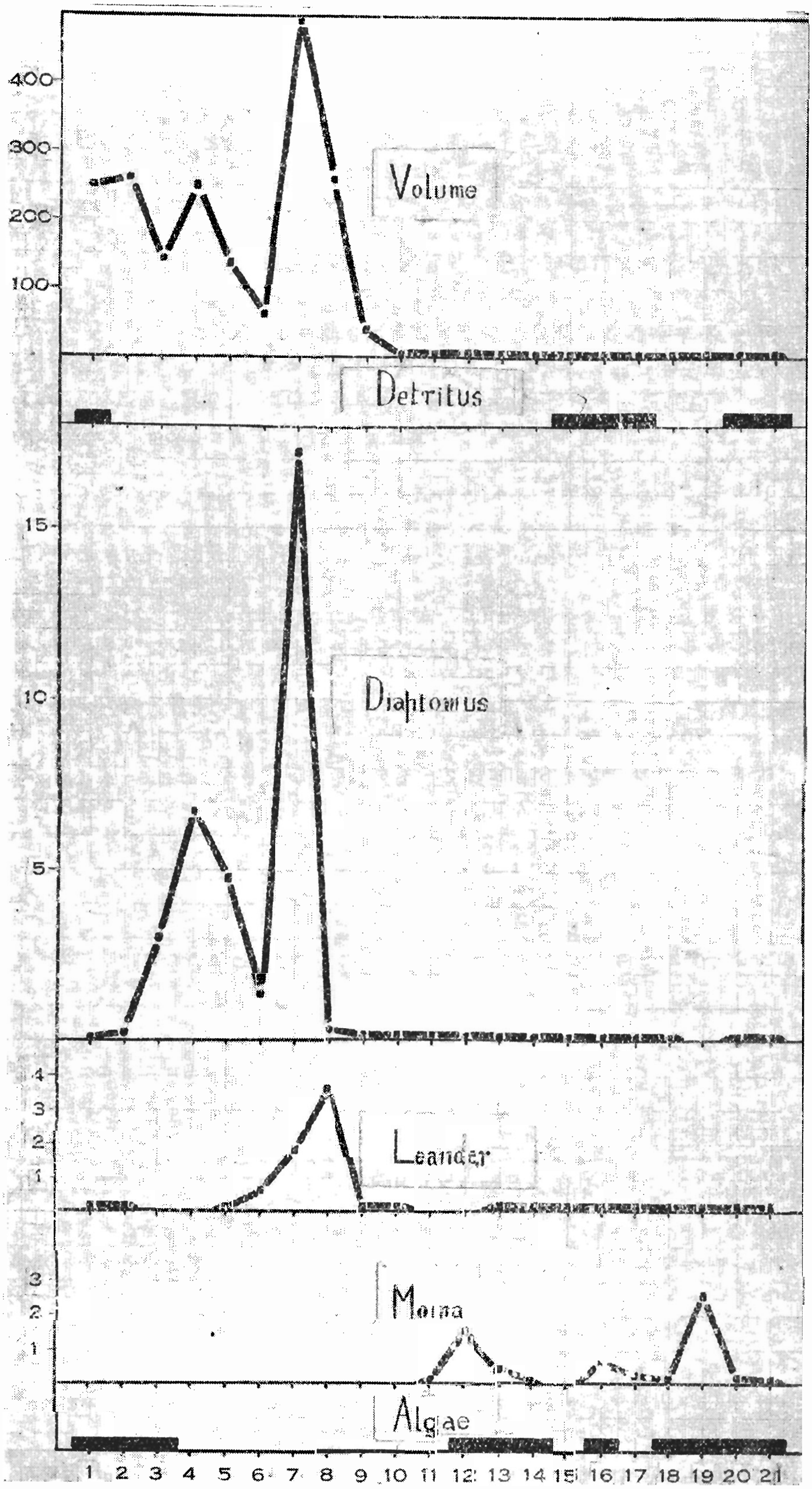

FIGURE 2.—Graph showing the volume in ccs., *Diaptomus salinus* in 100,000s, *Moina salinarum* in 1000s, *Leander squilla* in 10,000. presence of algæ and detritus by a blocked time, from twenty-one ten minute hauls made horizontally with a coarse " International " net at one position on Lake Qarun and taken mainly at fortnightly intervals between December 1930 and December 1931.

A General Consideration of the Data

The charted distributions of volume and species given in Figure 2, and the temperatures in the table on page 6, show that the annual period falls into two different parts best characterised by their temperatures. The first is from December to early May when most of the readings were below 20°C., and the second from mid-May to November where the temperature begins by increasing from 20°C to a maximum of 25.5°C in September, thence falling to the 20°C level in November.

In the first and cold period the settled volume of the plankton was rarely below 150 ccs., while in the second and warm period 10 ccs. was only once exceeded when in May the cold period was just over.

The copepod *Diaptomus salinus* Daday, as had been expected, proved to be the most common organism of the catches, being present at all hauls except that in mid-October. A prawn *Leander squilla* var. *elegans* Rathke also occurred throughout the year, being absent from only four of the estimates, namely, those of mid-February, early-March, mid-June and late-June. Beyond these two species there was only one other zooplankton form that occurred with any consistency. This was *Moina salinarum* Gurney, which was present in most samples from the warm period. The young of the common food fish of the lake, *Tilapia zillii* (Gervn.) were also found on three occasions in the warm period.

A few isolated occurrences which have only been referred to in their group or genus make up the total of the zooplankton. These records are given below and will not be commented on again. The first figure gives the number of the haul and the second the number of individuals estimated to have been present.

Cyclopeidea sp.	17. 15.
Caligus sp.	1. 200.
Nematode sp.	1. 400.
Foraminifera sp.	21. present.
Amœbea testacea sp.	12. present.

The occurrence of the various species of algæ is shown by thy thick line in Figure 2. In Figure 3 are given the mean monthle lake levels for 1927, the mean monthly discharges in million metrs square per second at Assuan also for 1927, and the temperaturel during the year of this investigation. The alterations in lake leve and Nile flood values during each year are sufficiently alike to justify the use of the 1927 figures for the purpose of a general comparison.

METRES BELOW SEA LEVEL

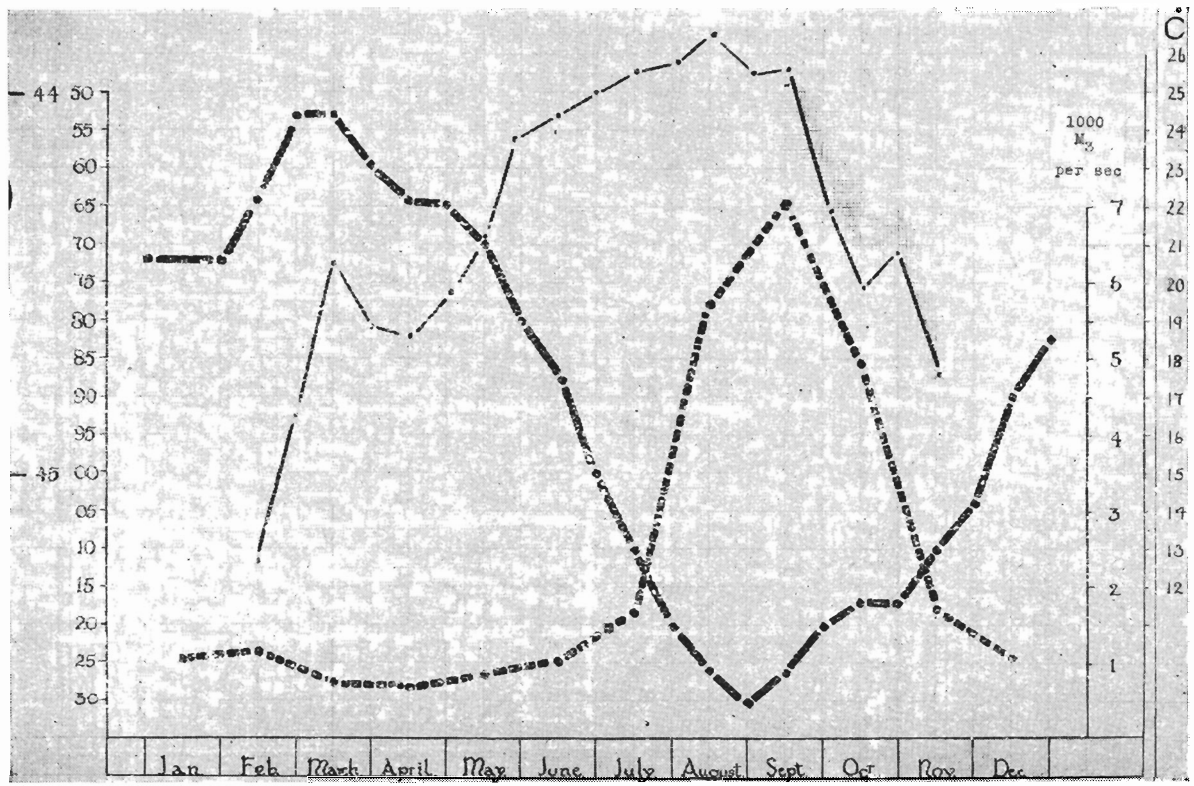

FIGURE 3

Mean monthly lake levels in metres below sea-level and mean monthly discharges in million cubic metres per second at Assuan both for 1927 and shown by a thick continuous and a thick broken line respectively. The values of the surface water temperature at the station discussed ln this paper are joined by a thin contiruous line.

It will be seen that the presence of algæ seems to have followed the Nile flood and to be in no way connected with the lake level, which is high when the flood is low. This is partly on account of the artificial draining it receives from the cotton irrigation, and partly the less evaporation of the winter period. Temperature also does not seem to be connected with the possibility of algæ reproduction in the lake, for algæ were found both at the hottest and the coldest times. Nevertheless, it must be mentioned that the most luxuriant algal growth was found in the coldest month, February, when the surface of the lake was partly covered with a blue-green species, probably *Oscillatoria limosa.*

With the exception of the species mentioned in the last paragraph, no effort has been made to identify the various species of algæ, as it is hoped that they will be dealt with specially elsewhere.

R.S.W.

Mass and Differentiation

This plankton study affords a particular case of what is believed to be a general law. This is that the mass of a community of living things becomes greater as its specific composition becomes simpler. Or conversely, as the specific composition of a community differentiates and becomes more complex the mass becomes less.

In connection with the commercial fisheries of Egypt there has already been occasion to refer to this generalisation (Wimpenny 5) with special reference to Lake Qarun. Here it was shown that the high yield per unit area of this lake was linked with a small number of species in the commercial catch. In the case of the plankton, we find a parallel state of affairs if we examine the seasonal distribution. This may be shortly summarised for our present purpose by saying that we have a cold period in which an abundance of organisms is regularly divided among two species, and a warm period in which a far smaller number is divided up among three regularly occurring species. These relations have been calculated more exactly in the diagrams below, in which the circles are proportional in area to the average number of organisms per haul for the appropriate period. The percentages in which the different species occurred are shown by the segments of the circles in which white represents *Diaptomus*, black *Leander*, and lined *Moina.* The cold period is on the left, and the warm on the right of the figure.

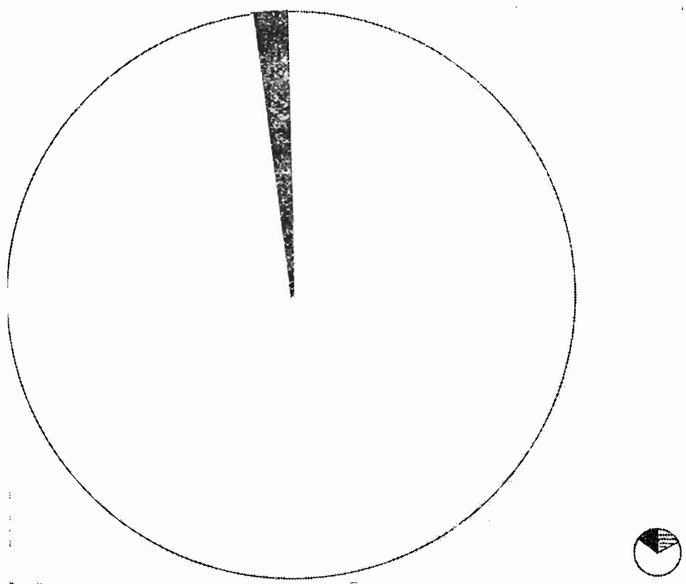

FIGURE 4

Circles, the areas of whose segments are proportional to the numbers of the important species present in the warm and cold periods. The circle on the left represents the cold period. White indicates *Diaptomus*, black *Leander* and lined *Moina*.

Though the diagram is based on numbers, as the individual organisms are shown later to be smaller as the temperature rises, the difference in mass between the cold and warm periods would be even more than is shown in the figure.

The underlying cause of the simple abundant community and its relation to the more complex sparse one does not, in this case, seem to be only that of abundant food favouring the former, as it has been seen that algæ occurred in the hot period. It seems likely that the simple abundant community depends not only upon the presence of food, but upon the ability to assimilate at a rate sufficient to make up for respiration. Furthermore, it is easily conceivable and even likely that the higher temperature of the warm period had interfered with this ability.

R.S.W.

The Relation of Ca to Na, K and Mg and the Fat Content of the Plankton

The results of this work show that the two highest fat values were found at times when the Ca content was lowest and when Ca was relatively least important compared with Na, K and Mg. It is impossible to establish the inverse relation that is suggested without a more extended series of observations and it is hoped that this will be done in the future.

The estimates of Ca, Mg, K and Na were made by the gravimetric method, and the quantity of K present being so extremely small, no attempt was made to separate the K and Na, and in the table below both were expressed as Na. The technique of the fat estimate has already been described.

Below are given the ratios between Mg and Ca and between Mg, Na, K and Ca, the date of sampling being shown on the left. Where available the fat value is also shown.

Date	Mg,K,Na. / Ca.	Mg. / Ca.	Fat
1– 3–1931	13.3	1.90	33.8
15– 3–1931	13.7	1.92	34.7
1– 4–1931	13.1	1.82	13.0
16– 4–1931	12.6	1.75	18.0
15– 5–1931	12.7	1.73	7.8
28– 5–1931	12.1	1.72	—
15– 6–1931	11.8	1.63	11.4
30– 6–1931	12.2	1.73	14.3
16– 7–1931	12.3	1.76	—
4– 8–1931	11.7	1.69	—
16– 8–1931	11.7	1.70	—
3– 9–1931	11.3	1.66	—
17– 9–1931	11.5	1.69	—
5–10–1931	11.3	1.58	—
1–11–1934	11.8	1.70	—

It will be seen that the amount of Ca and its relation to the other elements considered tends to go with the Nile flood (*See* fig. 3). Unfortunately water analyses and fat estimates are not available for January and December, while the water analysis for November was for 1934 and may not be strictly comparable. On the other hand, estimates made in the same general area by Azadian and Hug (6) in December 1928, January 1929, March 1929 and September 1930 support our view of the annual variation of Ca.

There is some evidence that both low temperature and the presence of Ca are factors favouring the formation of fats in living organisms. In Lake Qarun Ca may have a direct effect on the fat-content of the algæ of the lake and an inverse relation might be due to a lag period between the synthesis of fat by algæ and its accumulation by zooplankton. Indeed, it may be that in the synthesis of fat enough Ca is picked up from the water to account for the differences found.

In regard to temperature it can only be said that the two highest fat values in our series were taken in the spring before the temperature had risen to its maximum. Much more work is needed to resolve the speculations raised by these data.

R.S.W.
E.T.

Special Consideration of the Important Species

Diaptomus salinus Daday

This species occurred at all hauls except that of mid-October, and was most numerous on April 16, 1931, when it amounted to 1,720,000. The general abundance is shown in Figure 2 and in Table 1. It is evident that from February up to the maximum in April there were always well over 100,000 individuals in the estimates for each haul. On either side of this period the numbers diminished to tens of thousands in early May and in January, while for the rest of the year there were never 10,000 in any one haul. Clearly the period of abundance was the cold period.

The individuals of the species were separated into males, females, females with spermatophors, ovigerous females, copepodites, nauplii and egg bundles, some of the results being expressed graphically in figure 5, while all the details will be found in Table 2.

TABLE 2.—*Diaptomus salinus*

Haul	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Males	1,000	14,200	142,000	156,000	247,000	23,000	240,000	8,000	1,200	630	1,680	5,100	2,400	450	60	60	15	7	—	30	45
Spermatophor bearing males	—	—	—	4,000	—	—	—	—	—	—	—	150	—	—	—	—	—	—	—	—	—
Total males	1,000	14,200	142,000	160,000	247,000	23,000	240,000	8,000	1,200	630	1,680	5,250	2,400	450	60	60	15	7	—	30	45
Females	400	6,000	48,000	124,000	85,000	46,000	360,000	13,000	1,680	1,110	1,200	2,400	600	120	60	30	—	—	—	—	—
Spermatophor bearing fe males	—	800	—	—	10,000	1,000	—	2,000	660	30	—	—	—	—	—	—	—	—	—	—	—
Ovigerous fe-males	—	200	10,000	10,000	4,000	—	10,000	1,000	240	150	60	450	225	30	—	—	—	—	—	—	—
Total females	400	7,000	58,000	134,000	99,000	47,000	370,000	16,000	2,580	1,290	1,260	2,850	825	150	60	30	—	—	—	—	—
Copepodites ...	400	1,200	108,000	360,000	114,000	76,000	1,110,000	14,000	1,680	270	240	900	225	180	120	—	—	7	—	15	—
Metanauplii ...	400	200	—	4,000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Nauplii	200	200	—	—	2,000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Egg bundles ...	—	1,200	18,000	18,000	18,000	—	40,000	—	60	30	—	300	—	30	—	—	—	—	—	—	—

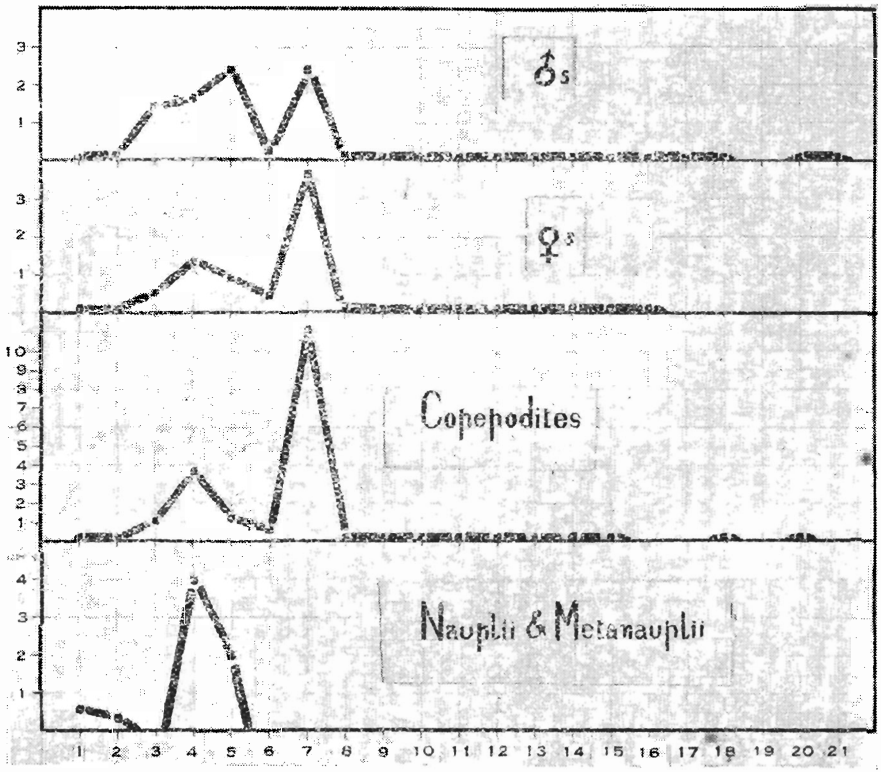

FIGURE 5

Graph showing the chief developmental groups of *Diaptomus* for the 21 hauls. The units of the ordinate represent 100,000s for males, females and copepodites and 1000s for nauplii and metanauplii.

Females, it will be seen, predominated over males only in April and May. Moreover, though they exceeded males for the first time during the year at the haul of maximum abundance of the species, it should be noted that this was at the end of the period of abundance. From mid-September to mid-November females were absent from the estimates.

An inspection of the seasonal distribution of ovigerous females, females with spermatophors, egg bundles and nauplii, suggests that, though breeding went on throughout the period when females were present, yet only two broods of any importance were raised. This is witnessed by the presence of nauplii at two periods, firstly from December 1930 to January 1931, and secondly in the early and middle parts of March 1931. These two occasions were followed by periods of copepodite abundance in early March and mid-April respectively. There followed a fortnight later in the first case and there coincided in the second maxima of adults.

The relations here described imply that the first brood took from two-and-a-half to three-and-a-half months to become adults in mid-March, whilst the second and more important brood became adult in mid-April after one to one-and-a-half months. It was this second brood, it will be noticed, that produced the excess of females.

The respective temperature ranges during these periods and from the data taken at the time would be 12.7—20.5 and 16.5—20.5. The rate of development has, therefore, been rather more than doubled for approximately 4° rise of minimum temperature.

The sizes of about a hundred males and a hundred females from four important times during the annual cycle of the species are shown in Figure 6.

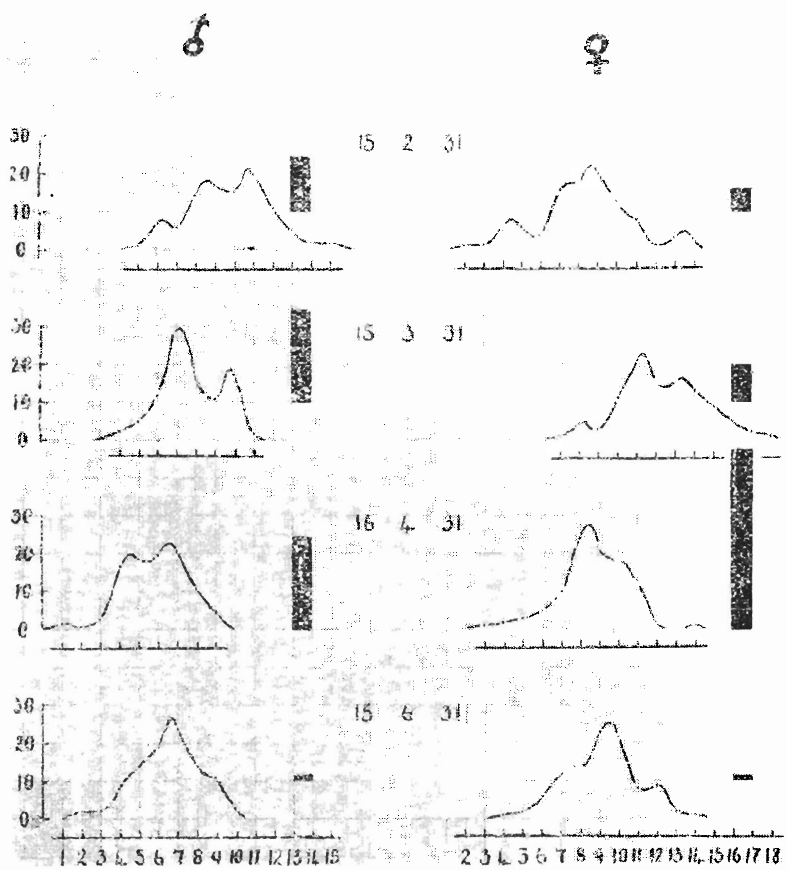

FIGURE 6

Diagram showing the length frequencies of approximately 100 males and 100 females of *Diaptomus salinus* taken on four occasions in 1931. The arbitrary measurement units are explained in the text and the frequency values are joined by lines using the Wollaston-Hodgson interpolation method. The histograms alongside each diagram are proportional in height to the number of individuals estimated to have been present in the sample.

Between mid-February and mid-March, the time of the first maximum, the males decreased in length and showed an apparent bimodality on the latter occasion. The females, on the other hand, increased in length. The next measurements were taken in mid-April, at the time of the second maximum of both males and females. At this time both sexes were reduced to a size at which they remained during the final series of measurements in mid-June.

These size distributions give evidence of a large and small group for both sexes. In order to show that the differences in the measurements of these samples of populations were not likely to be due to differential mortality, the sample of males of mid-March, which appeared to be made up of the last individuals of a big group and the earlier ones of a smaller one, was tested statistically and compared with the rest. The statistical value used was χ^2, the coefficient of discrepancy. Below I give the value of χ^2 calculated from my data and the same value likely to occur in a normal chance population once in twenty times (P = ·05):

Date	Males			Females		
	Calculated χ^2	χ^2 expected at P= ·05	Degrees of freedom	Calculated χ^2	χ^2 expected at P= ·05	Degrees of freedom
15- 2-1931	6.160	15.507	8	12.320	18.307	10
15- 3-1931	16.332	11.070	5	5.385	16.919	9
16- 4-1931	7.813	12.592	6	13.196	16.919	9
15- 6-1931	3.511	12.592	6	5.630	15.507	8

The probability value at which χ^2 might occur by chance once in twenty times has been stated by Fisher (7) to afford a useful upper value of χ^2, and he suggests as a convention to consider values of χ^2 above this as indicating a real discrepancy. Following this convention it will be seen that in my list only the male sample of February 15, 1931 would not be likely to be a sample from a normal curve. It is therefore, the more likely that it represents the mixture of two populations, the one large and the other small, that the rest of the data suggests.

The situation may now be summarised by saying that we begin February with " large group " males and " small group " females. In March, the time of the first adult maximum, the males are

TABLE 3.—THE DISTRIBUTION OF *Leander squilla* VAR. *elegans* AS OVIGEROUS FEMALES, OTHER ADULTS AND JUVENILES OF VARIOUS SIZE GROUPS

Sample	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Ovigerous females	—	—	—	—	1	1	—	8	—	—	—	—	—	—	—	—	—	—	—	—	—
Other adults	210	125	—	—	2	7	10	43	1	—	—	—	—	1	—	—	2	1	1	1	2
Juvenile forms:—																					
2·0 mms.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	15	—	—	—
2·5 ,,	—	—	—	—	—	—	—	—	—	—	—	—	—	30	60	150	—	—	—	—	—
3·0 ,,	—	—	—	—	2	—	—	—	—	—	—	—	2	90	540	270	450	—	300	15	45
3·5 ,,	—	—	—	—	3	800	—	1,480	—	—	—	—	—	—	180	120	—	15	75	60	—
4·0 ,,	—	—	—	—	2	—	—	10,360	—	—	—	—	4	—	420	150	360	—	—	15	30
4·5 ,,	—	—	—	—	4	1600	—	8,880	—	—	—	—	—	—	—	—	—	1	—	—	—
5·0 ,,	—	—	—	—	1	—	—	4,440	210	3	—	—	8	30	240	90	90	1	—	—	—
5·5 ,,	—	—	—	—	—	—	1,584	1,480	—	—	—	—	—	—	—	—	—	—	—	—	—
6·0 ,,	—	—	—	—	4	800	1,584	5,620	300	—	—	—	7	—	—	—	30	2	—	—	15
6·5 ,,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
7·0 ,,	—	—	—	—	—	400	3,166	1,480	300	—	—	—	3	—	—	—	—	1	—	—	—
7·5 ,,	—	—	—	—	—	—	1,584	1,480	—	—	—	—	—	—	—	—	—	—	—	—	—
8·0 ,,	—	—	—	—	2	—	7,916	—	60	—	—	—	3	—	—	—	—	1	—	—	—
8·5 ,,	—	—	—	—	—	—	3,166	—	—	—	—	—	—	—	—	—	—	—	—	—	—
9·0 ,,	—	—	—	—	—	1	—	1,480	—	—	—	—	—	—	—	—	—	—	—	—	—
9·5 ,,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
10·0 ,,	—	—	—	—	—	—	—	—	—	22	—	—	—	—	—	—	—	—	—	—	—
10·5 ,,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
11·0 ,,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
11·5 ,,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
12·0 ,,	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—

"large group" mixed with some "small group" individuals, while the females are pure "large group." By the second adult maximum in mid-March both males and females are "small group" and continue so in mid-June. Though no measurements are available from October, November and December, it seems likely that they would have revealed the male small group again, and we must consider that the large group, probably the result of the drop to a temperature minimum in February, is formed earlier by the males than the females.*

The data of these *Diaptomus* measurements, the calculations of χ^2, and explanations thereof are given in the Appendix on page 37.

Leander squilla VAR. *elegans* RATHKE

As will be seen from the graphed frequencies in Figure 2, this decapod was nearly as extensively distributed throughout the period as the copepod we have just been discussing. Like the copepod, it also had two maxima, but at different times. The first was in May and the second, after a short period in which the species disappeared from the plankton, occurred from mid-August, to mid-September. Gurney (8) states that the *Leander squilla* var *intermedia* De Man of British coastal waters has two broods during the year and it seems as if such is also the case with the variety *elegans* found in Lake Qarun.

The distribution of the species as ovigerous females, other adults and larvæ given in Table 3, shows that, unlike *Diaptomus salinus*, the bulk of the individuals were at most times young stages, and that only 10 ovigerous females were found, one each in mid-March and early April and eight in early May. Other adults to the number of sixty-three occurred at about the same time as the ovigerous females, eight during the autumn period of abundance, and three hundred and thirty-five during January and December when all other stages were absent.

The juvenile stages so plentiful during the spring and autumn have been further differentiated into size classes in the estimates of their numbers given in Table 3.

When this was done it was seen that the autumn individuals formed a class definitely smaller than those of the spring. As it was thought possible that the earlier stages might be swimming in the autumn and not in the spring, an identification of the various

* Measurements made since this paper was written and dealing with material taken in October 1934 bear out these conclusions as both male and female small groups were found. The modes of these groups were actually 5-8 arbitrary units smaller than those of 1931.

stages was made, and a few of them were measured in millimetres. These measurements are set down below :

	15–3–31	16–4–31	16–8–31	17–10–31	1–11–31	17–11–31
Stage I	3·1	2·8	2·7	—	—	—
	—	—	2·8	—	—	—
	—	—	2·7	—	—	—
	—	—	2·7	—	—	—
	—	—	2·6	—	—	—
,, II	—	3·2	2·9	2·7	3·3	—
	—	3·0	—	2·9	3·4	—
	—	3·3	—	—	3·4	—
	—	3·4	—	—	3·1	—
,, III	—	3·2	3·2	3·0	3·3	—
	—	3·7	3·3	—	—	—
	—	3·8	3·2	—	—	—
	—	—	3·2	—	—	—
	—	—	3·1	—	—	—
,, IV	—	4·5	3·6	—	3·2	4·1
	—	—	—	—	3·6	—
	—	—	—	—	3·5	
					3·8	
,, V	—	3·9	4·5	—	—	4·6
	—	4·7	—	—	—	4·5
	—	5·0	—	—	—	4·7
	—	4·2	—	—	—	—
,, VI	—	6·8	5·4	—	—	—
	—	7·6	—	—	—	—
,, VII	—	9·4	—	—	—	—
	—	9·3	—	—	—	—
	—	8·9	—	—	—	—

The observations show that in each stage from which evidence is available there is a reduction of the measured length for the warm autumn period of abundance.

Some Considerations on Refduction in Size

In the two foregoing species, there has been shown to occur a reduction of size, as the season advances. This change has been thought sufficiently interesting and important to merit a short discussion of the question as a whole.

A change in size with latitude has been shown by Bogorov (9 who found that the same stages of *Calanus finmarchicus* were larger in the Barents Sea than in the English Channel where the water is warmer. Bogorov (9) and Orr, Marshall and Nicholls (10) have also produced evidence which suggests that the broods of *Calanus* produced at the colder times of the year, give rise to larger adults. This latter case seems to be a parallel of that shown to obtain in Lake Qarun.

I would suggest an explanation of these circumstances that may be a general one. This is that in the warmer period there is a shortage of algal food and an increased rate of respiration; respiration overtakes assimilation and bulk suffers. It will be noted that during the time of greatest heat and quickened metabolism, the males of *Diaptomus salinus* continue to be caught when the females have disappeared. This is presumably due to the slightly quicker metabolism of the males.

There are two other reasons that might be advanced to explain the decreases in size in Lake Qarun, one of them probably valid. The first is, that as the temperature rises the viscosity will decrease, and so an organism of a given size will tend to sink without additional and directional swimming taking place. Smaller individuals will maintain themselves with the same amount of energy as the ones we began by considering. Against this effect we have to remember that as the temperature rises and the viscosity tends to decrease the water concentrates and becomes denser. This would largely, if not completely, cancel the decreased viscosity, and for this reason is not, I think, a factor of importance. There is, however, a second reason which I think may be more important. Between the beginning and middle of the warm period there is a reduction of dissolved Oxygen of from 6.05 ccs. per mille, or 104 per cent saturation, to 3.33 ccs. per mille or 64.8 per cent saturation. This lowering of the Oxygen tension at a time when vital processes would be accelerated by the rise of temperature would be likely to limit growth and assimilation, or even to exert a lethal effect. Marshall, Nicholls and Orr (11) found that adult *Calanus* were sluggish after one hour at 3.3 ccs. per litre of 0^2 at 13°C, that many died after two hours of an 0^2 of 2.5 ccs. at the same temperature.

Moina salinarum (Gurney)

The numerical distribution of this species throughout the year is shown in Figure 1. It was absent in the cold period and occurred twice during the warm period. The first appearance was from mid-June to early August, having a maximum at the end of June

The second extended from early September to mid-November, with a maximum for the year in mid-October. Below I have separated the species into ovigerous females, other adults and juveniles for the two periods:

FIRST PERIOD

Date of Haul	15-6-31	30-6-31	16-7-31	4-8-31
Ovigerous females... ...	—	1,350	300	—
Other adults	120	150	75	60
Juveniles	—	150	75	—

SECOND PERIOD

Date of Haul	3-9-31	17-9-31	5-10-31	17-10-31	1-11-31	17-11-31
Ovigerous females	150	30	—	1,125	60	15
Other adults ...	390	210	105	1,275	60	15
Juveniles	120	15	15	225	45	—

These figures show that while the ovigerous females never exceeded the other adults or juveniles in the second period, in the first their excess was considerable. The estimates also suggest that the second maximum was the greater.

According to Southern and Gardiner (12) the abundance of Cladocera is correlated with the amount of detritus in the water. The times when flocculent detritus was present in sufficient quantities to be specially noticed in the estimates have been shown by a thick blocked line in Figure 1. These occasions were all during the period of the Nile flood and at the end of each of the two periods of abundance of *Moina*. Nevertheless, I think that detritus must be present throughout the period of the Nile flood and so throughout the time when *Moina* is present.

In its behaviour towards temperature the species somewhat resembled that found by Southern and Gardiner (*loc. cit.* supra p. 63) for *Bosmina coregoni* Baird and *B. longirostris* (O. F. Muller). In the case of the *Bosmina* species, the disappearance takes place as the temperature rises from 14 to 18°C., though it appears to be present at the lower temperatures. On the other hand, *Moina salinarum* in Lake Qarun appeared when the temperature rose to 24.4, disappeared as 26°C. was reached, and reappeared again as the temperature fell below 26°C., and diminished again as the temperature fell further to 17.6° C. The optimum would, therefore, appear to be between 20°C and 25°C.

Tilapia Zillii (Gervn.)

Six young fish of the commonest species of the lake fishery were caught by the net on four occasions. Certain measurements and other particulars relating to them are set out in the following table:

	16-7-31	16-8-31	17-10-31			
Total length	14	7	28	28	19	19
Length from snout to eye	1.3	38	2.5	2.6	1.7	1.6
Length of eye ...	1.3	.84	2.6	2.6	1.8	2.0
Length from eye to origin of pectoral	1.8	1.06	3.8	3.6	2.6	2.8
Length of pectoral	2.2	1.14	7.5	8.0	3.3	4.4
Length from end of pectoral to end of caudal peduncle	5.5	2.73	8.5	6.0	6.1	4.9
Length of caudal rays	3.3	1.52	6.0	7.0	4.5	5.0
Number of dorsal spines	14	14	15	14	15	15
Number of soft rays	12	12	11	12	12	11
Scales	Present	Not seen	Present	Present	Present	Present
Stomach contents	Rmns, of Crustacea	Coscinodiscus sp	Not examined	None recognisable	Not examined	Filamentous algæ and diatoms

From this it seems that scales appear at a very early stage in the young of this *Tilapia* and probably at a length of about 10 millimetres. At 14 millimetres and above it also appears that both crustacean and algal food may be taken, an indication at an early age of the omnivorous habit of the adult.

R.S.W.

PART II

THE STAGES OF *Leander Squilla* VAR. *Elegans* RATHKE

The development of *Leander squilla* has been studied by Gurney (13). Though larval stages III and IV were absent from his material, he considered that *L. squilla* would almost certainly resemble *L. serratus* and *Palaemonetes varians* in which he had shown that there were usually five larval and two post-larval stages. Similarly Mortensen has indicated five stages in the development of *Leander adspersus* (14). On the other hand, Yu Yokoya (15) describes no fewer than ten stages for individuals of *Leander paucidens* De Haan taken from a fresh water pond and reared in an aquarium. Of these stages seven were pelagic. In this connection, however, it is interesting to note that Gurney (*loc. cit.* p. 961 and p. 319) found rearing larvæ under artificial conditions often gave confusing results which " cannot be taken as typical for larvæ under natural conditions."

In the case of *Leander squilla elegans* here figured and shortly to be described, there were seven stages to be recognised in the plankton, of which it seems likely that six correspond to Gurney's five larval stages and the seventh to his first post-larval one.

With the exception of mid-August, when the species was absent the breeding of *Leander squilla elegans* appears to have been going on from March to the end of November, as stage I larvæ were present throughout this time. It has already been pointed out that the interruption in mid-August and the diminution in size suggests two breeding periods. In higher latitudes it is interesting to note that Gurney (*loc. cit.* p. 974) gives the breeding season of *L. squilla* in British waters as May to September. For *L. paucidens* in Japan Yu Yokoya gives the spawning season as March to October.

The Egg

The egg is oval and measures from .572 by .704 to .616 by .792 millimetres. That of *L. paucidens* in fresh water is given by Yu Yokoya as 1.75 by 1.28 millimetres, while Gurney (13), discussing the brackish water shrimp *P. varians* gives from .7 by .8 to .9 by 1.2 millimetres as the comparable egg measurement for this species. The egg of the Egyptian *Leander* must, therefore, be considered as small.

Stage I

The length is 2.8—3.1, and compares with 3.0—3.2 millimetres given for the European *L. squilla* by Gurney. In the report of the Cambridge Expedition to the Suez Canal, Gurney (16) records having hatched out a single brood of *L. squilla elegans*. He figures the dorsal aspect of one of these stage I larvæ and says that except for pigmentation they were similar to the European *L. squilla*.

In addition to its size, the stage I larva from Lake Quaroun differs from the *L. squilla* stage I described by Gurney by the presence of biramous, unsegmented and functionless first and second pereiopods, the straightness of the rostrum and the usual absence of minute hooks on the under extremity of the rostrum.

FIGURE 7. STAGE I.

1. Entire animal from right side x 23 ¾.
2. 1st. antenna x 56½.
3. 2nd. antenna x 56½.
4. Mandible x 56½.
5. 1st. Maxilla x 56½.
6. 2nd. Maxilla x 56½.
7. 1st. Maxilliped x 56½.
8. 2nd. Maxilliped x 56½.
9. 3rd. Maxilliped x 56 ½.
10. 1st. Pereiopod x 56½.
11. 2nd. Pereiopod x 56½.
17. Telson x 56 ½.

Stage II

Length 2.7—3.4 millimetres (*L. paucidens* 5.8, *L. longirostris* 3.5, *P. varians* 3.83—4.25, *L. squilla intermedia* 3.13—3.7).

The rostrum is sometimes hooked and sometimes straight.

Apart from its smaller size this stage differs from Gurney's stage II, in that legs 3–5 are not distinguishable.

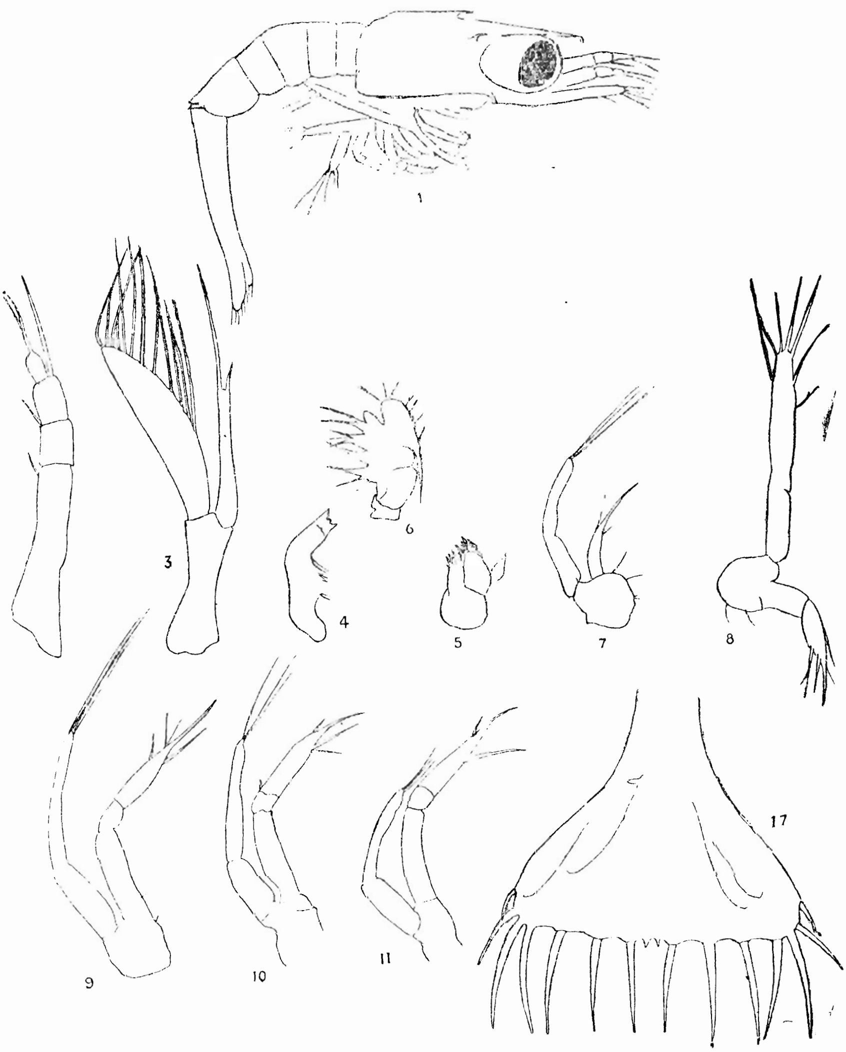

FIGURE 8. STAGE II.

1. Entire animal from right side x $23^3/_4$.
2. 1st Antenna x $56^1/_2$.
3. 2nd Antenna x $56^1/_2$.
4. Mandible x $56^1/_2$.
5. 1st Maxilla x $56^1/_2$.
6. 2nd Maxilla x $56^1/_2$.
7. 1st Maxilliped x $56^1/_2$.
8. 2nd Maxilliped x $56^1/_2$.
9. 3rd Maxilliped x $56^1/_2$.
10. 1st Pereiopod x $56^1/_2$.
11. 2nd Pereiopod x $56^1/_2$.
17. Telson x $56^1/_2$.

Stage III

Length, 3.0—3.8 millimetres. (*L. longirostris* 3.5, *L. paucidens* 6.3, *p. varians* 4.3—4.9).

The rostrum is straight and the carapace bears two median spines. In addition to a supra-orbital spine such as is found in stage II, there is also a small spine present at the antero-lateral edge of the carapace just underneath the eye. The endopodite of the second antenna is three-jointed and three-quarters the length of the scale. The third and fifth pereiopods are present as well developed, but unsegmented limbs, biramous in the first case and uniramous in the second. The fourth pereiopod is a biramous rudiment.

At this stage the larva differs from those of *P. longirostris* and *P. varians* as described by Gurney and from *L. paucidens* as described by Yu Yokoya in the absence of the rudimentary pleopods and in that the uniramous fifth pereiopod is not greatly larger than the third.

As in *P. varians* the pleurobranchs have appeared. The telson is separated from the sixth abdominal somite and the exopodite of the uropod is setose.

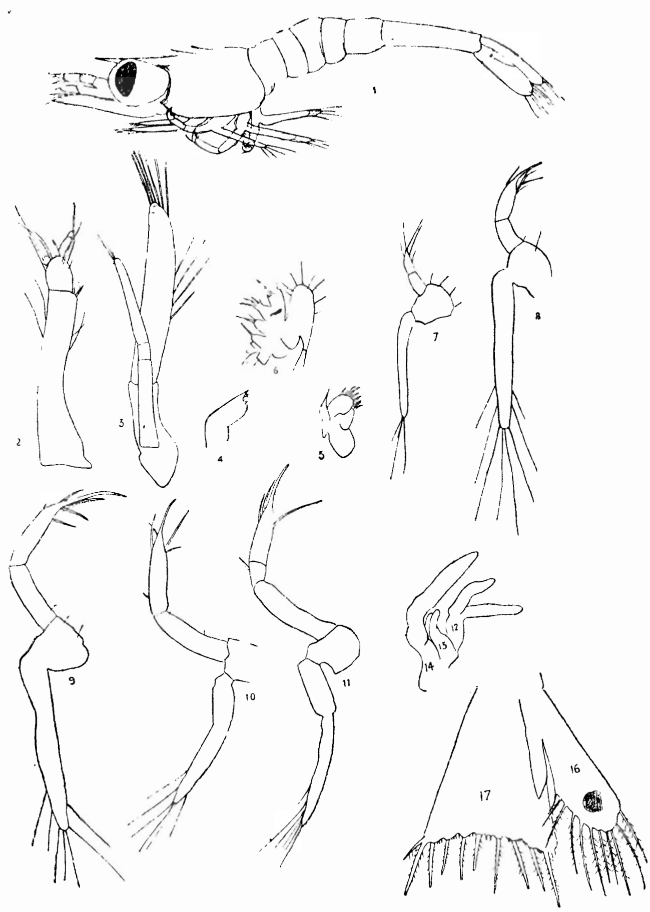

FIGURE 9. STAGE III.

1. Entire animal from left side x 16.
2. 1st Antenna x $34^1/_3$.
3. 2nd Antenna x $34^1/_3$.
4. End of Mandible x $34^1/_3$.
5. 1st Maxilla x $34^1/_3$.
6. 2nd. Maxilla x $34^1/_3$.
7. 1st Maxilliped x $34^1/_3$.
8. 2nd Maxilliped x $34^1/_3$.
9. 3rd Maxilliped x $34^1/_3$.
10. 1st Pereiopod x $34^1/_3$.
11. 2nd Pereiopod x $34^1/_3$.
12. 3rd Pereiopod (Rudimentary) x $34^1/_3$.
13. 4th Pereiopod (Rudimentary) x $34^1/_3$.
14. 5th Pereiopod x $34^1/_3$.
16. Uropod x $34^1/_3$.
17. Telson x $34^1/_3$.

Stage IV

Length. 3·2—4·5 millimetres. (*L. paucidens* 6·3—6·6, *P. varians* 4·5—5·4).

There are three dorsal spines on the rostrum, as in *P. varians* the endopodite of the second antenna is shorter by about three-quarters than the length of the scale. The first and second pereiopods are not chelate and do not show any marked signs of becoming so. They differ in this respect from *P. varians* and *L. paucidens*.

All the pereiopods are present, the fifth being without an exo-podite. The pleopods are absent or present only as small buds. The telson is subquadrate but on the whole wider at its distal than its proxmal end.

FIGURE 10. STAGE IV.

1. Entire animal seen from left x 24½.
2. 1st Antenna x 23 ½.
3. 2nd Antenna x 23 ½.
4. Mandible x 60.
5. 1st Maxilla x 57½.
6. 2nd Maxilla x 60.
7. 1st Maxilliped x 23½.
8. 2nd Maxilliped x 23½.
9. 3rd Maxilliped x 23½.
10. 1st Pereiopod x 23½.
11. 2nd Pereiopod x 23½.
12. 3rd Pereiopod x 23½.
13. 4th Pereiopod x 23½.
14. 5th Pereiopod x 23½.
16. Uropod x 24½.
17. Telson x 60.

Stage V

Length, 3.9—5.0 millimetres. (*P. varians* Va 5.0—6.2 Vb. 6.54—7.2).

The rostrum is straight and shorter than the antennal scales, and the spines of the rostrum and anterior part of the carapace remain as in the last stage. The flagellum of the second antenna is still barely as long as the scale, a character which differentiates it from *P. varians*, *L. longirostris* and *L. paucidens*. The first and second pereipods are now chelate. Pleopods are present as buds or more advanced non-setose limbs. The telson is sub-quadrate but has its greatest width nearer its proximal than its distal end

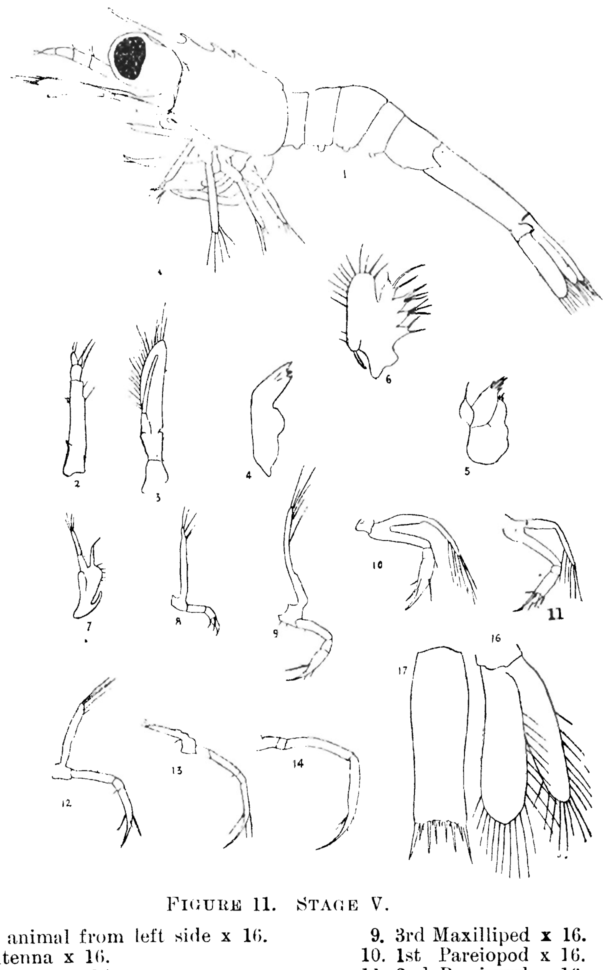

FIGURE 11. STAGE V.

1. Entire animal from left side x 16.
2. 1st Antenna x 16.
3. 2nd Antenna x 16.
4. Mandible x 34 1/3.
5. 1st Maxilla x 34 1/3.
6. 2nd Maxilla x 34 1/3.
7. 1st Maxilliped x 16.
8. 2nd Maxilliped x 16.
9. 3rd Maxilliped x 16.
10. 1st Pareiopod x 16.
11. 2nd Pereiopod x 16.
12. 3rd Pereiopod x 16.
13. 4th Pereiopod x 16.
14. 5th Pereiopod x 16.
16. Uropod x 34 1/3.
17. Telson x 34 1/3.

Stage VI

Length, 5·4—7·6 millimetres (*L. paucidens* 7·4—7·9).

The rostrum and spines remain as in the last stage. The flagellum of the second antenna exceeds the scale in length and has nine or more joints. All the pleopods are now fairly well developed and a few setæ may be present. The width of the distal end of the telson is further diminished, and it is now less than a quarter the length of the whole telson.

The larva at this stage is very similar to that described by Gurney for *P. varians* as Vb.

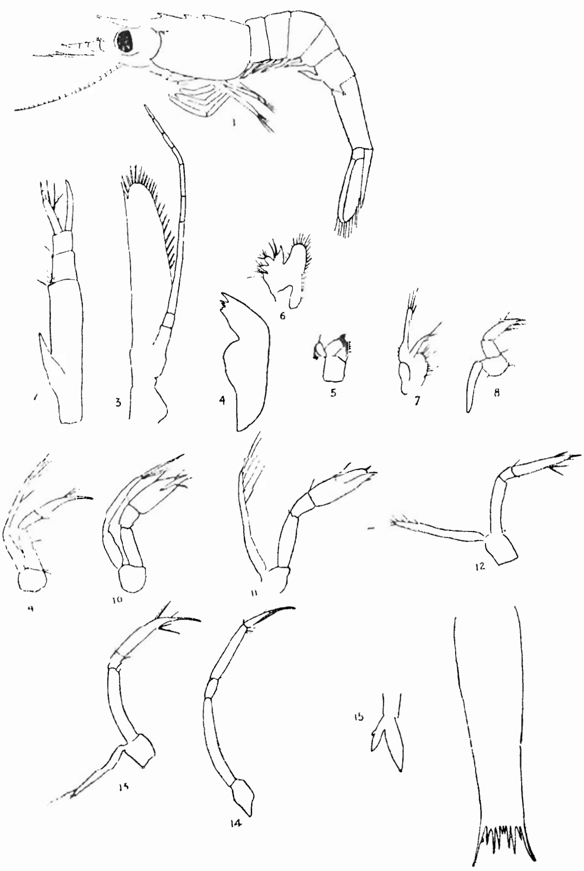

FIGURE 12. STAGE VI.

1. Entire animal seen from the left side x $7^1/_{10}$.
2. 1st Antenna x $11^1/_3$.
3. 2nd Antenna x $11^1/_3$.
4. Mandible x 35.
5. 1st Maxilla x$15^1/_2$.
6. 2nd Maxilla x$15^1/_2$.
7. 1st Maxilliped x $15^1/_2$.
8. 2nd Maxilliped x $15^1/_2$.
9. 3rd Maxilliped x $15^1/_2$.
10. 1st Pereiopod x $15^1/_2$.
11. 2nd Pereiopod x $15^1/_2$.
12. 3rd Pereiopod x$15^1/_6$.
13. 4th Pereiopod x $15^1/_2$.
14. 5th Pereiopod x$15^1/_2$.
15. 5th Pleopod x $15^1/_2$.
17. Telson x 35.

Stage VII

Length, 8.9—9.4 millimetres (*L. squilla intermedia* 8.5—8.62, *L. longirostris* 7.4, *P. varians* 7.07—7.6).

I think there is little doubt that this stage corresponds to Gurney's first post-larval stage as described by him for *P. varians L. serratus and L. squilla.*

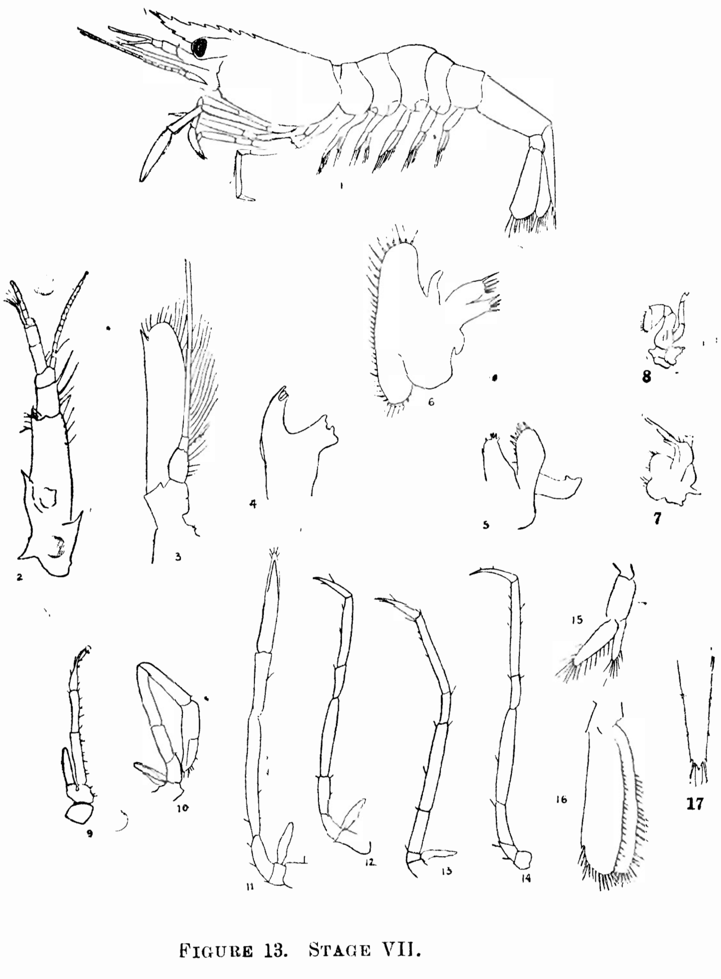

FIGURE 13. STAGE VII.

1. Entire animal from left side x 7[1]/10.
2. 1st Antenna x 16.
3. 2nd Antenna x 16.
4. Mandible x 34[1]/3
5. 1st Maxilla x 34. 1/3.
6. 2nd Maxilla x 34[1]/3.
7. 1st Maxilliped x 16.
8. 2nd Maxilliped x 16.
9. 3rd Maxilliped x 16.
10. 1st Pereiopod x 16.
11. 2nd Pereiopod x 16.
12. 3rd Pereiopod x 16.
13. 4th Pereiopod x 16.
14. 5th Pereiopod x 16.
15. 5th Pleopod x 16.
16. Uropod x 16.
17. Telson x 16.

The spinous armature of the rostrum approaches that of the adult, there being eight above and three below. The supra-orbital spine has disappeared, as has also a backwardly directed spine on the pleuron of the fifth abdominal segment—a feature present at all stages up to this. In addition to the spine present since stage III at the antero-lateral edge of the carapace, another small spine has developed above this and at the base of the antenna. The inner arm of the first antenna is seven-jointed, whilst the outer has three basal and three distal joints of approximately equal length. The mandible is cleft, but without a palp, and the maxillæ have almost attained adult form. Exopodites are present on the first pereiopods, but they are small, without setæ, and functionless. I have not been able to see any pre-anal spine on the sixth abdominal somite at this stage.

R.S.W.

APPENDIX

The Detailed Workings of the Value χ^2 from the *Diaptomus* Length Measurements

The purpose of this appendix is to show the workings and to explain in as simple a way as possible how the value χ^2 is obtained, and how in practice simple biologists with no mathematical flaire, such as the writer, are to set about fitting the curve on which the value χ^2 is based.

χ^2 is a measure of the discrepancy between the frequencies of observations, be they of length or any other measure, that would be expected were they referable to a sample from a chance or normal population, and the frequencies in each measurement class that are actually observed. In making this comparison one is only free to compare the statistical values that vary freely and are not identical for both the observed and calculated series, *i.e.* one may not compare the same things. In the calculations about to be made here, the means (m), the estimate of the variance (s) and the total number of observations (n) are common to both series. This means that in comparing the χ^2 found from eleven measurement-classes of male *Diaptomus* given at the head of the list below, the χ^2 obtained must be compared with that appropriate to 11–3, or 8 classes free to vary. These 8 classes are usually called " 8 degrees of freedom."

The measurements that follow were made with a micrometer eyepiece whose divisions were .036 millimetres. For convenience in the calculations these eyepiece divisions have been summed by twos and translated into a series of arbitrary units running from 1 to 18, the unit " 1 " consisting of all the values falling between 50 and up to, but not including, 52 eyepiece units.

Diaptomus Males

15-2-31	—	—	—	—	1	7	6	14	17	15	20	11	5	2	2	—	—	—
15-3-31	—	—	—	3	5	12	29	18	11	18	2	—	—	—	—	—	—	—
16-4-31	2	1	3	17	19	20	21	11	5	—	—	—	—	—	—	—	—	—
15-6-31	—	2	2	8	14	19	24	14	11	3	—	—	—	—	—	—	—	—

Diaptomus Females

15-2-31	—	1	1	6	6	4	16	18	20	13	8	1	3	3	—	—	—	—
15-3-31	—	—	—	—	—	—	1	4	3	11	21	15	15	13	9	5	2	1
16-4-31	—	—	1	2	3	5	10	24	22	18	13	1	0	1	—	—	—	—
15-6-31	—	—	—	1	2	6	12	14	23	22	8	—	2	1	—	—	—	—
Key Groups ...	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Micrometer Divisions ...	50 & 51	52 & 53	54 & 55	56 & 57	58 & 59	60 & 61	62 & 63	64 & 65	66 & 67	68 & 69	70 & 71	72 & 73	74 & 75	76 & 77	78 & 79	80 & 81	82 & 83	84 & 85

Though in my workings I have used all the measurement groups available, it is the better practice to lump the end frequencies of each set of readings into groups giving not less than 10 observations. My examples show a fit or misfit so definitely that this restriction is of little importance.

The workings may now be explained column by column.

Column 1.—The figures set down here are the intervals of the key groups, the end values being shown as groups above or below the penultimate ones in the grouping given above. For instance, in the sample of males for February 15, 1931, there was one measurement in key group 5. In the workings this is stated as falling in the interval below key group 6.

Column 2.—This gives the number of measurements falling in the intervals of column 1. These are summed at the bottom to give the total number of observations (n).

Column 3.—The mid-point of the key group containing the mean is taken as an arbitrary origin from which the mid-point of each group below is counted as negative difference and each above as a positive one. The mid-point is of course zero. In the calculations the frequencies are considered to be concentrated at the mid-points.

Column 4.—The values in column 3 are multiplied by those in column 2. The sum of these negative and positive results is expressed at the bottom of the column as Sx.

Column 5.—The squares of the values in column 3 art multiplied by the frequencies in column 2. These are summed up at the bottom of the column as Sx2.

Column 6.—This contains the differences of the limits of the intervals from the estimated true mean. Because they are *limits of intervals* they are set down between the values in the previous column, as they refer to the mid-points of the intervals themselves. An instance of how the differences are obtained may be taken from the first set of workings. Here the arbitrary mean group is that from 10 to 11, and the working mean (W.M.) is as is set down below the columns, the mid-point of this group—10.5.

A correction of the working mean (c) to obtain an estimate of the true arithmetic mean (A.M.) is made by dividing Sx by n, giving in this case—.21 or 10.29. The limit 10 will, therefore, be .29 less than the estimate of the arithmetic mean and there is written opposite it " —.29. " The limit 9 will be —1·29 and so on. On the other hand, the limit 11 is plus ·71 more than the mean, the limit 12 plus 1.71, and so on.

Column 7.—At the same level as the figures in the preceding column there are entered a series of values consisting of those of the preceding column divided by the estimate of the variance for the whole set of measurements. This statistic is worked out below the columns according to the formula there shown.

Column 8.—Still at the same level as the figures in column 6 are a series of values taken from Pearson's tables (17) and corresponding to the figures in the previous column. These figures indicate the calculated area at the interval limits on either side of the mean of a normal frequency curve built up with the statistics available and considering the whole area as unity.

Column 9.—Reverting to the level of the earlier columns the calculated areas of successive group intervals as shown in column 8, are subtracted from each other in such a way as to give the area corresponding to the intervals themselves, except for the interval containing the mean, where the limit values on either side are added. The limit values at the ends of the column are subtracted from 5.

Column 10.—The corresponding figures in the foregoing column are each multiplied by the total number of measurements in the sample (n). in the first set of workings (n) was 100. This column gives the expected frequencies.

Column 11.—The " expected frequencies " of the last column are subtracted from the observed frequencies in column 2 without setting down differences of sign.

Column 12.—The figures in the last column are squared and divided by the corresponding entries in column 10. The sum of these values is our χ^2.

R.S.W.

Key group intervals	Frequencies f	Differences from arbitrary mean x	Differences from arbitrary mean times frequencies xf	Differences from arbitrary mean squared times frequencies $x^2 f$	Differences from estimated true mean $x-\bar{x}$	Differences from true mean estimate divided by estimate of variance $\frac{x-\bar{x}}{S}$	Calculated area $(\frac{1}{2}(1-\alpha)-\frac{1}{2})$	Successive differences	Expected frequency	Observed minus expected frequencies	Observed minus expected frequencies squared and divided by expected frequencies	Diaptomus salinus ♂ 15–2 31
6	1	—5	—5	25				.0212296	2.122960	1.12296	.59400	
					—4.29	2.029	4787704					
6— 7	7	—4	—28	112				.0386267	3.86267	3.13733	2.54820	
					—3.29	1.556	4401437					
7— 8	.6	—3	—18	54				.0795505	7.95505	1.95505	.48063	
					—2.29	1.083	3605932					
8— 9	14	—2	—28	56				.1315241	13.15241	.84759	.05462	
					—1.29	.610	2290691					
9—10	17	—1	—17	17				.1745851	17.45851	.45851	.01205	
					— .29	.137	0544840					
10—11	15		—96					.1860470	18.60470	3.60470	.69841	
					.71	.336	1315630					
11—12	20	1	20	20				.1591784	15.91784	4.08216	1.04687	
					1.71	.809	2907414					
12—13	11	2	22	44				.1093354	10.93354	.06646	.00040	
					2.71	1.282	4000768					
13—14	5	3	15	45				.0602916	6.02916	1.02916	.17567	
					3.71	1.755	4603684					

14 -15	2	4	8	32	4.71	2.228	4870592	.0266908	2.66908	.66908	.16364
15	2	5	10	50				.0129408	1.29408	.70592	.38508
	100 (n)		75	455 (Sx²)							6·15957 (χ^2)
			—96								
			—21 (Sx)								

Working mean... ... ... (W.M.) 10·5

Correction ... ... $(\bar{x}) = \left(\frac{Sx}{n}\right)$ — ·21

Estimate of arithmetic mean ... ... (A.M.) 10·29

$$S^2 = \frac{Sx^2 - n\bar{x}^2}{n-1} - .0833 \text{ (Shepherd's correction)}$$

$$S^2 = \frac{455 - 4\cdot41}{99} - \cdot0833$$

$$S^2 = 4\cdot468$$

$$S = 2\cdot114$$

Key group intervals	Frequencies f	Differences from arbitrary mean x	Differences from arbitrary mean times frequencies xf	Differences from arbitrary mean squared times frequencies $x^2 f$	Differences from estimated true mean $x-\bar{x}$	Differences from true mean estimate divided by estimate of variance $\frac{x-\bar{x}}{s}$	Calculated area $(\frac{1}{2}(1-\alpha)-\frac{1}{2})$	Successive differences	Expected frequency	Observed minus expected frequencies	Observed minus expected frequencies squared and divided by expected frequencies	Diaptomus salinus ♂ 15-3-31
5	3	—4	—12	48	—3.22	1.986	4764820	0235180	2.30476	.69524	.20972	
5—6	5	—3	—15	45	— 2.22	1.370	4146565	0618255	6.05890	1.05890	.18506	
6— 7	12	—2	—24	48	—1.22	.753	2742726	1463839	13.75762	1.75762	.22455	
7— 8	29	—1	—29	29	—.22	.128	0508251	2237475	21.92726	7.07275	2.28155	
8— 9	18		—80		.78	.481	1847410	2355661	23.08548	5.08548	1.12028	
9—10	11	1	11	11	1.78	1.698	3638958	1791548	17.55717	6.55717	2.44894	
10—11	18	2	36	72				6929296	9.10716	8.89390	8.68573	

11	2	3	6	18	2.78	1.715	4568254	0431746	4.23111	2.23111	1.17649
	98		53 —80 —27 (Sx)	271 (Sx^2)							16.33212 (χ^2)

Working mean ... . (W.M.) 8.5

Correction... ... ... (x) = $\left(\frac{Sx}{n}\right)$ —.28

Estimate of arithmetic mean ... (A.M.) 8.22

$$S^2 = \frac{Sx^2 - n\bar{x}^2}{n-1} - .0833 \text{ (Shepherds' correction)}$$

$$S^2 = \frac{271 - 7.682}{97} - .0833$$

$$S^2 = 2.632$$

$$S = 1.621$$

Key group intervals	Frequencies f	Differences from arbitrary mean x	Differences from arbitrary mean times frequencies xf	Differences from arbitrary mean squared times frequencies $x^2 f$	Differences from estimated true mean $x-\bar{x}$	Differences from true mean estimate divided by estimate of variance $\frac{x-\bar{x}}{s}$	Calculated area $\frac{1}{2}(1-\alpha)-\frac{1}{2})$	Successive differences	Expected frequency	Observed minus expected frequencies	Observed minus expected frequencies squared and divided by expected frequencies	Diaptomus salinus ♂ 16-4-31
2	2	—5	—10	50	—4.32	2.526	4942310	.0057690	.57113	1.42887	3.57478	
2—3	1	—4	—4	16	—3.32	1.942	4739305	0263065	2.009975	1.06975	.50732	
3—4	3	—3	—9	27	—2.32	1.357	4126071	0613234	6.07102	3.07102	1.55347	
4—5	17	—2	—34	68	—1.32	.772	2799410	1326661	13.13394	3.86606	1.13800	
5—6	19	—1	—19	19	—.32	.187	0741689	2057721	20.37144	1.37144	.09233	
6—7	20		—76		.68	.398	1546837	2288526	22.65641	2.65641	.31146	
7—8	21	1	21	21	1.68	.982	3369481	1822644	18.04418	2.95582	.48419	

8— 9	11	2	22	44	2.68	1.567	4414408	1044927	10.34478	.65522	.04150
9	5	3	15	45				0585592	5.79736	.79736	.10967
	99 (n)		58	290 (Sx^2)							7.81272 (χ^2)
			—76								
			—18 (Sx)								

$$S^2 = \frac{Sx^2 - n\bar{x}^2}{n-1} - .0833 \text{ (Shepherd's correction)}$$

$$S^2 = \frac{290 - 3.28}{98} - .0833$$

Working mean ... ... (W.M.) 6.5

Correction... ... ... $\bar{x} = \left(\frac{Sx}{n}\right) - .18$ $S^2 = 2.924$

Estimate of arithmetic mean ... ... (A.M.) 6.32

$S = 1.713$

Key group intervals	Frequencies f	Differencies from arbitrary mean x	Differences from arbitrary mean times frequencies xf	Differences from arbitrary mean squared times frequencies $x^2 f$	Differences from estimated true mean $x - \bar{x}$	Differences from true mean estimate divided by estimate of variance $\frac{x-\bar{x}}{s}$	Calculated area $(\frac{1}{2}(1-\alpha) - \frac{1}{2})$	Successive differences	Expected frequency	Observed minus expected frequencies	Observed minus expected frequencies squared and divided by expected frequencies	Diaptomus salinus ♂ 15-6-31
3	2	—5	—10	50				0093369	.90568	1.09432	1.32325	
					—4.06	2.352	4906631					
3— 4	2	—4	—8	32				0287790	2.79156	.79156	.22445	
					—3.06	1.773	4618841					
4— 5	8	—3	—24	72				0791259	7.67522	.32479	.01374	
					—2.06	1.194	3827582					
5— 6	14	—2	—28	56				1523683	14.77972	.77973	.04114	
					—1.06	.614	2303899					
6— 7	19	—1	—19	19				2164299	20.99370	1.99370	.18933	
					— .06	.035	0139600					
7— 8	24		—89					2210809	21.44866	2.55134	.30348	
					.94	.545	2071269					
8— 9	14	1	14	14				1623697	15.74986	1.74986	.19442	
					1.94	1.124	3694906					

9—10	11	2	22	44	2.94	1.703	4557142	0862236	8.36369	2.63631	.83099
10	3	3	9	27				0442858	4.29572	1.29572	.39083
	97 (n)		45	314 (Sx^2)							3.31163 (χ^2)
			$\frac{-89}{-44}$ (Sx)								

$$S^2 = \frac{Sx^2 - n\bar{x}^2}{n-1} - .0833 \text{ (Shepherd's correction)}$$

$$S^2 = \frac{314-19.99}{96} - .0833$$

$$S^2 = 2.979$$

$$S = 1.726$$

Working mean ... ... (W.M.) 7.5

Correction ... ... $(\bar{x}) = \left(\frac{Sx}{n}\right)$ —.45

Estimate of arithmetic mean ... (A.M.) 7.06

Key group intervals	Frequencies f	Differences from arbitrary mean x	Differences from arbitrary mean times frequencies xf	Differences from arbitrary mean squared times frequencies $x^2 f$	Differences from estimated true mean $x-\bar{x}$	Differences from true mean estimate divided by estimate of variance $\frac{x-\bar{x}}{S}$	Calculated area $(\frac{1}{2}(1-\alpha)-\frac{1}{2})$	Successive differences	Expected frequency	Observed minus expected frequencies	Observed minus expected frequencies squared and divided by expected frequencies	Diaptomus salinus ♀ 15–2–31
3	1	—7	— 7	49				·0075495	·75495	·24505	.07954	
					—5.80	2·421	4924505					
3— 4	1	—6	—	36				·0150403	1·50403	·50403	·16891	
					—4·80	2·003	4774102					
4— 5	6	—5	—30	150				·0337820	3·37820	2·62180	2·03181	
					—3.80	1.586	4436282					
5— 6	6	—4	—24	96				.0648311	6.48311	.48311	.03600	
					—2.80	1.169	3787971					
6— 7	4	—3	—12	36				.1024244	10.24244	6.24244	3.80457	
					—1.80	.751	2763727					
7— 8	16	—2	—32	64				.1456640	14.56640	1.43360	.14108	
					— .80	.334	1307087					
8— 9	18	—1	—18	18				.1637826	16.37826	1.62174	.16058	
					.20	.083	0330739					
9—10	20		—129					.1619004	16.19004	3.80996	.89659	
					1.20	.501	1949743					
10—11	13	1	13	13				.1256143	12.56143	.43857	.01531	
					2.20	.918	3205886					
11—2	8	2	16	32				.0886342	8.86342	.86342	.08411	
					3.20	1.336	4092228					

12—13	1	3	3	9				.0509746	5.09746	4.09746	3.29364
					4.20	1.753	4601974				
13—14	3	4	12	48				.0247992	2.47992	.52054	.10926
					5.20	2.170	4849966				
14	3	5	15	75				.0150034	1.50034	1.49966	1.49886
	100 (n)		59	626 (Sx^2)							12.32024 (X^2)
			—129								
			— 70 (Sx)								

Working mean ... ...(W.M.) 9.5

Correction ... ... $(\bar{x}) = \left(\frac{Sx}{n}\right)$ —.70

Estimate of arithmetic mean... ...(A.M.) 8.80

$$S^2 = \frac{Sx^2 - n\bar{x}^2}{n-1} - .0.833 \text{ (Shepherd's correction)}$$

$$S^2 = \frac{626-49}{99} - .0833$$

$$S^2 = 5.745$$

$$S = 2.396$$

Key group intervals	Frequencies f	Differences from arbitrary mean x	Differences from arbitrary mean times frequencies xf	Differences from arbitrary mean squared times frequencies $x^2 f$	Differences from estimated true mean $x-\bar{x}$	Differences from true mean estimate divided by estimate of variance $\frac{x-\bar{x}}{s}$	Calculated area $(\frac{1}{2}(1-\alpha)-\frac{1}{2})$	Successive differences	Expected frequency	Observed minus expected frequencies	Observed minus expected frequencies squared and divided by expected frequencies	Diaptomus salinus ♀ 15-3-31
8	1	—6	—6	36				.0142262	1.42262	.42262	.12555	
					—4.81	2.191	4857738					
8— 9	4	—5	—20	100				.0271461	2.71461	1.28539	.60861	
					—3.81	1.735	4586277					
9—10	3	—4	—12	48				.0589003	5.89003	2.89003	1.41854	
					—2.81	1.280	3997274					
10—11	11	—3	—33	99				.1044162	10.44162	.55838	.02909	
					—1.81	.825	2953112					
11—12	21	—2	—42	84				.1513757	15.13757	5.86243	2.27036	
					— .81	.369	1439355					
12—13	15	—1	—15	15				.1760554	17.60554	2.60554	.38561	
					.19	.086	0321199					
13—14	15		—128					.1739694	17.39694	2.39694	.33020	
					1.19	.542	2060893					
14—15	13	1	13	13				.1347690	13.47690	.47690	.01836	
					2.19	.998	3408583					
15—16	9	2	18	36				.0897277	8.97277	.02723	.00007	
					3.19	1.453	4305860					
16—17	5	3	15	45				.0412824	4.12824	.87176	.18409	
					4.19	1.909	4718684					

17—18	2	4	8	32	5.19	2.364	4909599	.0190915	1.90915	.09085	.00432
18	1	5	5	25				.0090401	.90401	.09599	.01008
	100 (n)		59	533 (Sx^2)							5.38486 (X^2)

59
—128
— 69 (Sx)

Working mean ... ... (W.M.) 13. 5

Correction ... ... $(\bar{x}) = \left(\frac{Sx}{n}\right)$ —.69

Estimate of arithmetic mean ... (A.M.) 12.81

$$S^2 = \frac{Sx^2 - n\bar{x}^2}{n-1} - .0833 \text{ (Shepherds' correction)}$$

$$S^2 = \frac{533 - 47.610}{99}$$

$$S^2 = 4.8206$$

$$S = 2.195$$

Key group intervals	Frequencies f	Differences from arbitrary mean x	Differencies from arbitrary mean times frequencies xf	Differences from arbitrary mean squared times frequencies x^2f	Differences from estimated true mean $x-\bar{x}$	Differences from true mean estimate divided by estimate of variance $\frac{x-\bar{x}}{s}$	Calculated area $(\frac{1}{2}(1-\alpha)-\frac{1}{2})$	Successive differences	Expected frequency	Observed minus expected frequencies	Observed minus expected frequencies squared and divided by expected frequencies	Diaptomus salinus ♀ 16–4–31
					—5.15	2.836	4977156					
4	1	—6	—6	36				.0022844	.22844	.77156	2.60956	
					—4.15	2.285	4888428					
4— 5	2	—5	—10	50				.0088728	.88728	1.11272	1.39544	
					—3.15	1.735	4586277					
5— 6	3	—4	—12	48				.0302151	3.02151	.02151	.00153	
					—2.15	1.184	3807967					
6— 7	5	—3	—15	45				.0778370	7.78370	2.78370	.99554	
					—1.15	.633	2356210					
7— 8	10	—2	—20	40				.1451697	14.51697	4.51697	1.40546	
					—.15	.083	0330739					
8— 9	24	—1	—24	24				.2025471	20.25471	3.74529	.69254	
9—10	22		—87					.2131803	21.31803	.68197	.02182	
					.85	.468	1801064					
10—11	18	1	18	18				.1657911	16.57911	1.42089	.12178	
					1.85	1.019	3458975					
11—12	13	2	52	52				.0957778	9.57778	3.42222	1.23323	
					2.85	1.569	4416753					
12—13	1	3	9	9				.0413217	4.13217	3.13217	2.37413	
					3.85	2.120	4829970					

13—14	0	4	0	0	4.85	2.671	4962185	.0132215	1.32215	1.32215	1.32215
14	1	5	5	25				.0037815	.37815	.62185	1.02260
	100 (n)		52	347 (Sx^2)							13.19578 (X^2)
			—87								
			—35 (Sx)								

Working mean ... ...(W.M.) 9·5

Correction... ... ...$(\bar{x}) = \left(\frac{Sx}{n}\right)$ —·35

Estimate of arithmetic mean ... ...(A.M.) 9·15

$$S^2 = \frac{Sx^2 - n\bar{x}^2}{n-1} - .0833 \text{ (Shepherd's correction)}$$

$$S^2 = \frac{347 - 12{\cdot}25}{99} - .0833$$

$$S^2 = 3.298$$

$$S = 1.816$$

Key group intervals	Frequencies f	Differences from arbitrary mean x	Differences from arbitrary mean times frequencies xf	Differences from arbitrary mean squared times frequencies $x^2 f$	Differences from estimated true mean $x - \bar{x}$	Differences from true mean estimate divided by estimate of variance $\frac{x-\bar{x}}{s}$	Calculated area $(\frac{1}{2}(1-\alpha) - \frac{1}{2})$	Successive differences	Expected frequency	Observed minus expected frequencies	Observed minus expected frequencies squared and divided by expected frequencies	Diaptomus salinus♀ 15–6–31
5	1	—5	—5	25				.0100100	1.00100	.00100	.00010	
					—4.41	2.326	4899900					
5— 6	2	—4	—8	32				.0260001	2.60001	.60001	.13847	
					—3.41	1.799	4639899					
6— 7	6	—3	—18	54				.0658552	6.58552	.58552	.05206	
					—2.41	1.271	3981347					
7— 8	12	—2	—24	48				.1265757	12.65757	.65757	.03416	
					—1.41	.744	2715590					
8 — 9	14	—1	— 14	14				.1860538	18.60538	4.60538	1.13997	
					— .41	.216	0855052					
9—10	23		—69					.2068451	20.68451	2.31549	.25920	
					.59	.311	1213399					
10—11	22	1	22	22				.1779244	17.79244	4.20756	.99496	
					1.59	.839	2992643					
11—12	8	2	16	32				.1147636	11.47636	3.47636	1.05304	
					2.59	1.366	4140279					
12—13	9	3	27	81				.0567918	5.67918	3.32082	1.94180	
					3.59	1.893	4708197					

13—14	2	4	8	32	4.59	2.421	4922608	.0214411	2.14411	.14411	.00969
14	1	5	5	25				.0077392	.77392	.22608	.00660
	100 (n)		78	365 (Sx^2)							5.63605 (χ^2)
			−69								
			9 (Sx)								

Working mean ... ... (W.M.) 9.5

Correction ... ... $(\bar{x}) = \left(\frac{Sx}{n}\right)$ .09

Estimate of arithmetic mean ... (A.M.) 9.41

$$S^2 = \frac{Sx^2 - n\bar{x}^2}{n-1} - .0833 \text{ (Shepherd's correction)}$$

$$S^2 = \frac{365 - .81}{99} - .0833$$

$$S^2 = 3.595$$

$$S = 1.896$$

Summary

PART 1

1· Fortnightly observations on the zooplankton of a station in Lake Qarun show the existence of three important species: *Diaptomus salinus* Daday, *Leander squilla* var. *elegans* Rathke, and *Moina salinarum* Gurney, their abundance being in the order named.

A cold period was characterised by a simple community abundant in individuals. A warm period followed with a more complex community and fewer individuals.

2. In *Diaptomus* and *Leander* there was a diminution in size stage for stage as between warm and cold seasons.

3. The two highest ether-soluble matter values per unit dry weight of a short series of samples of dried zooplankton occurred in the spring, before the lake temperature had risen to its maximum. This was also at a time when the Ca content was lowest and when Ca was relatively least important compared with Na, K and Mg.

PART II

Seven larval stages of *Leander squilla* var. *elegans* are described. Six of these correspond to the five larval stages presumed for *Leander squilla* var. *intermedia* and the seventh to the first post-larval stage of the European species.

Bibliography

(1) CLOWES, G. H. A.—" *Protoplasmic Equilibrium,*" Journal of Physiological Chemistry 20, p. 407, 1916.

(2) OSTENFELD AND JESPERSON.—" Standard Net for Plankton Collections," Conseil Permanent International pour l'Exploration de la Mer.

(3) OXNER AND KNUDSEN.—Bull. Comm. Int. pour l'Exploration Sci. de la Mer Méditérranee, No. 3, 1920.

(4) WINKLER.—International Revue Gesam. Hydrog., XI Heft.

(5) WIMPENNY, R. S.—Report on the Fisheries of Egypt for the Year 1929, Government Press, Cairo, 1931.

(6) AZADIAN AND HUG.—" Etudes sur la salinité du Lac Quaroun ", Bulletin de la Société Royale de Géographie d'Egypte, T. XVII, 1931.

(7) FISHER, R. A —" Statistical Methods for Research Workers," London, 1430

(8) GURNEY, R.—' Some Notes on *Leander longirostris* and Other British Prawns," Proceedings of the Zoological Society of London, 1923, p. 105.

(9) BOGOROV, B. G.—" Seasonal Changes in the Biomass of *Calanus finmarchius* in the Plymouth Area in 1930," J.M.B.A., Vol. XIX, No. 2, pps. 599, 601 and 605.

(10) MARSHALL, S. M., NICHOLLS. A. G., and ORR, A. P.—" On the Biology of *Calanus finmarchicus*; V. Seasonal Distribution, Size, Weight and Chemical Composition in Loch Striven in 1923 and their relation to the Phytoplankton." J.M.B.A. N. 8. Vol. XIX, No. 2, 1934.

(11) MARSHALL, S. M., NICHOLLS, A. G., and ORR, A. P.—" On the Biology of *Calanus finmarchicus.* VI Oxygen Consumption in Relation to Environmental Conditions." J.M.B.A. 1934.

(12) SOUTHERN AND GARDINER.—" Seasonal Distribution of the Crustacea of the Plankton in Lough Derg and the River Shannon." Fisheries, Ireland, Sci. Invest. 1926, I. (1926).

(13) GURNEY, R.—" The Larval Development of Some British Prawns." Proceedings of the Zoological Society of London, 1924, pps. 297 and 961.

(14) MORTENSEN, Th.—" Untersogelser over von almindelige Rejes (*Palaemon fabricii*) Biologi og Udviklingshistorie." Vid. Undersog. paa. Fiskeriernes omraade udgivne af Danske Fiskeriforening. I. Copengahen, pp. 1-79.

(15) YU YOKOYA.—" On the Metamorphosis of two Japanese Freshwater Shrimps, *Paratya compressa* and *Leander paucidens* with Reference to the Development of their Appendages." Journal of the College of Agriculture, Imperial University of Tokio, Vol. XI, No. 2, 1931.

(16) GURNEY, R.—" Report on the Larvæ of the Crustacea Decapoda " p. 278. Trans. Zool. Soc. Part. 2, 1927.

(17) PEARSON, K.—Tables for Statisticians and Biometricians. Cambridge University Press, 1914.