FISHERIES RESEARCH BOARD OF CANADA

UNDER THE CONTROL OF

THE HON. THE MINISTER OF FISHERIES

BULLETIN No. LXXVIII

PONTOPOREIA AND *MYSIS* IN ATHABASKA, GREAT BEAR, AND GREAT SLAVE LAKES.

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INTRODUCTION

The purpose of this study has been to investigate the ecology and economic importance of *Pontoporeia affinis* and *Mysis relicta* in Great Slave lake, Great Bear lake and lake Athabaska. During the summers of 1944-1946 the Fisheries Research Board of Canada conducted a series of investigations on these three lakes. In the course of the field work, it became apparent that a special study of these two crustaceans would be valuable because of their economic importance and scientific interest.

In Europe these species have been widely discussed as glacial relicts, and detailed accounts of their ecology and distribution have been given by Ekman (1918-1920), Thienemann (1925, 1928), Samter (1905), and Samter and Weltner (1902, 1904). In North America work on these species has been largely concerned with their role in the productivity of lakes and their importance as fish food (Huntsman 1915; Adamstone 1924; Rawson 1930; Eggleton 1936, 1937). The work of Birge and Juday (1914, 1921, 1927) marks the only attempt to study the ecology and life history of these forms in North America.

The biological nature of Great Bear lake, Great Slave lake and lake Athabaska has been outlined by Rawson (1947a and b) and Miller (1947). The following brief description of the lakes is derived in large part from these accounts and describes the essential features of the lakes which are pertinent to an ecological study of *Pontoporeia* and *Mysis*.

GEOLOGY, GEOGRAPHY AND MORPHOMETRY

Great Slave lake, Great Bear lake and lake Athabaska lie on the margin of the Canadian Shield and are all a part of the large Mackenzie river drainage system (see fig. 1). Great Slave lake has an area of 27,195 square kilometres (10,500 square miles) and lies entirely within the Northwest Territories. The altitude of the lake is 151 metres (495 feet). Lake Athabaska has an area of 7,920 square kilometres (3,058 square miles) and lies in the northern parts of the provinces of Alberta and Saskatchewan at an altitude of 213 metres (699 feet). Lake Athabaska and Great Slave lake are joined by the Slave river, and on its west side Great Slave lake gives rise to the Mackenzie river which flows to the

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Arctic ocean. Great Bear lake lies approximately sixty miles east of the Mackenzie river to which it is connected by the Great Bear river. It is the largest and also the most northern of the three lakes. Its area is 30,044 square kilometres (11,660 square miles) and its northern tip, at latitude 67°, extends just beyond the Arctic circle. Its altitude is 119 metres (391 feet).

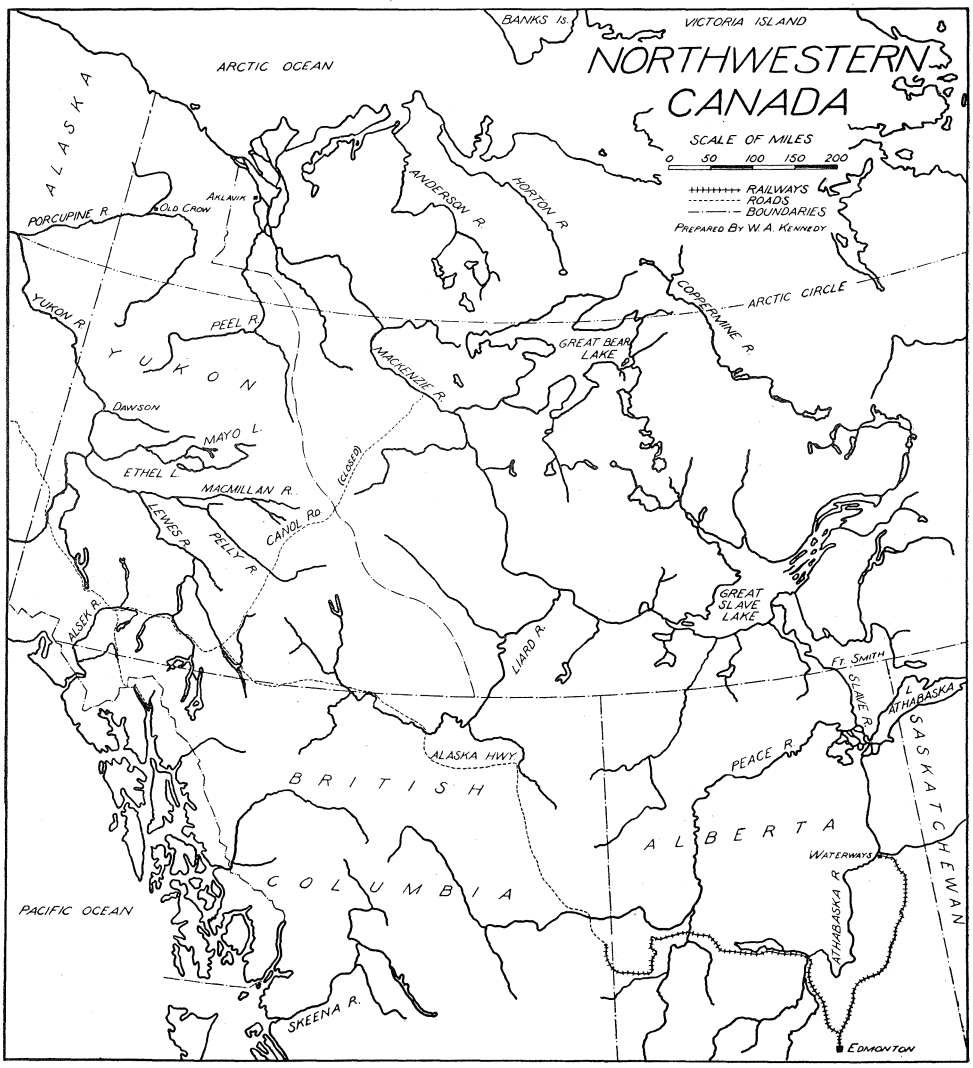


FIGURE 1. Northwestern Canada.

The north and east shores of all of the lakes lie in the Precambrian rocks of the Canadian Shield and are therefore irregular and much dissected by small bays and islands. The south and west shores lie in the sedimentary rocks of the Mackenzie lowlands and are more regular.

In general these lakes are very deep; all have a maximum depth of greater than 120 metres. The depths of the various parts of Great Slave lake and lake Athabaska are shown in figures 2 and 3. Great Slave lake can be conveniently separated into two portions: the "east arm", lying east of longitude 113° west, and the main lake. The main lake has an area of 19,425 square kilometres, a mean depth of 35 metres and a maximum depth of 163 metres. The north arm and the south shore are the shallower parts of the main lake. The east arm consists of a number of troughs separated by high ridges which run in a northeast to southwest direction. Soundings in these troughs have indicated that they are usually of great depth and in some cases they are almost completely cut off from the main body of the lake. The greatest depth observed was 612 metres,

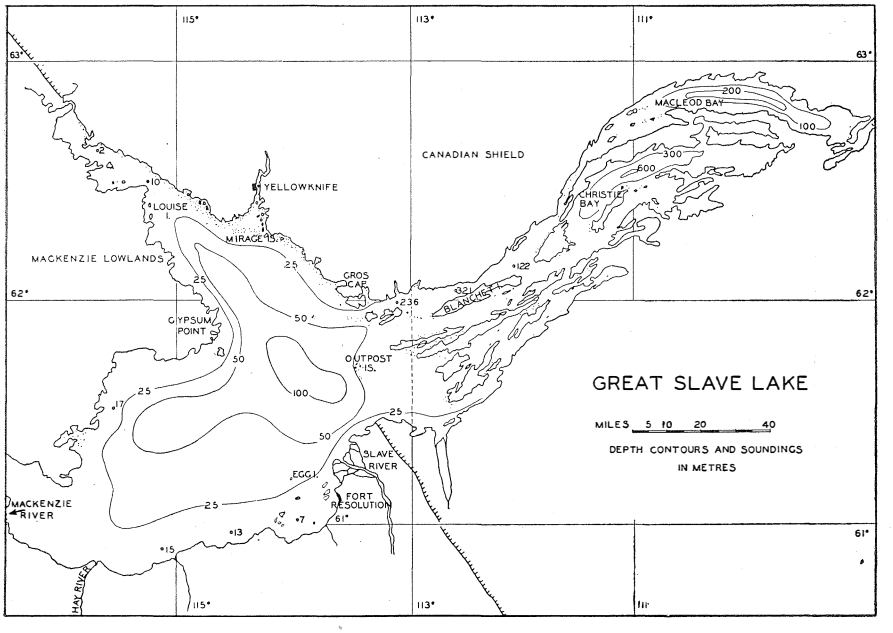


FIGURE 2. Great Slave lake.

in the central part of Christie bay. The mean depth of the larger bays and inlets of the east arm considered together is approximately 150 to 200 metres.

Lake Athabaska has a mean depth of 26 metres. The entire western portion (west of Beartooth island) has a depth of less than 25 metres, the eastern portion from Goldfields to Fond du Lac a depth of from 30 to 50 metres, while the central part is from 40 to 120 metres deep. The areas of depth greater than 90 metres are limited to a single narrow depression extending across the mouth of Black bay.

Extensive soundings have not been made in Great Bear lake. Miller (1947) states that it is of great depth, and there are no large areas of shallow water. A large part of the MacTavish arm is greater than 365 metres deep.

Physical and Chemical Conditions

As the great depth and area of these lakes would suggest, they are all cold. No thermocline has been observed on any of the lakes and it is probable that with the short summer season and the occasional circulation of water caused by the strong winds which blow intermittently throughout the summer, thermal stratification is rare or completely absent.

Water temperatures are highest in lake Athabaska. The mean temperature for lake Athabaska in August, 1945, was approximately 10° C., for the main portion of Great Slave in the same month 7° C., and for Great Bear lake approximately 5° C. In all of the lakes at depths greater than 30 metres, temperatures above 7° C. were observed on only a few occasions in late August.

In enclosed and shallow bays of the lakes considerable warming of the water takes place for short periods in the summer. These conditions are most pro-

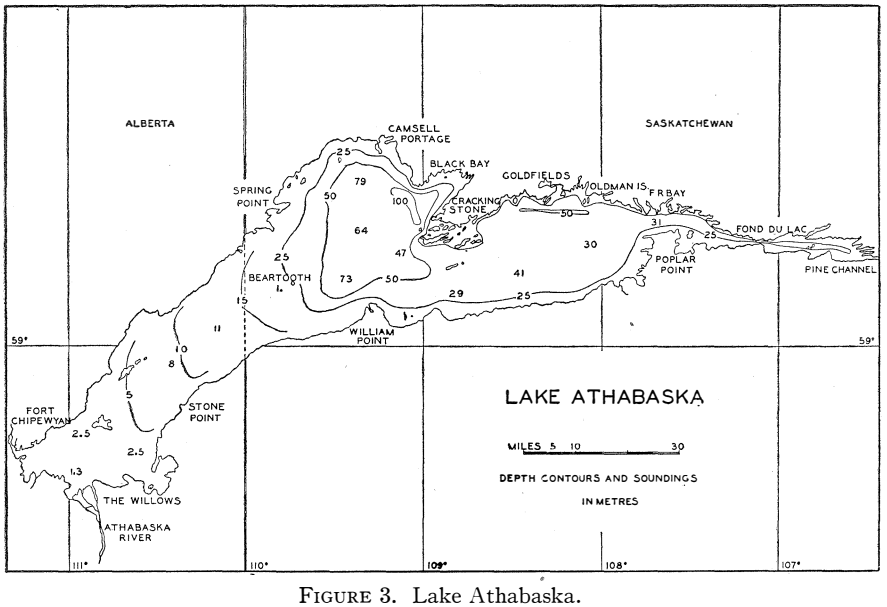


Figure 3. Lake Athabaska.

longed in lake Athabaska where the ice cover disappears two weeks before it does on Great Slave lake, and a month before Great Bear lake. The shallow water temperature conditions and their duration in the three lakes are summarized as follows:

	Range of temperature in shallow water in midsummer	Approximate duration of summer period
Great Bear lake	11.5°-15.5° C.	July 1-September 15
Great Slave lake	13.5°-17° C.	June 15-September 15
Lake Athabaska	15° -21° C.	June 1-September 30

The oxygen concentration is high at all depths in all of the lakes; the lowest concentration observed was 5 c.c. per litre.

From the foregoing brief description it is apparent that these lakes may all be considered as extremely oligotrophic. Assuming that area, depth, temperature, and duration of the summer season may be used as criteria in comparing the degree of oligotrophy of the three lakes, they may be placed in the order (from most oligotrophic to least) Great Bear lake, Great Slave lake, lake Athabaska.

PONTOPOREIA AFFINIS

Taxonomy

Mr. C. R. Shoemaker (Smithsonian Institution, Washington D.C.) has given the writer the following information concerning the taxonomy of *Pontoporeia affinis*. The European freshwater form of *Pontoporeia* is named *Pontoporeia affinis* Lindstrom. A number of freshwater species have been described from North American lakes including *P. hoyi* (Smith 1874), *P. filicornis* (Smith 1874), *P. filicornis* (Adamstone 1928). Segerstrale (1937a and 1937b) has proved conclusively that all fresh water forms of the genus *Pontoporeia* are identical to *P. affinis* Lindstrom with the possible exception of *P. filicornis* Adamstone which he suggests be described as *P. affinis brevicornis*.

Specimens from Great Slave lake were identified by Mr. Shoemaker as *P. affinis* Lindstrom.

The Depth Distribution of Pontoreia

GREAT SLAVE LAKE

In the three summers of collecting on Great Slave lake a total of 443 quantitative dredging samples was taken. Most of the samples were collected with an Ekman dredge of standard design. For dredgings in extremely deep water an automatic-closing modification of the Ekman dredge was used (Rawson 1947c). A Peterson dredge was used on a few occasions, chiefly on hard bottom.

The 443 samples contained a total of 39,629 organisms, of which 24,493 (62 per cent) were *Pontoporeia*. The total wet weight of these organisms was 71,331 mg.; of *Pontoporeia*, 39,127 mg. (54 per cent). *Pontoporeia* was abundant at all depths and was by far the most important organism of the bottom fauna.

The depth distribution is summarized in table I and figure 4. The average number of *Pontoporeia* per square metre is greater than 1,200 for all depth zones down to 60 metres, with the exception of the 15-20 metre depth zone, which probably represents a sublittoral minimum. Two concentration zones are present, one at 5-10 metres and another at 25-30 metres. The 25-30 metre depth zone has the highest average number per square metre (1,748). The numbers of *Pontoporeia* decrease from the peak at 25-30 metres, to 1,218 in the 50-60 metre zone and to approximately 200 per square metre at all depths beyond 160 metres.

The average wet weight per square metre is closely correlated to the numbers per square metre in depths down to 50 metres. The average wet weight per individual ranges from 1.65 to 1.95 mg. in these depths, and the

TABLE I. Depth distribution of *Pontoporeia* in Great Slave lake.

Depth zone (m.)	No. of dredgings	Average no. per dredging	Average no. per sq. m.	Average wet wt. (mg.) per dredging	Average wet wt. per sq. m.	Average wet wt. per individual
0-5	58	78.5	1570	134.5	2690	1.71
5-10	47	85.7	1714	143.5	2870	1.67
10-15	51	72.4	1448	119.2	2384	1.65
15-20	28	41.7	834	78.0	1560	1.87
20-25	32	64.2	1284	118.1	2362	1.84
25-30	19	87.4	1749	157.5	3150	1.95
30-40	28	69.2	1384	114.5	2290	1.66
40-50	15	67.7	1354	116.7	2334	1.73
50-60	25	60.9	1218	88.5	1770	1.45
60-70	20	46.2	924	51.1	1022	1.11
70-80	25	25.7	514	21.8	436	0.85
80-90	7	29.8	596	28.5	570	0.96
90-100	11	16.3	326	10.2	204	0.63
100-120	16	17.9	358	12.1	242	0.68
120-140	11	13.9	278	7.9	158	0.57
140-160	5	18.2	364	10.8	216	0.59
160-200	10	10.5	210	4.7	94	0.45
200-300	11	6.0	120	2.7	54	0.45
300 +	23	9.1	182	4.4	88	0.48
Total....	443					Mean 1.59

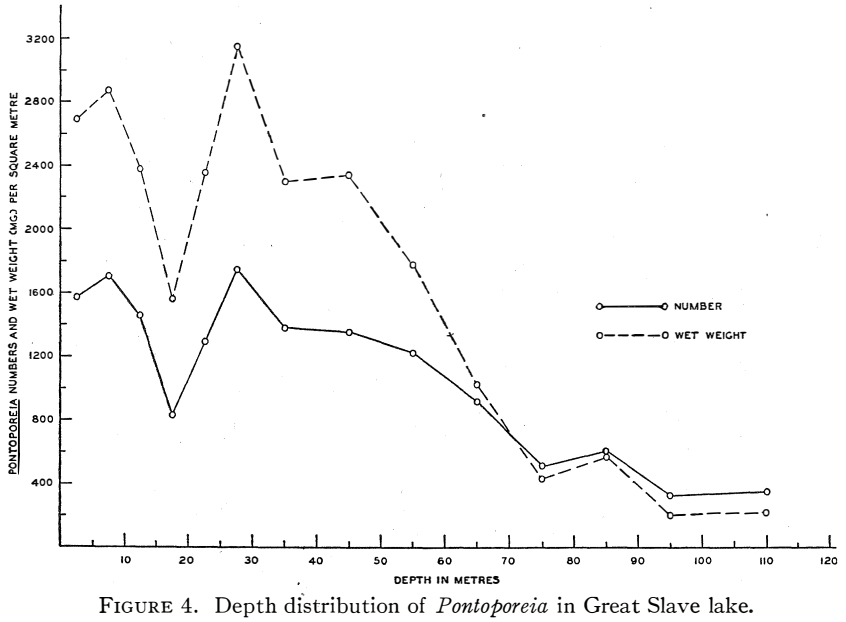


FIGURE 4. Depth distribution of *Pontoporeia* in Great Slave lake.

highest average wet weight per individual corresponds to the highest average number per square metre in the 25-30 metre depth zone. In depths greater than 50 metres, the average wet weight per square metre decreases more rapidly than the numbers, so that in depth zones greater than 70 metres the average wet weight per individual is less than 1 mg.

Tables II and III, and figure 5 show the depth distribution in the two parts of Great Slave lake. The most significant features of this comparison are the larger numbers of *Pontoporeia* in depths greater than 60 metres in the main lake, and the larger numbers of *Pontoporeia* in the 0-15 metre depth zones in the east arm. The average wet weight per square metre is less in all of the depth zones greater than 15 metres in the east arm, and is particularly low in depths greater than 60 metres. The average wet weight per individual is less than 0.77 mg. at all depths beyond 60 metres.

TABLE II. Depth distribution of *Pontoporeia* in the main portion of Great Slave lake.

Depth zone (m.)	No. of dredgings	Average no. per dredging	Average no. per sq. m.	Average wet wt. (mg.) per dredging	Average wet wt. per sq. m.	Average wet wt. per individual
0-5	45	72.8	1456	121.2	2424	1.67
5-10	43	77.6	1552	124.0	2480	1.60
10-15	47	72.0	1440	122.5	2450	1.70
15-20	24	41.8	836	81.6	1632	1.95
20-25	29	63.6	1272	123.6	2472	1.94
25-30	19	87.4	1748	157.5	3150	1.95
30-35	13	65.2	1304	121.2	2424	1.86
35-40	8					
40-45	8	69.2	1384	127.0	2540	1.84
45-50	4					
50-55	4	61.1	1222	93.2	1864	1.52
55-60	16					
60-65	5	68.0	1360	78.3	1566	1.15
65-70	7					
70-75	7	37.3	746	40.2	804	1.08
75-80	2					
80-85	0	48.3	966	58.3	1166	1.21
85-90	3					
90-95	0	28.3	566	20.0	400	0.70
95-100	4					
100 +	12	31.7	634	26.7	534	0.65
Total....	300					Mean 1.66

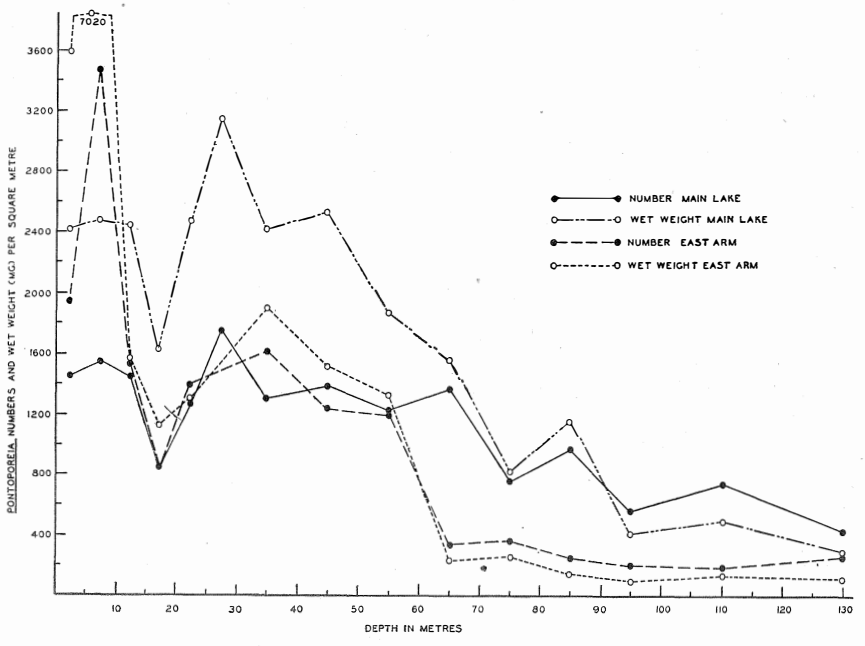


FIGURE 5. Depth distribution of *Pontoporeia* in the two major parts of Great Slave lake.

TABLE III. Depth distribution of *Pontoporeia* in the east arm of Great Slave lake.

Depth zone (m.)	No. of dredgings	Average no. per dredging	Average no. per sq. m.	Average wet wt. (mg.) per dredging	Average wet wt. per sq. m.	Average wet wt. per individual
0-5	13	98.3	1966	180.0	3600	1.83
5-10	4	173.8	3476	351.3	7020	2.02
10-15	4	76.8	1536	78.8	1576	1.02
15-20	4	41.5	830	56.3	1126	1.36
20-25	3	70.3	1406	64.0	1280	0.91
25-30	0	—	—	—	—	—
30-40	7	80.7	1614	95.0	1900	1.18
40-50	3	61.7	1234	76.0	1520	1.28
50-60	5	60.0	1200	69.8	1336	1.16
60-70	8	16.9	338	10.5	210	0.77
70-80	16	18.0	360	11.5	230	0.60
80-90	4	16.0	320	6.3	126	0.40
90-100	7	9.4	188	4.6	92	0.48
100-120	11	8.9	178	5.8	116	0.66
120-140	8	11.5	230	5.0	100	0.43
140-160	2	18.5	370	2.0	40	0.50
160-200	9	6.4	128	2.9	58	0.45
200-300	11	6.0	120	2.7	54	0.46
300 +	23	9.1	182	4.4	88	0.49
Total....	143					Mean 1.32

TABLE IV. Depth distribution of *Pontoporeia* in lake Athabaska.

Depth zone (m.)	No. of dredgings	Average no. per dredging	Average no. per sq. m.	Average wet wt. (mg.) per dredging	Average wet wt. per sq. m.	Average wet wt. per individual
0-5	33	37.6	752	75.2	1504	2.00
5-10	22	43.0	860	69.9	1398	1.63
10-15	16	39.8	796	92.1	1842	2.32
15-20	9	31.7	634	73.6	1472	2.33
20-25	8	35.9	718	99.3	1986	2.76
25-30	14	39.8	796	115.1	2302	2.89
30-35	17	48.5	970	127.4	2548	2.68
35-40	13					
40-45	6	51.6	1032	120.8	2415	2.32
45-50	11					
50-55	9	46.5	931	122.1	2442	2.62
55-60	2					
60-65	5	69.0	1380	138.3	2766	2.01
65-70	2					
70-75	2	52.0	1040	87.5	1750	1.68
75-80	4					
80-85	4	72.5	1450	115.3	2305	1.59
85-90	0					
90-95	0	43.0	860	83.0	1660	2.16
95-100	1					
100	3	62.7	1254	125.0	2500	2.00
Total....	181					Mean 2.24

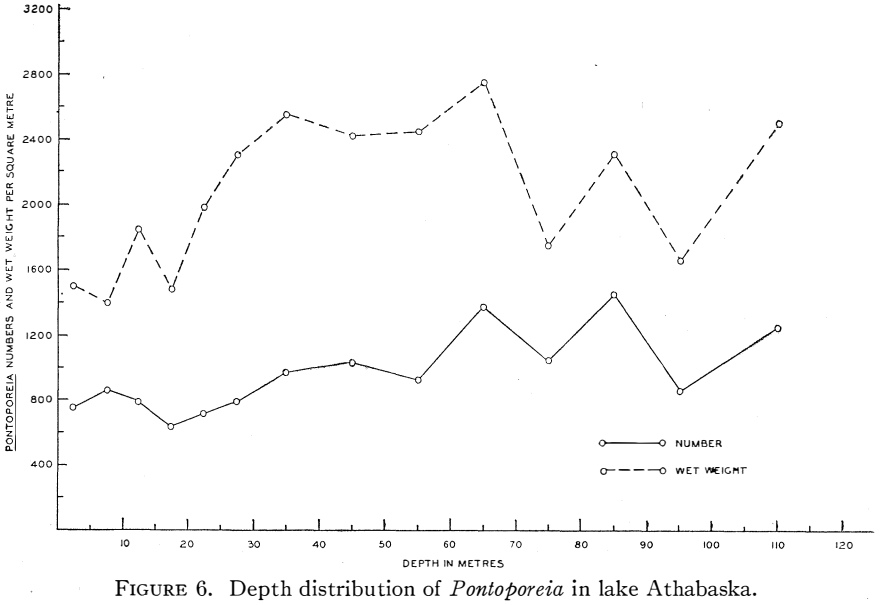


FIGURE 6. Depth distribution of *Pontoporeia* in lake Athabaska.

LAKE ATHABASKA

During the summer of 1945 a total of 181 dredging samples was taken on lake Athabaska. All of the samples were collected with an Ekman dredge. The 181 samples contained a total of 13,432 organisms of which 8119 (61 per cent) were *Pontoporeia*. The total wet weight of all organisms collected was 25,955 mg.; of *Pontoporeia*, 18,200 mg. (70 per cent).

The depth distribution is summarized in table IV and figure 6. The average number per square metre ranges from 633 in the 15-20 metre depth zone to 1,450 in the 80-90 metre depth zone. The apparent concentration zones in depths of 60-70 metres, 80-90 metres and 100 plus are probably attributable to sampling errors, as they represent the averages of small numbers of dredgings.

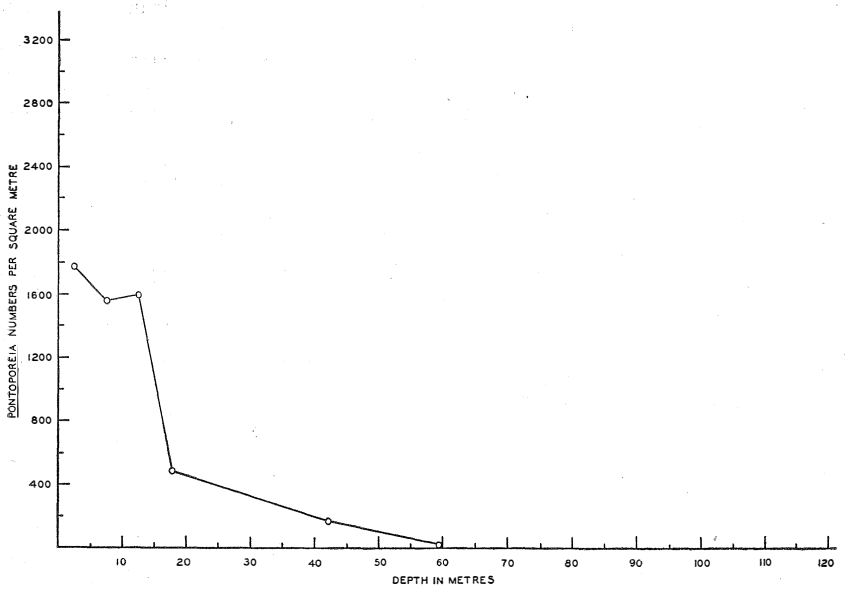


FIGURE 7. Depth distribution of *Pontoporeia* in Great Bear lake.

There is a slight suggestion of a sublittoral minimum at the 15-20 metre depth zone. The average wet weight per square metre does not fall below 1,300 mg., and is greatest in the depth zones from 20 metres to 60 metres. The average wet weight per individual ranges from 1.59 to 2.89 mg., and is highest in the 25-30 depth zone.

GREAT BEAR LAKE

A total of 19 dredgings was taken on Great Bear lake in 1945. Figure 7 shows the approximate depth distribution of *Pontoporeia* from these samples. Twelve of the dredgings were taken in depths down to 15 metres and showed an average number per square metre of 1,593. From seven dredgings taken at depths from 15 to 54 metres, the average number per square metre was 183. The most important feature of the depth distribution evident from this small

number of samples is the low density of *Pontoporeia* in all but the shallow bays of the lake. Miller (1947) has reported that in all open water areas of Great Bear lake the bottom fauna is almost negligible; and he describes the bottom deposit in these areas as "a fine greyish material apparently devoid of organic matter".

DISCUSSION

Ekman (1915) and Thienemann (1926, 1928), from work on north European lakes, concluded that temperature and oxygen concentration were the important factors in limiting the distribution of *Pontoporeia*. In oligotrophic lake Vaettern, Ekman stated that 14.5° C. was the upper limit of temperature that *Pontoporeia* would tolerate. Thienemann observed that a similar condition prevailed in some north German lakes, while in others, where the oxygen concentration fell below 4.5 cc. per litre in the hypolimnion, *Pontoporeia* was forced to occupy

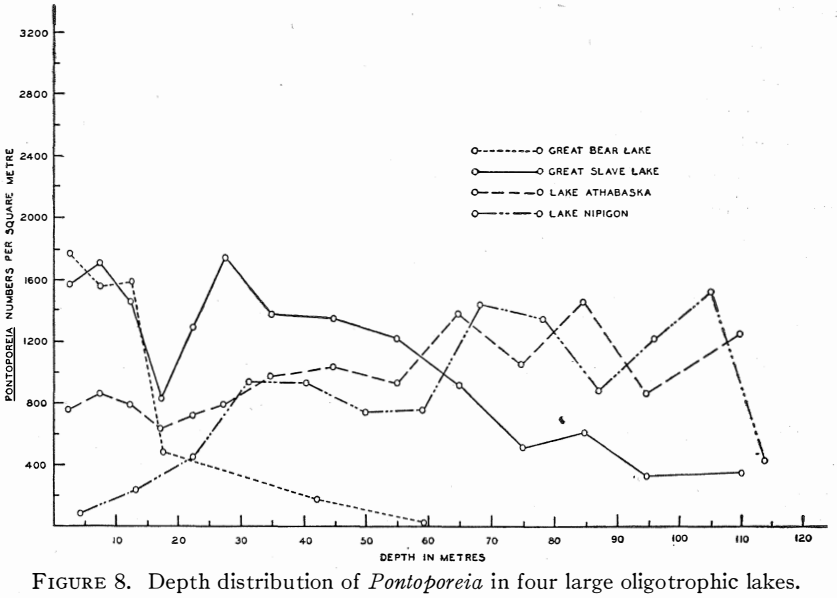


FIGURE 8. Depth distribution of *Pontoporeia* in four large oligotrophic lakes.

regions where temperatures were greater than 14.5° C. In the latter case Thienemann believed that *Pontoporeia* was becoming extinct.

None of the three lakes, Great Slave, Great Bear, and Athabaska is suitable for studying oxygen concentration as a controlling factor in the distribution of *Pontoporeia*. Their slight differences in temperature, however, are reflected to some degree in the depth distribution. Figure 8 shows the depth distribution of *Pontoporeia* in the three northern lakes, and in lake Nipigon (Adamstone 1924).

There are two chief differences in the depth distribution of *Pontoporeia* in these four lakes. The first is the abundance of *Pontoporeia* in depths of less than 15 metres in Great Slave and Great Bear as contrasted with its scarcity in the same depths in lake Nipigon, lake Athabaska occupying an intermediate position.

The second is the reverse condition in depths greater than 60 metres; *Pontoporeia* is abundant in lake Athabaska and lake Nipigon and virtually absent in Great Bear, with Great Slave in the intermediate position.

Shallow water temperature conditions in the three northern lakes have been summarized in the introductory remarks of this paper. Corresponding observations for lake Nipigon are: range of midsummer shallow water temperatures 16 to 24.5° C.; duration of summer period, May 15 to October 15 (Clemens 1923, 1924). The greater abundance of *Pontoporeia* in shallow water in the more northern lakes is apparently correlated with their lower temperatures and shorter summer seasons.

The difference between Great Slave lake and lake Athabaska is emphasized by an examination of the depth distribution within the first 5 metres of depth, where the effects of higher temperatures and their prolongation are most marked. Of the 33 dredgings taken in this depth zone in lake Athabaska, 14 from depths of 0-2 metres yielded an average of 160 per square metre, while 19 from depths of 2-5 metres showed an average of 1,080 per square metre. In Great Slave lake 21 dredgings taken in depths of 0-2 metres yielded an average of 1,716 per square metre, which is higher than the average for the entire 0-5 metre depth zone (1,570). In Great Slave lake apparently *Pontoporeia* is not affected in even the shallowest depths by high temperatures.

An explanation of the second feature of this comparison, i.e., the greater abundance of *Pontoporeia* in depths greater than 60 metres in lake Athabaska and lake Nipigon, is offered by an examination of the depths and areas of these lakes. Rawson (1930) has emphasized the relationship of depth and area to the productivity of the benthos in lakes. The chief source of organic debris in the bottom sediments is presumably the rich flora and fauna of the littoral and sublittoral zones. When an area of great depth is extensive, its central portion is far removed from these productive regions and its bottom fauna is correspondingly poor.

The extent of areas of great depth in Great Bear lake has already been described. In Great Slave lake, depths of over 50 metres occupy an area of 9,583 square kilometres; in lake Athabaska an area of 1,165 square kilometres; in lake Nipigon an area of approximately 2,331 square kilometres (Adamstone 1924). The large areas of these depths in Great Bear lake and Great Slave lake suggest therefore that they would be relatively unproductive and would support a smaller number of bottom organisms.

If the two portions of Great Slave lake are considered separately, the lower productivity of the deeper east arm is clearly shown. The comparison is as follows:

	Area of depth greater than 50 m. (sq. km.)	Number of dredgings 50 to 100 m.	Average no. *Pontoporeia* per sq. m.	Av. wet wt. *Pontoporeia* per sq. m.	Av. wet wt. per individual
East arm	5957	40	422	337	0.8
Main lake	3626	48	1197	1425	1.3

In depths of 50 to 100 metres *Pontoporeia* is two and one-half times as abundant in the main lake as in the east arm. Further, the smaller numbers of *Pontoporeia* in the east arm have a lower average wet weight per individual, so that the average wet weight per square metre is thus less than one quarter of that of the main lake in these depths.

Figure 9 shows the relationship between the average number per square metre and the average wet weight per individual in Great Slave lake. From depths of 50 to 300 metres the correlation is close, the average wet weight per individual decreasing as the numbers decrease with depth. This suggests that

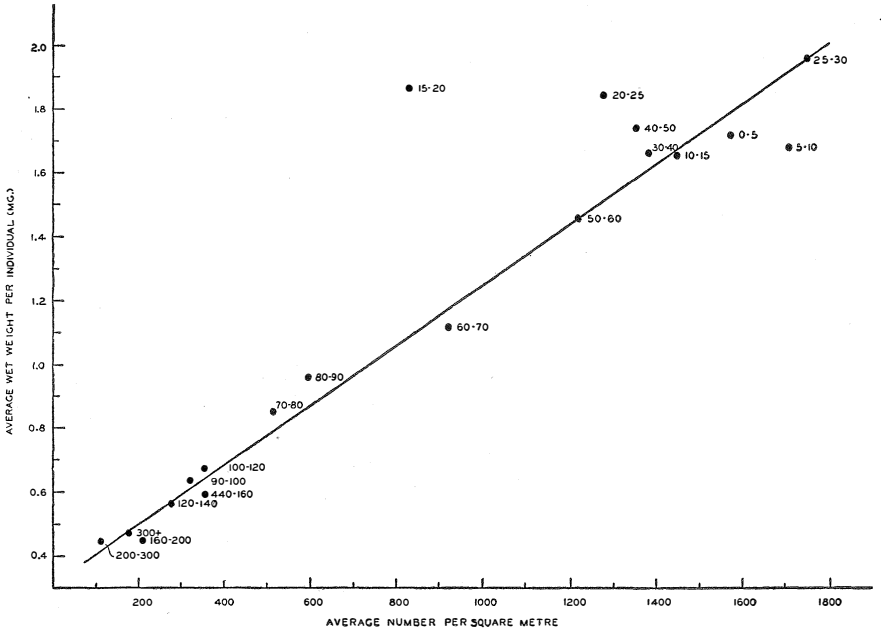


FIGURE 9. Relation between the average number per square metre and average wet weight per individual *Pontoporeia* in Great Slave lake.

the sparsity of organic material is reflected not only in the number of individuals present but also in their weight. In a later section of this paper it is shown that the lower average weight per individual in these areas is not due to any peculiarity in the age distribution of the population on the lake bottom as a whole, but that "dwarfing" of all age groups occurs there.

The correlation is less evident in shallower depth zones, where presumably a greater number of factors are important in regulating the number and the average size of the individuals. In these depths the type of bottom is less uniform, higher temperatures affect the period of reproduction, and there is extensive predation by bottom feeding fish. The coincidence of the highest average wet weight per individual with the maximum number per square metre at the 25-30 metre depth zone suggests that it may represent the optimum

conditions of uniformly abundant food, low temperature and relatively little predation as compared to shallow depths.

Importance in Total Bottom Fauna

Pontoporeia is by far the most important single organism in the bottom fauna of Great Slave lake and lake Athabaska. Table V summarizes the per-

Table V. *Pontoporeia* and total bottom fauna in Great Slave lake.

Depth zone (m.)	Area of depth zone (per cent of total)	Average number all organisms per dredging	Average number *Pontoporeia* per dredging	Per cent *Pontoporeia*	Average wet wt. all organisms per dredging	Average wet wt. *Pontoporeia* per dredging	Per cent *Pontoporeia*
0-25	37	124.0	71.75	57.9	252.5	123.0	48.7
25-50	27	88.3	74.3	84.4	150.1	128.0	85.3
50-100	20	55.3	39.5	71.4	66.7	46.5	69.7
100 +	16	20.8	12.0	57.7	12.6	6.8	54.0
Average		84.1	56.4	67.1	149.3	90.5	60.6

centage of *Pontoporeia* of the total bottom fauna, by numbers and wet weight in four depth zones of Great Slave lake. *Pontoporeia* makes up 67.1 per cent of the total bottom fauna by numbers and 60.6 per cent of the total by wet weight. In the 25-50 metre depth zone *Pontoporeia* represents almost the sole food organism for bottom feeding fish.

Table VI. *Pontoporeia* and total bottom fauna in lake Athabaska.

Depth zone (m.)	Area of depth zone (per cent of total)	Average number all organisms per dredging	Average number *Pontoporeia* per dredging	Per cent *Pontoporeia*	Average wet wt. all organisms per dredging	Average wet wt. *Pontoporeia* per dredging	Per cent *Pontoporeia*
0-5	24.3	87.65	37.55	44.1	166.67	75.18	45.0
5-10	13.2	55.46	42.95	77.4	93.46	69.86	74.7
10-20	15.5	53.50	36.84	68.9	107.77	85.44	79.1
20-30	8.4	54.96	38.36	69.9	129.29	109.37	84.6
30-50	23.7	70.35	49.83	71.0	153.08	125.05	81.7
50-75	10.7	81.95	54.30	66.2	152.20	125.25	82.4
75-100	3.3	111.30	61.55	55.5	129.28	97.22	75.4
100-125	0.9	107.60	62.67	58.0	144.00	125.00	79.9
Average		71.66	44.05	61.4	138.51	96.24	69.2

Table VI gives similar averages for lake Athabaska where a more detailed estimate has been made of the percentage areas of the different depth zones. With the exception of the 0-5 metre depth zone, *Pontoporeia* makes up more than 50 per cent of the total bottom fauna by numbers and wet weight at all depths. In the lake as a whole *Pontoporeia* contributes 61.4 per cent to the total number of organisms, and 69.2 per cent to the total wet weight.

Importance As Fish Food

The predominance of *Pontoporeia* in the bottom fauna is reflected in the stomach contents of bottom feeding fish. Stomach content samples were taken on both lakes from the common whitefish, *Coregonus clupeaformis*, the Northern sucker, *Catostomus catostomus*, and the common sucker, *Catostomus commersonii*. Stomach contents of a number of individuals of one species, netted at the same time, were grouped together and considered as a "sample", which was regarded as representative of that particular depth and locality. Samples from Great Slave lake are summarized as follows:

	Total number of samples	Number of samples with *Pontoporeia*	Estimated percentage of *Pontoporeia* of food in entire lake
Common whitefish	37	34	65
Northern sucker	11	10	60
Common sucker	5	3	15

For the commercially important whitefish *Pontoporeia* is the chief source of food, and in the depth zones from 25 to 100 metres where *Pontoporeia* makes up over 70 per cent of the bottom fauna, it contributes more than 70 per cent of the food of the whitefish. In depths of less than 15 metres *Pontoporeia* is largely replaced by molluscs as the chief food of whitefish. Table VII shows representative series of stomach contents analyses of common whitefish illustrating the increasing importance of the amphipod as a source of food with increasing depth.

Of 21 samples from whitefish in lake Athabaska 19 contained *Pontoporeia*. Table VIII shows the analyses of nine samples, each of which was made up of the stomach contents of more than 50 fish. This series shows the importance of *Pontoporeia* as food for the whitefish in the deeper parts of the lake. In the extensive area of shallow water in the west end of the lake, molluscs are the most important food material. The samples listed in table VIII were regarded as representative and were used to estimate the percentage of *Pontoporeia* and molluscs of whitefish food, in four depth zones of the lake, as follows:

Depth zone (m.)	Per cent of area of lake	Per cent *Pontoporeia*	Per cent molluscs
0-10	37.5	5	90
10-20	15.5	25	70
20-30	8.4	50	35
30-124	38.6	80	5

TABLE VII. Representative series of stomach contents of common whitefish from Great Slave lake (percentage volume analyses).

Locality	Date	Depth (m.)	Molluscs		*Ponto-poreia*	Chiro-nomid larvae	Others
			Gastro-pods	Sphae-riids			
Yellowknife	1945 July 20	0-3	60	25	5	+	Corixidae alga, water mites
Yellowknife	1944 July 9	3		50	5	10	Dragonfly nymph *Gammarus* 5, caddis larvae 20, alga, mayfly nymph
Fort Resolution	1945 June 17	3-4		80	5	5	Plant debris 10
Louise is.	1944 Aug. 29	8	20	20	30	+	Caddis larvae 3, alga
Blanchet is.	1945 Aug. 20	0-15	70	20	10	+	Alga, Cladocera
Yellowknife, Joliffe is.	1944 Sept. 1	4-19	10	30	10		Mollusc debris 20, fish remains 30
Yellowknife, Mosher is.	1945 July 14	9-12	20	50	25	5	Chironomid pupae, alga
Hay river	1944 Aug. 5	13	1	47	45	5	*Mysis* 3
Gypsum point	1944 June 28	14	5	35	50	10	Water mites, alga, Corixidae
Egg island	1944 June 26	18-20	2	15	75	5	Fish remains, *Mysis* 3
Yellowknife, E. Mirage is.	1944 July 27	23-26	1	17	75	7	
Outpost islands	1945 July 25	20-30		2	82	13	*Planaria*, alga, woody debris 5
Yellowknife bay	1944 June 30	58-60		+	95	5	
Yellowknife bay	1945 July 18	50-65		23	80	7	Alga, Oligochaete egg capsules, Bryozoa

TABLE VIII. Representative series of stomach contents of common whitefish from lake Athabaska (percentage volume analyses).

Locality	Date	Depth (m.)	Molluscs		*Pontoporeia*	Chironomid larvae	Others
			Gastropods	Sphaeriids			
The Willows	June 7	2.5	40	45	2	1	Terres. insects 2, mayfly nymphs 2, Corixidae 1, fish eggs 5, watermites 1, caddis larva 1
The Willows	June 6	2.5	45	45	5	1	Fish eggs 2, alga, terres. insects 2, Corixidae, watermites
Camsell Portage	Aug. 4	10-16	35	35	25	2	Watermites 1, *Mysis*, Bryozoa, terres. insects 2, caddis adult
Spring point	Aug. 2	20	15	30	45	8	Terres. insects 2, nematodes, Bryozoa, ostracods
F. R. bay	Aug. 8	21-26	20	15	60	5	Bryozoa watermites
Fond du Lac	July 20	26-29	3	30	50	15	*Mysis* 2
Cracking-stone	Aug. 3	26-27	5	25	55	15	Terres. insects, oligochaete egg capsules, Bryozoa
William point	Aug. 5	30-33			60	35	Terres. insects, oligochaete egg capsules 5, ostracods
Oldman islands	Aug. 9	37-48		2	75	20	Terres. insects 3, Bryozoa

Pontoporeia is not as important relative to other sources of food in lake Athabaska as it is in Great Slave lake, but in both it plays an important role in the food cycle by utilizing the organic material of the bottom sediments and making it available as food for fish.

LIFE HISTORY IN GREAT SLAVE LAKE

In Great Slave lake the larger part of the breeding season falls in the winter

months. A few embryo bearing females were collected in the summer months but they represented a small fraction of the total population. The young are released from the brood pouch of the mother when they reach a length of approximately 0.3 mm. In June young *Pontoporeia* ranging in size (total length from rostrum to tip of uropods, along the curve of the back) from 1 to 2.5 mm. are numerous, suggesting that they are born in the late winter months of March and April. Figure 10 gives the size frequency distribution of 160 *Pontoporeia* collected in early June in depths of less than 11 metres near Fort Resolution. The smallest size group represent the young of the year, and they range in size from 1.3 to 2.3 mm. One-year-old individuals range in size from 5.0 to 7.5 mm.

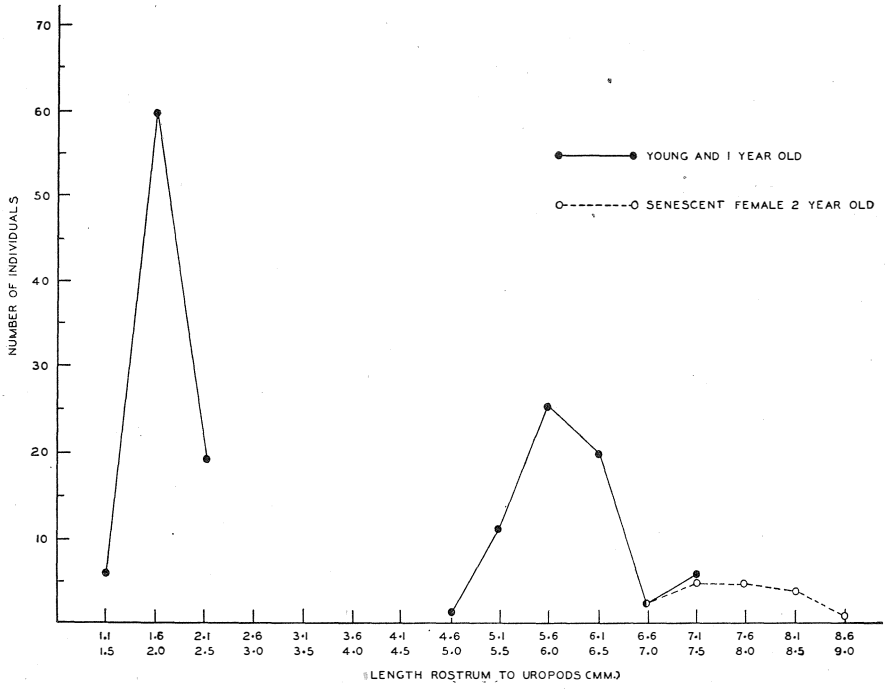


FIGURE 10. Size frequency distribution of 106 *Pontoporeia* collected from depths of less than 11 metres in early June.

in length, so that there is a distinct gap of 2.7 mm. between the largest of the young of the year and the smallest of the one-year-olds. Those individuals represented on the graph by a broken line are two years of age and were collected in a *Mysis* tow at a depth of 11 metres. They exhibit morphological characters indicative of senescence. The body is translucent rather than opaque, the eye pigment is in various stages of disintegration in different specimens, the brood pouch of the female is enlarged, and the first to fourth gill pairs are frequently milky white in appearance rather than transparent. These individuals are undoubtedly the parents of the young of the year, and their scarcity in the col-

lections in June suggests that the majority die soon after the young are born. These individuals range from 6.6 to 9.0 mm.; the average size is 7.7 mm.

In samples taken from deep water the size groups are not as easily distinguished. Figure 11 shows the size frequency distribution of 513 individuals collected in late June in depths of 40 to 60 metres. The curve shows four modes and there is considerable intergrading between the size groups. Those individuals of less than 3.0 mm. represent the young of the year and correspond to those of the same size in figure 10. The size group from 5.0 to 7.5 mm. likewise corresponds to the same in figure 10 and represents individuals one year of age.

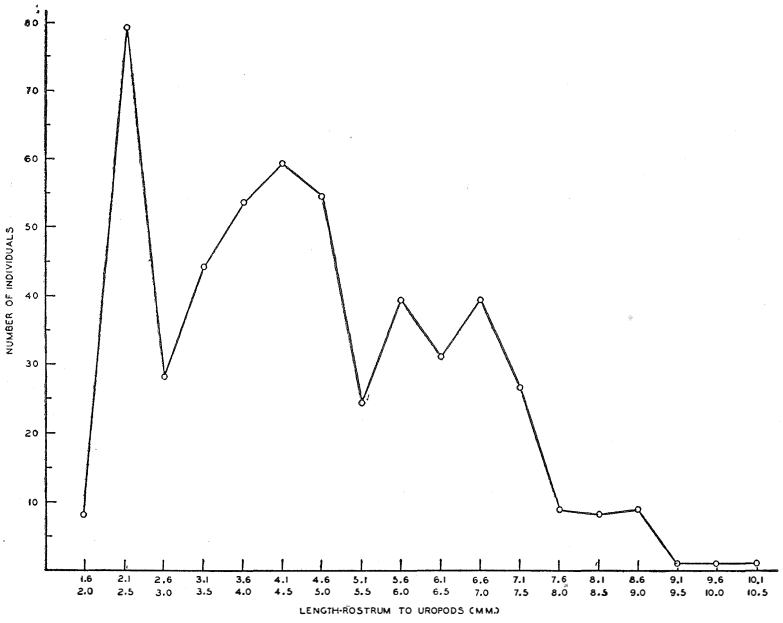


FIGURE 11. Size frequency distribution of 513 *Pontoporeia* collected from depths of 40 to 60 metres in late June.

The small numbers of individuals greater than 7.5 mm. were not senescent. Those individuals from 9.1 to 10.3 mm. in size, together with others of similar size taken in other parts of the lake, though exhibiting no senescent characters had enlarged brood pouches, suggesting that they are parents of the current brood, that will live to produce a second. The size group 3.0 to 5.0 mm. is not represented in shallow water. The average size of this year group is 4.33 mm. A total of nine pregnant females was collected in 1944 and 1945; all from depths of greater than 25 metres. The average size of these specimens was 6.8 mm.

Figure 12 is an attempt to show the rate of growth of *Pontoporeia*. The points on the graph are average sizes of numbers of individuals collected at different times in the summer, in depths of less than 11 metres, near Fort Resolution. The average sizes are as follows:

Date	Number of individuals measured	Size range (mm.)	Average size (mm.)
June 10	86	1.3-2.3	1.88
	67	5.0-7.5	6.12
	18 senescent females	6.6-9.0	7.7
July 10	101	1.9-3.0	2.43
	69	4.6-7.5	6.15
August 4	53	2.3-3.6	3.00
	15	5.9-7.7	6.78
September 8	85	3.1-5.0	4.15
	33	5.2-8.3	6.48

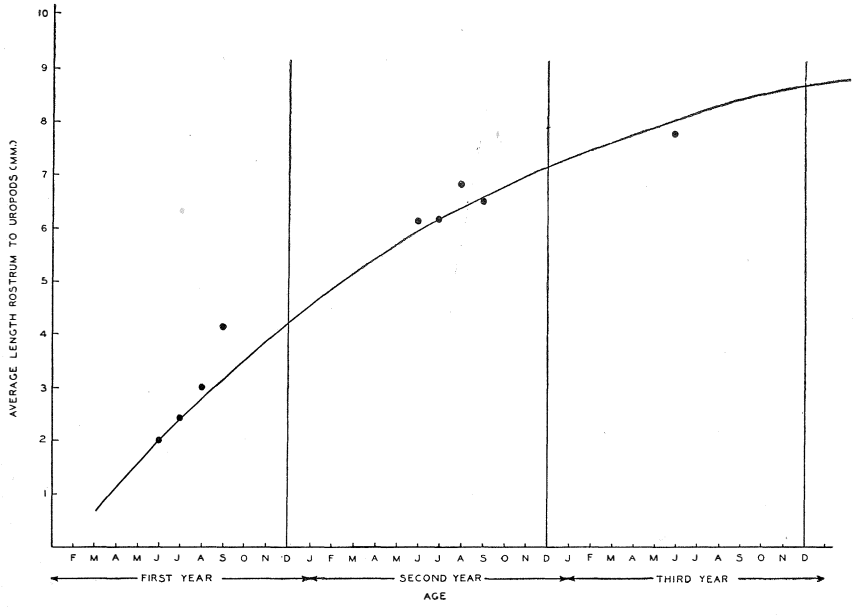


FIGURE 12. Rate of growth of *Pontoporeia*.

The curve drawn through these points suggests that growth continues throughout the entire life of the individual, and is most rapid in the first year.

DISCUSSION

Samter and Weltner (1904) and Ekman (1915) state that the reproductive period of *Pontoporeia* falls in the winter months in European lakes. Birge and Juday (1927) found that *Pontoporeia* reproduced in Green lake during the winter months. Samter and Weltner observed that temperatures greater than 7° C. prevented egg production, so that the type and the locality of a lake determine to a large extent the time and the duration of the reproductive period.

The probable explanation for the differences in the size frequency distribution at different depths at the same time of year lies in the temperature conditions in the two regions. In depths of less than 10 metres temperatures in excess of 7° C. (limiting temperature for reproduction) are present throughout most of the summer, while at depths of greater than 30 metres they are rare. One would expect therefore that reproduction would continue over a more prolonged period in deep water than it does in shallow depths.

The prolongation of the reproductive period apparently means that the end of one winter breeding season and the beginning of another are brought closer together so that a "summer brood" is observed. This summer brood is of a mixed nature, in that the parents are made up of (a) the smaller individuals of one age group which bear young after the normal breeding season, (b) the larger individuals of the following age group which bear young in the early winter before the normal breeding period. The latter group probably make up the greater portion of the parents of the summer brood. The total of only nine pregnant females collected in the summers of 1944 and 1945 suggests that their contribution to the summer broods of the years following would be small.

If the average size of the summer brood, i.e., 4.33 mm., is extrapolated on the growth curve in figure 12, the age from the time of liberation from the mother is estimated at from 7 to 8 months. This means that the summer brood is born largely in the months of November and December. According to Samter and Weltner the young are carried in the brood pouch of the mother for from 3 to 4 months before liberation at a length of 0.75 to 0.8 mm. The parents would therefore be the larger individuals which reach maturity during the late summer months and which bear their young in the early winter. These young would in turn be the parents of the greatest part of the summer brood two years later. The higher temperatures in shallow water prevent reproduction there for the entire summer period causing a distinct break in the cycle of reproduction, shown by the gap between the sizes of the young of the year and one-year-olds.

The life span of *Pontoporeia* in Great Slave lake is two years. A few individuals (figure 11, 9.1 to 10.3 mm.) may live to produce a second brood and thus live slightly more than three years.

In the east arm where great depths are characterized by low numbers of *Pontoporeia* of low average wet weight, the life cycle is essentially similar to that outlined above. In shallow water two distinct size groups are present in the summer collections. The average size of 70 one-year-old individuals, collected at a depth of two metres on July 31, was 7.45 mm.; of 59 young of the year, 3.02 mm. These average sizes represent a rate of growth comparable to that in the Fort Resolution area (fig. 12).

In collections made in depths of 98 to 280 metres in late July and August the number of size groups was the same as in figure 11, but the average size of the individuals of each size group was considerably smaller. Young of the year ranged from 1.6 to 2.6 mm. in size. The average size of the young of the year was 2.01 mm.; of the one-year-olds 4.77 mm. If these sizes are extrapolated on

the growth curve (fig. 12) the young of the year are found to be the equivalent of approximately two months behind those in the shallow parts of the lake, and the one-year-olds the equivalent of approximately seven months behind. In other words, in these depths of the east arm a "dwarfing" of *Pontoporeia* occurs, which accounts for the low observed average wet weight per individual.

Parasites

A few specimens of *Pontoporeia* collected in Great Slave lake and lake Athabaska were parasitized by the plerocercoid larva of *Cyathocephalus* sp. The parasite occupies the midportion of the body and frequently protrudes between the body segments. Individuals parasitized by mature stages of the larva are readily picked out by the orange colour which the parasite imparts to the host. The degree of infestation is approximately 0.5 per cent and the parasite is equally abundant at all depths and in all parts of the lake. The adult of *Cyathocephalus* occurs in the gut of the common whitefish.

Diurnal Migration

At a depth of 1 to 2 metres in Pearson harbour in the east arm of Great Slave lake, *Pontoporeia* was observed to move upwards to the surface at night. Observations were made on only two occasions in late August, 1946. Individuals were collected at the surface as early as 10 p.m., when it was almost dark. The numbers at the surface reached a peak at slightly after 11 p.m., and gradually decreased until dawn at 4 a.m. No attempt was made to estimate the percentage of individuals of the total population which took part in the migration.

Food

The stomach contents of 25 specimens of *Pontoporeia* from Great Slave lake were examined. They contained unidentifiable organic debris and occasional diatom valves. Adamstone (1924) reported similar results from his analyses.

MYSIS RELICTA

Taxonomy

A number of European workers (Ekman 1918-1920; Thienemann 1925; Lundbeck 1926) have adopted the convention of designating the fresh water form, *Mysis oculata* var. *relicta* Loven by simply *Mysis relicta* Loven. This convention has been accepted also by Mr. C. R. Shoemaker who identified specimens from Great Slave lake by this name. The North American fresh water form is identical to the fresh water form in European lakes.

Methods and Material Collected

Mysis was collected extensively in Great Slave lake only. In Great Bear lake no special effort was made to collect *Mysis* although its abundance there was evident from its frequent occurrence in dredgings and stomachs of fish. In lake Athabaska, *Mysis* is apparently rare. It was found in the stomachs of fish on a few occasions, but repeated efforts to collect large numbers were unsuccessful.

Because *Mysis* swims freely away from the bottom and migrates diurnally it is difficult to sample quantitatively. Three kinds of nets were used on Great Slave lake: (1) Drag nets,—cotton mesh approximately 180 meshes per square inch; (2) Drag nets,—silk bolting cloth, 480 meshes per square inch; (3) "Beauchamp" net, a bottom drag net on steel runners as described by Beauchamp (1932), silk bolting cloth, 480 meshes per square inch. All of these nets were held open by strap iron frames.

A total of 77 tows was taken, of which 18 were partial vertical tows (from a point above the bottom to the surface); 31 total vertical tows; 9 diagonal tows; 8 Beauchamp tows; and 11 horizontal bottom tows in shallow water. The Beauchamp net was used for bottom tows in deep water. This type of net is not closing and it samples also through the upper strata as it is pulled to the surface. These tows yielded 9,478 *Mysis*, and these together with occasional specimens from dredgings and plankton tows made a total of approximately 10,000 collected individuals.

Depth Distribution

Table IX summarizes data pertinent to partial and total vertical tows. These 49 tows contained a total of 720 *Mysis*. Seventeen daytime partial hauls taken at depths down to 100 metres below the surface yielded 200 *Mysis* of which 33 were adult and 167 immature. Eighteen daytime total vertical hauls taken in depths down to 100 metres contained 267 *Mysis* of which 117 were adult, 150 immature. The greater percentage of adults in the total hauls indicates that adults are concentrated near the bottom, while the immature individuals are scattered more evenly throughout the overlying strata. Partial tows taken in depths down to 30 metres below the surface indicated the preponderance of immatures in these upper strata. Eleven such tows yielded 178 *Mysis* of which 154 were immature.

To collect larger numbers of adults the drag nets used for vertical tows were dragged across the bottom for a short distance and then diagonally to the surface. Nine diagonal tows collected 797 adults and 454 immature specimens (table X).

Eight Beauchamp tows (table X), which also collect extensively on the bottom, yielded 4,456 *Mysis*. In one tow 3,678 *Mysis* were collected of which 3,299 were immature. With the exception of this one tow, the Beauchamp net also collected a large proportion of adults.

Horizontal tows proved the abundance of *Mysis* in shallow water. The considerable quantity of detritus and algal material collected in these tows necessitated the sorting and preservation of small samples of the total numbers of animals captured. Five tows taken at Gros Cap and Fort Resolution in June indicated that *Mysis* was abundant at depths greater than two metres. Specimens of *Mysis* were also collected in dredgings in July at depths of less than five metres in these localities, suggesting that they are present in these areas for most of the summer period, in spite of high temperatures. Six tows were taken in depths of less than five metres in Pearson harbour. Parts of the bottom of this

TABLE IX. Partial and total vertical *Mysis* tows—Great Slave lake.

Date and time	Depth (m.)	Type of haul	No. of specimens	Mature	Immature
July 8/45, 4 p.m.	72	Total	31	31	0
July 10/45, 4 p.m.	24	"	0	0	0
July 19/45, 7 p.m.	18	"	0	0	0
July 19/45, 8 p.m.	24	Total—2 tows	0	0	0
July 28/45, noon	20	Partial	1	0	1
"	30	"	72	11	61
"	48	Total	52	19	33
July 30/45, 1 p.m.	14	Partial	0	0	0
"	15	Total	7	5	2
Aug. 2/45, 1 p.m.	12	Partial	0	0	0
"	25	"	38	—	—
"	50	"	43	5	38
"	73	Total	20	6	14
Aug. 8/45, 7.30 a.m.	25	Partial	46	3	43
"	100	"	0	0	0
"	282	Total	11	8	3
Aug. 13/45, 1.30 p.m.	72	Total	15	13	2
June 10/46, 4 p.m.	20	Partial	21	10	11
June 16/46, 9 p.m.	23	Total	7	7	0
June 22/46, noon	16	"	0	0	0
June 24/46, noon	39	"	0	0	0
June 28/46, 1 a.m.	25.5	"	3	3	0
July 1/46, noon	72	Partial	0	0	0
"	145	Total—2 tows	9	5	4
July 5/46, 9.30 a.m.	30	Partial	0	0	0
"	348	Total	5	5	0
July 13/46, 3 p.m.	68	Total	109	24	85
July 15/46, 3 p.m.	25	Partial	0	0	0
"	50	"	2	0	2
"	100	"	12	4	8
"	220	Total	15	4	11
"	220	"	24	8	16
"	51	Total	0	0	0
July 16/46, 10 a.m.	57	"	1	0	1
July 18/46, 2 p.m.	46	"	21	13	8
July 19/46, 9 p.m.	30	Partial	0	0	0
"	470	Total	12	6	6
July 24/46, 4 p.m.	30	Partial	0	0	0
"	150	Total	10	10	0
July 28/46, noon	30	Partial	0	0	0
"	50	Partial	3	0	3
"	145	Total	52	21	31
July 30/46, 10 p.m.	60	Total—2 tows	1	1	0
Aug. 1/46, 11 a.m.	145	Total	7	3	4
Aug. 10/46, 11 a.m.	42	"	1	0	1
Aug. 21/46, 10 a.m.	120	"	69	19	50

shallow bay are covered with *Cladophora*, while other areas are bare of plants. The bottom is clearly visible down to depths of five metres. Four tows in the alga covered areas yielded large numbers of *Mysis;* while two in the bare patches contained only five *Mysis*. There is a rich microscopic flora and fauna associated with the coarse *Cladophora* strands, and the *Mysis* are probably attracted to them by this abundant food supply.

Three horizontal bottom tows taken in the Slave river near the delta, in depths of 2.5 to 12.5 metres, collected no *Mysis*.

A number of observations were made near Pearson harbour on diurnal migrations of *Mysis*. A series of six tows taken on the surface at midnight August 1, over depths from 2 to 120 metres, collected 46 *Mysis*. Similar tows at noon of August 2 yielded no *Mysis*. Partial vertical tows in the upper 30 metres, taken in this area in the daytime throughout the summer collected no *Mysis*, so

TABLE X. Diagonal and Beauchamp *Mysis* tows, Great Slave lake.

Date and time	Depth (m.)	Type of haul	No. of specimens	Mature	Immature
June 10/46, noon	20-33	Diagonal—5 tows	311	121	190
June 10/46, noon	19	"	483	233	250
July 7/45, 8 p.m.	55	" 3 tows	457	443	14
July 2/46, 2 p.m.	40-70	Beauchamp	100	46	54
July 4/46, noon	90-120	"	3678	379	3299
July 18/46, 10 a.m.	140-151	"	329	129	200
July 30/46, 10 p.m.	60	"	0	0	0
Aug. 1/46, 11 a.m.	145	"	100±	—	—
Aug. 10/46, 11 a.m.	14-25	"	56	37	19
Aug. 21/46, 10 a.m.	120	"	156	105	51
Aug. 27/46, 10 a.m.	260-280	"	37	12	25

that the amplitude of the diurnal migration is probably at least 30 metres. Four series of surface tows taken at different hours of the night over depths of two metres in Pearson harbour, indicated that the migration began at darkness at 10 p.m., reached a peak at midnight, and that few individuals remained at the surface until dawn. On rare occasions *Mysis* was observed at the surface in full daylight.

DISCUSSION

Mysis, like *Pontoporeia*, is limited in its distribution largely by temperature and oxygen conditions. Samter and Weltner (1904) set 14° C. as the upper temperature limit for *Mysis*, and attributed its absence from the shallow waters of oligotrophic lakes in northern Germany to high temperature. Ekman (1915) and Birge and Juday (1927) observed that *Mysis* would exceed this temperature limit temporarily in its diurnal migrations. Thienemann (1926) set 4 cc. per litre as the lowest oxygen concentration that *Mysis* would tolerate. The

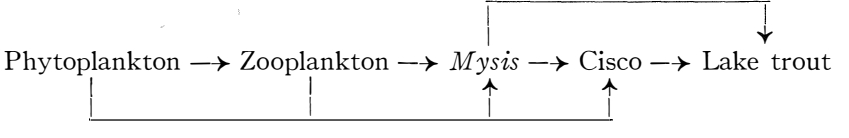
abundance of *Mysis* in all depths of Great Slave lake is thus in large measure accounted for by the extreme degree of oligotrophy of the lake.

The negative phototropism of *Mysis* has been recorded by a number of writers (Birge and Juday 1927, Valle 1930). Southern and Gardiner (1926) observed that the adult *Mysis* were more sensitive to light than the immatures, and for this reason the adults are concentrated in the strata nearer the bottom while the immatures are more evenly distributed throughout the overlying strata. These observations are confirmed by the Great Slave lake collections.

The sensitivity of adults to light in shallow water has apparently not been considered. In those localities in Great Slave lake where *Mysis* was collected in depths of less than five metres it was found either in association with algae (Gros Cap, Pearson harbour) or where the water was excessively turbid (Fort Resolution; Secchi's disc reading 8 inches). This suggests that light as well as temperature may be important in preventing *Mysis* from inhabiting shallower depths in oligotrophic lakes. A simple experiment conducted at Pearson harbour in August, 1946, in which live *Mysis* were kept under different conditions of temperature and exposure to light, indicated that the greatest mortality was caused by the combination of high temperature and bright light. Temperatures of from 16 to 18° C. were not lethal to *Mysis* if the animals were kept in darkness. The transparency of the water and the amount of protective vegetation should probably therefore be considered in addition to temperature in accounting for the distribution of *Mysis* in shallow water.

Importance as Fish Food

Mysis was found in the stomach contents of most of the abundant fish species of Great Slave lake. It was found commonly in the stomachs of ciscoes (*Leucichthys* spp.) and young lake trout (*Cristivomer namaycush*), frequently in the stomachs of burbot (*Lota lota maculosa*) and large lake trout, and on rare occasions in the stomachs of whitefish and inconnu (*Stenodus mackenzii*). The most important role that *Mysis* plays in the food cycle of the lake is in its contribution to the food of ciscoes and young trout. The ciscoes are in turn the chief food of larger lake trout, so that *Mysis* makes both a direct and an indirect contribution to the food of the latter species. *Mysis* feeds on the smaller plankton organisms, both plant and animal, and the food cycle may therefore be depicted as follows:



Mysis thus forms an important, though not essential link in the food chain. A similar food cycle has been described by Clemens et al. (1924) as typical of the open water association of lake Nipigon.

The extent to which ciscoes feed on *Mysis* in Great Slave lake varies widely from one locality to another, so that it is difficult to estimate the percentage of *Mysis* in their food in the lake as a whole. A crude estimate of approximately 40 per cent has been made on the bases of field observations and the analyses of preserved samples.

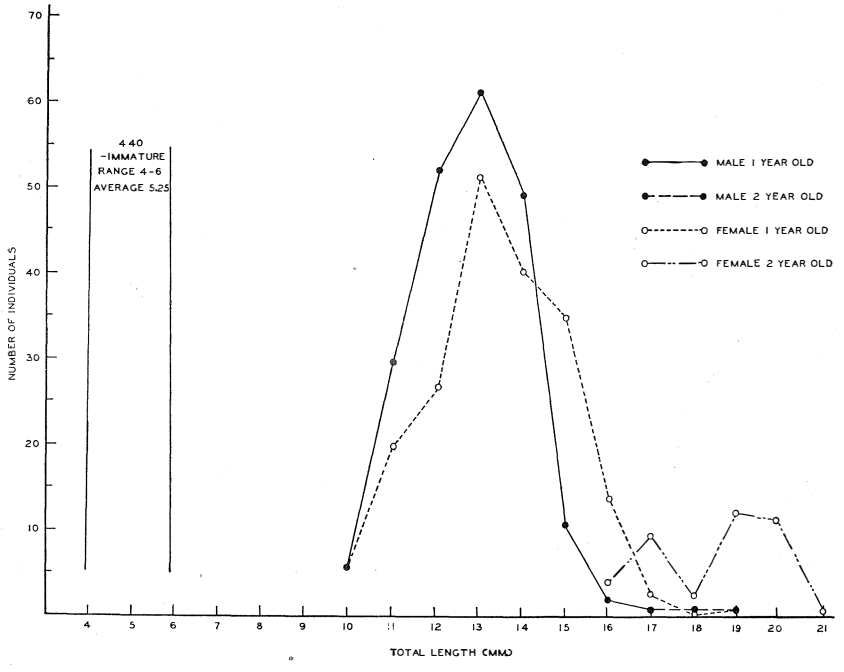


FIGURE 13. Size frequency distribution of 894 *Mysis* collected in June at depths of 19 to 40 metres.

LIFE HISTORY IN GREAT SLAVE LAKE

The life history of *Mysis* has been inferred from a consideration of the sizes of the specimens collected and the characters of maturity which some of them exhibit. Young *Mysis* are liberated from the brood pouch of the mother when they reach a length of 3 to 4 mm. At a length of 9 mm. the sexes are distinguishable. In the female brood valves develop on the last two thoracic segments; in the male a conical sex organ is formed on the last thoracic segment and the fifth pleopods become enlarged.

Figure 13 gives the size frequency distribution of 894 individuals collected June 10 at depths of 19 to 40 metres. The peak at 4 to 6 mm. represents the young of the year. Larger individuals are divisible into two distinct age groups. The majority are one-year-olds. A smaller proportion of the largest individuals of each sex represent the two-year-old parents of the current brood of young.

The females of this group have large brood pouches, the males large fifth pleopods. The ratio of the three size groups is difficult to assess because of the peculiarities in their distribution noted above and the difficulty of quantitative sampling. The sex ratio is very nearly 1:1. Of 2,010 mature individuals, collected in 1945 and 1946, 944 were male, 1,066 female. These totals include 101 two-year-old females, and six two-year-old males. The sex ratio in the one-year-old group is thus 938 to 965.

The size frequency distribution as shown in figure 13 is typical for all of the collections made. As summer progresses the number of two-year-old individuals decreases. In one collection made July 7, 1945, 3 embryo-bearing *Mysis* were found. Apparently the majority of the two-year-old males die soon after the winter reproductive period; while some of the two-year-old females survive throughout the summer. It is possible that some may live to produce a second brood the following winter.

Figure 14 shows the rate of growth of *Mysis*. The points on the graph are average sizes of numbers of specimens collected at different times in the summer, as follows:

Date	Sex and age	No. of specimens	Range in size (mm.)	Average size (mm.)
June 10	Immature	190	4-6	5.25
	1 year	195	10-19	13.50
	1 year	215	10-17	12.67
	2 year	42	16-21	18.57
July 4	Immature	101	4-8	5.50
July 7	1 year	194	10-17	14.60
	1 year	222	10-17	13.65
	2 year	39	17-22	18.40
July 28	Immature	31	5-7.5	6.31
Aug. 21	Immature	49	4.5-10.5	7.15
All summer	2 year	6	17-19	18.17

The curve drawn through these points is useful in estimating the age of individual *Mysis*. As the average size of the one-year-old individuals increases as the summer progresses, the characters of sexual maturity become more evident. Specimens of 17 mm. in size have well developed brood pouches by late August, so that they probably reproduce as early as September or October, at an age of approximately two years.

DISCUSSION

Samter and Weltner (1904) observed that the reproductive period of *Mysis* usually occurred in the winter months. They believed that the normal reproductive period extended over the entire year, but because reproduction did not take place until water temperatures were less than 7° C., a break in the yearly

cycle was usually observed. The temperature of the deeper strata thus determined the period and duration of the reproductive season. Ekman (1918-1920) found that in lake Vaettern reproduction took place during the winter only, but that in the deeper strata of lake Vaenern there was also considerable summer reproduction. Thienemann (1925) summarized the data on the reproductive period of *Mysis* from his own studies on north German lakes and from the work of Ekman, and Samter and Weltner. He concluded that summer

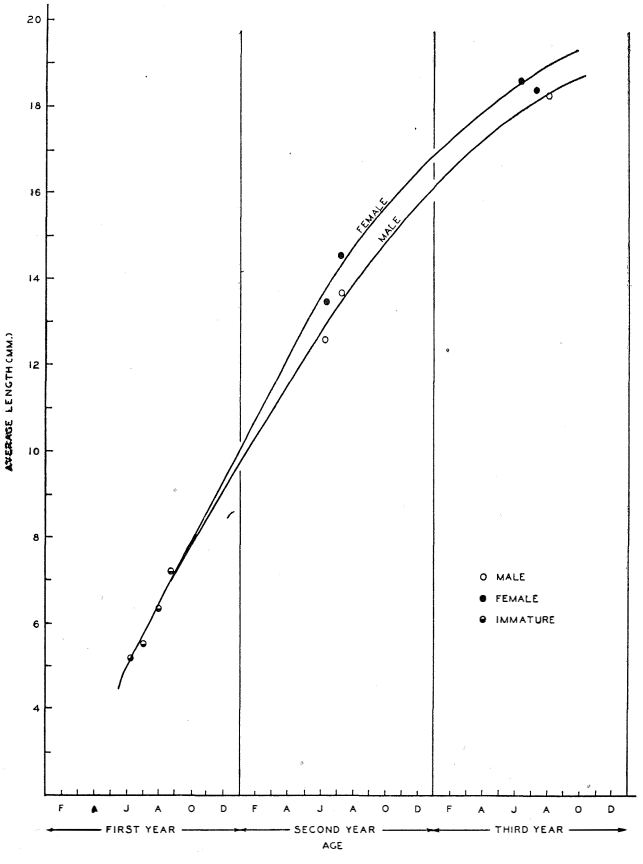


FIGURE 14. Rate of growth of *Mysis*.

reproduction was unpredictable from one lake to another. In some oligotrophic lakes reproduction occurred only in the winter months (lake Vaettern and some north German lakes); while in others reproduction occurred in both summer and winter (Lucin lakes and lake Vaenern). In eutrophic lakes summer reproduction was absent (Madue lake). In Great Slave lake summer reproduction is negligible. Only three embryo bearing females were found in all of the summer collections. Whether Samter and Weltner are justified in assuming that year-round reproduction is the normal situation is difficult to decide. Certainly

conditions in the profundal region of Great Slave lake are suitable for year-round reproduction as far as temperature is concerned.

A second feature of interest is the length of life of *Mysis*. Ekman found that *Mysis* became sexually mature at the age of one year but lived to produce a second brood, thus having a life span of two years. In Great Slave lake *Mysis* become mature at the age of two years, and it is doubtful if more than a small fraction of individuals live on to produce a second brood in their third year. The limits of the reproductive period are probably September or October until June.

GENERAL DISCUSSION

The distribution of *Pontoporeia* and *Mysis* has been studied extensively in eutrophic lakes. Thienemann, Samter and Weltner, and Ekman have all described the ecology of these crustaceans, and it was largely on the basis of the study of eutrophic lakes that they established temperature and oxygen limits for them. Studies of *Pontoporeia* and *Mysis* in North American lakes have proved to be contradictory to the European work. Birge and Juday (1927) found that in Green lake, *Mysis* and *Pontoporeia* could be found where oxygen concentrations were below 1 cc. per litre, which is far below Thienemann's limit of 4 cc. per litre. In Shakespeare Island lake (Cronk 1932) *Pontoporeia* is found in the hypolimnion where oxygen concentrations fall to 2.3 cc. per litre in midsummer. In this lake, however, *Pontoporeia* is not found where temperatures exceed 14.5° C. which is in accord with the limit set by Ekman.

While the study of the northern oligotrophic lakes is not suited to observing the effect of oxygen concentration as a controlling factor, their shallow waters show the limiting effect of high temperatures. In this case also the tolerance limits are not as clear cut as those observed in European lakes. In lake Athabaska and lake Nipigon, *Pontoporeia* is less abundant where temperatures are higher but it is not excluded entirely from the shallower depths. *Mysis* also is found in Great Slave lake in spite of high temperatures, where conditions of low light intensity prevail.

This would suggest that some other factors are of importance in limiting the distribution of *Mysis* and *Pontoporeia* in both the eutrophic and oligotrophic lakes of North America in which they are found. The question of the origin of these relicts is an important consideration in attributing their absence from any particular lake to peculiarities of its physical and chemical conditions. The writer has collected a considerable quantity of information concerning the distribution and origin of these species in North America and it is his hope that this study of the northern lakes will be preliminary to a more general consideration of the distribution and ecology of relict crustacea in the lakes of the continent as a whole.

In general *Mysis* and *Pontoporeia* thrive in oligotrophic lakes, and occasionally in moderately eutrophic lakes. Inasmuch as they make important

contributions to the fish food in the lakes in which they occur, transplanting them into alpine and subalpine lakes of low productivity might be a valuable experiment. A number of relatively unproductive lakes of this kind are described by Rawson (1942).

CONCLUSIONS

1. *Pontoporeia* is the most important organism of the macroscopic bottom fauna in each of the three northern lakes, Great Bear, Great Slave and Athabaska. In the latter two, *Pontoporeia* makes up more than 60 per cent of the total bottom fauna both by numbers and wet weight.

2. The depth distribution of *Pontoporeia* in these lakes reflects their respective degrees of extreme oligotrophy: (a) In Great Bear lake *Pontoporeia* is present only in depths of less than 50 metres; (b) In Great Slave lake *Pontoporeia* is present at all depths, but in depths greater than 50 metres the numbers and average size of the individuals are reduced; the latter to the extent that one-year-olds are retarded 7 months in their development. (c) In lake Athabaska *Pontoporeia* is present at all depths. Neither the number nor average size is significantly reduced in depths greater than 50 metres. In depths of less than two metres it is limited in its abundance by sustained high temperatures.

3. *Pontoporeia* contributes 60 per cent to the food of the common whitefish in Great Slave lake; 40 per cent in lake Athabaska.

4. *Pontoporeia* lives for slightly more than two years in Great Slave lake, and reproduces at the age of two years. Reproduction takes place during the winter months at all depths of the lake. In depths of less than 10 metres summer reproduction is inhibited by temperatures greater than 7° C. (confirming the work of Samter and Weltner 1904). In depths of greater than 30 metres a "summer brood" is conceived, the major portion of which is "born" in the early winter months.

5. *Mysis* is abundant in Great Bear lake and Great Slave lake and is rare in lake Athabaska.

6. *Mysis* is found at all depths of Great Slave lake, and in depths of less than 10 metres it is found in spite of high temperatures where conditions of low light intensity prevail.

7. Adult *Mysis* tend to concentrate near the bottom while immature *Mysis* are scattered more evenly throughout the overlying strata, indicating the greater sensitivity of the adults to light (confirming Southern and Gardiner 1926).

8. *Mysis* plays an important role in the food cycle of Great Slave lake in its contribution to the food of ciscoes and young lake trout.

9. *Mysis* lives for slightly more than two years in Great Slave lake and reproduces in the winter months at the age of two years.

10. Both *Mysis* and *Pontoporeia* were observed to vertically migrate diurnally in Great Slave lake; the former commonly, the latter on only one occasion in shallow water.

11. It is suggested that these crustaceans might be transplanted to augment the sparse bottom fauna of some subalpine and alpine lakes.

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