

MEDDELELSER OM GRØNLAND

UDGIVNE AF

KOMMISSIONEN FOR VIDENSKABELIGE UNDERSØGELSER I GRØNLAND

Bd. 100 · Nr. 10

TREARSEXPEDITIONEN TIL CHRISTIAN DEN X's LAND 1931-34

UNDER LEDELSE AF LAUGE KOCH

EAST GREENLAND LAKES AS HABITATS
FOR CHIRONOMID LARVAE

STUDIES ON
THE SYSTEMATICS AND BIOLOGY OF CHIRONOMIDÆ. II.

BY

F. SØGAARD ANDERSEN

WITH 1 FIGURE IN THE TEXT AND TWO PLATES

KØBENHAVN

C. A. REITZELS FORLAG

BIANCO LUNOS BOGTRYKKERI A/S

1946

CONTENTS

	Page
I. Introduction	5
II. Methods	9
III. Description of the Lakes.....	11
1. Position.....	11
2. Langsø.....	11
3. Rundsø	20
4. Ulvesø	29
5. Bjørnesø	31
IV. Remarks on the Animals.....	33
1. Forms found in the bottom samples.....	33
2. Forms found in the conserved plankton	39
3. Forms found by examination of the living plankton	42
4. Forms caught occasionally	43
V. Hibernation of the Chironomids.....	45
VI. Duration of Development of the Chironomid Larvae.....	50
VII. Comparison of the Lakes.....	51
VIII. Comparison with other Lakes.....	56
1. Type of lakes.....	56
2. Zonation of the bottom	58
IX. Main Results.....	61
X. Literature.....	64

I. INTRODUCTION

In the present paper the author has tried to describe some small, shallow, East Greenland lakes on the basis of one year's investigation on the spot, and it is the intention to give as much information as possible on the lakes and the animals living in them, these being the first arctic lakes in which the bottom fauna has been subject to a quantitative investigation.

The position, form and size of the lakes can be seen on the map published by the Geodetic Institute and appended to this paper; the geology of the surroundings is described by BÜTLER (1937).

Hydrographic measurements were not carried out owing to lack of time and apparatus. Bottom samples have, on the other hand, given pretty thorough information on depths and the various kinds of bottom material.

A great number of plankton samples, taken at regular intervals all the year round, has already been dealt with in two papers (POULSEN 1940 a and b).

In the present paper the main stress is therefore laid on the description of the bottom fauna. This is, in these lakes, almost entirely composed of chironomid larvae. The great importance of these animals for the description and classification of lakes is known from the extensive literature on types of lakes. As reviews and criticisms of this literature have recently been published (LANG 1931, BERG 1938, PAGAST 1940 and others) it will not be generally dealt with here, and the reader is likewise referred to the extensive list of literature on this subject given by the authors just mentioned. There is, however, one single aspect of this matter to which, in my opinion, too little attention is generally paid, viz., the question of the determination of the chironomid larvae. It is common knowledge that many species of *Chironomidae* cannot be distinguished as larvae, and in the systematics of the larvae the authors therefore operate with groups instead of species, one group covering all the species, the larvae of which cannot be distinguished. A determination of the larvae as to species is accordingly possible only by

rearing them. This fact has, however, only slightly worried the authors of the literature on types of lakes, because they have generally accepted the rule that larvae, which are uniform in their morphology, are also physiologically alike. This has been clearly formulated by LENZ (1928, p. 3): "eine Larvenform, die morphologisch ihr besonderes Gepräge hat, besitzt auch meist ihre ganz spezielle Reaktionsnorm gegenüber der Aussenwelt, ganz gleichgültig ob sie die gemeinsame Larvenform einer Artengruppe, einer Gattung oder einer Gattungsgruppe ist". This rule has been generally accepted (also by the present author, 1938, p. 322); limnological papers have been published dealing mainly with chironomid larvae (e. g. LANG 1931 and BRUNDIN 1942), and ecological and physiological experiments have been made with these larvae, all without any attempt at rearing them.

One exception to the rule is already found in the same paper in which it was first published (LENZ 1928, p. 5): "Indes scheint es doch, als wenn wir nur eine Art als die ausgesprochene Charaktertype für den ganz oligotrophen See bezeichnen können, nämlich die Art *Lauterbornia coracina* KIEFF. Leider aber ist diese Art von den übrigen Arten der *Eutanytarsus*-Gruppe nur sehr schwer zu unterscheiden (vergl. ZAVŘEL 1926 und THIENEMANN 1928). Jedenfalls aber dürfte in diesem Falle die Imaginalart die ökologische Type sein."

PAGAST (1940, p. 388) curtly announces that the rule is wrong: "Dieser "Kurzschluss" in der Analyse der Chironomidenbesiedlung der Gewässer ist unberechtigt." Here PAGAST is not quite right, because when representative bottom samples have been taken in a lake, and the chironomid larvae from the samples have been carefully determined as to group, it is often possible to a certain extent to place the lake in relation to the main types of lakes, even if no rearing is carried out, and PAGAST himself discusses the ecology of the groups *gregarius*, *inermipes* and *lauterbornia* (loc. cit.). On the other hand it is right that a determination of the larvae as to species is necessary for a more detailed determination of the type of a lake and above all for the introduction of a new type.

A further example of ecologically different species within a group of larvae may be mentioned here, viz. those of the *Sergentia* group. The larvae of this group were first described by LENZ (1927). In his paper LENZ plainly takes it for granted (p. 155) that *Sergentia* from North Germany and from the Norwegian mountains have the same ecological valence, and that in spite of the fact that only *S. profundorum* has been reared in Germany and only *S. longiventris* in Norway. BRUNDIN (1942) finds a distinct discrepancy in the claims of the *Sergentia* larvae regarding the humosity of some lakes in Sweden and in the claims of those investigated by LENZ in the Norwegian mountains, but he does

not draw the conclusion that the different species of *Sergentia* make different ecological claims.

This has, however, been irrefutably proved by THIENEMANN (according to verbal communication) during investigations in the Lunzer Unter- and Mittlersee. In these two lakes, which lie so close together that a chironomid may easily fly from one to the other, he has found two different species of *Sergentia*, one in each lake. This has been confirmed through examination of the megachromosomes, which show clear differences between the two larvae, these being otherwise quite homogeneous.

From this it can be concluded that species belonging to the same group of larvae cannot be considered ecologically equal unless so proved in every single case. This implies that if chironomid larvae are to be used to characterize a lake, it is necessary to rear them. It is, however, impossible to rear every larvae in all samples, for one thing because often rearing does not succeed. It is, therefore, necessary to make representative catches of imagines round the lake and to collect exuvia of the pupae on its surface in order to find out which species might possibly live as larvae in the lake.

The present paper should therefore be regarded in connection with the earlier one (1937), which contains determinations and descriptions of the imagines, and descriptions of the stages of metamorphosis of the *Chironomidae* from the neighbourhood of the lake.

The reason why the lakes dealt with here have been subjected to such a detailed description, is the hope that the present paper in conjunction with the earlier one may serve as a means of comparison for future investigators of arctic lakes.

In the previous paper the diagnosis of the genera of *Chironomidae* were without exception taken from Faune de France (GOETGHEBUER). Since then many names of genera have been altered or changed (e.g. *Trichotanytus* → *Procladius*; *Pentapedilum* (*Sergentia*) → *Sergentia*). The names used in the former paper have, however, been retained in the present one in order to avoid confusion.

It was as a participant in The Three-Year Expedition to Chr. X's Land that I carried out these investigations. I am much indebted to Prof. ADOLF S. JENSEN for making it possible for me to take part in the expedition. On my arrival up there, I found a complete winter station, entirely equipped and with valuable traditions, so that I could immediately commence my work. That year in Greenland was one of my happiest and best working years. This is primarily due to the leader of the expedition, Dr. phil. LAUGE KOCH, who, on account of his

experience through many years as a Greenland explorer and his understanding interest in the requirements and anxieties of every participant, can lay claim to the gratitude of everyone who took part in the expedition. I am also deeply grateful to those scientists, who, in the first year of the expedition, used several months of their valuable time in building and fitting out the station, and in creating traditions of which we later members were proud. In this connection I likewise wish to express my gratitude for the work which others have carried out at the station and which has benefited my own work: Dr. phil. G. THORSON and Dr. phil. TH. SØRENSEN, who, two years before, stayed the winter at the station as marine biologists and botanist respectively, and who, with a primitive apparatus, carried out a quantitative investigation of the bottom fauna in Langsø. I had the opportunity of working with this material under the guidance of Prof. Dr. phil. R. SPÄRCK, before my departure, which gave me the great advantage of knowing the most important forms of chironomid larvae before arriving in Greenland. The knowledge of the bottom fauna in Langsø was also an important presupposition to the inspiring instructions I received from Prof. SPÄRCK on my departure; in this place I also want express my grateful thanks to the Professor for the help he has given me in my work both then and later. Land-surveyer O. SIMONSEN, mag. scient., and Topographer, Stabsofficiant S. O. STENØR carried out an exact survey of the Cape Oswald peninsula; the map, which is appended, has been an invaluable support, both during my work in Greenland and during the preparation of the manuscript for the present treatise. Dr. phil. TH. SØRENSEN partly with the help of the telegraphist, A. DE LEMOS, undertook meteorological observations at the station, these meteorological measurements have not been directly employed in my work, but they will be of great interest for comparison with other arctic lakes, which may be investigated in the future. The same may be said of the accurate geological investigation made by Dr. H. BÜTLER of the territory in which the lakes are situated.

Thanks are likewise due to the Director of the Zoological Museum, Prof. Dr. R. SPÄRCK, for allowing me to carry out my work at the museum.

I am also indebted to G. SEIDENFADEN, cand. polit., for the loan of the photograph, fig. 1, and to Miss D. W. BROWN for having corrected the manuscript with reference to the English language.

II. METHODS

For collecting of material two main sorts of gear were used, an Ekman-Birge bottom sampler and a fine plankton net.

The work with the bottom sampler will be thoroughly described, because in the arctic difficulties arise, which are avoided during investigations in a warmer climate. The sampler covered an area of $15 \times 15 \text{ cm}^2$, it was 17 cm high and weighed about 2 kg. With this gear 173 samples were taken. About two thirds of them were taken in open water from a rubber boat; as this boat was very light, it was often necessary to put out an anchor to prevent it from drifting with the wind, while the samples were taken. The rest of the samples were taken through holes in the ice; in this way one can very quickly take some samples when the ice is thin, but when it is 1 m or more, it takes more than an hour to make a hole. Such holes were made in two spells; first a hollow of $1 \times 1 \text{ m}$ was made as deep as possible with a long-helved axe; through the rest of the ice a hole was made by means of an ice chisel, just big enough to allow the sampler to pass. Throughout the work it was necessary now and then to dig out the ice powder from the bottom of the hollow. When samples were taken through the ice, the temperature of the atmosphere was generally more than 20 degrees below zero; under these conditions the jaws of the sampler would soon freeze to the box. It is most practical to leave it open when used and let it freeze while open; when the next sample is to be taken, the sampler is thawed by holding it for a while in the water before letting it down to the bottom. When the chains are made of brass, as was the case with the sampler used in the investigation in question, and the links are simple rings with an incision on one side, they would often snap off owing to the softness of the metal. During the work in Greenland one of the small brass pieces holding the jaws when the sampler is open, was lost in consequence. It is therefore advisable to have a reserve of such pieces as well as chain-links. The best thing would be to have chains of the kind shown by LUNDBECK (1926 fig. 1 and 2) as the links of these chains cannot open.

When the sampler came up either on the deck of the rubber boat or on to the ice, it was opened over a sieve, which was so fine that the

gyttja could not go through; the contents were brought home where they were put into a white enamel tray in small portions, and the animals were picked out under sharp electric light. Other authors have used sieves with 0.6 mm meshes, so that the gyttja could be washed through. This method is quicker, but has the fault that many larvae of the small species of *Chironomidae* such as *Corynoneura* and young larvae of the bigger species will go through the meshes (see also OLSTAD 1925).

The chironomid larvae from the samples were as far as possible determined in a living condition and some of them used for rearing and determination (see ANDERSEN 1937).

The plankton net used was a simple bag without a pail. Samples were taken in Langsø and Rundsø every fortnight. In the summer they were taken from the rubber boat. As the same boat and net were used in both Langsø and Rundsø, and as the two lakes lie close together plankton organisms may have been carried from one lake to the other, but the net was thoroughly washed before and after every use, and the fact that the two lakes have no plankton crustaceans in common (except *Cyclops strenuus*, see p. 35) proves that this source of error did not influence the results of the investigation. In the winter, the samples were taken through permanent holes in the ice. On Langsø the hole was kept open by the Eskimos, fetching the water for the station in it. On Rundsø the hole was protected by a little shed that could be warmed by a Primus radiator. (This is a comfort, when samples have to be taken in 20—40 degrees of cold, but it is not necessary). Of course both holes had often to be hewn out in order to prevent them from closing. (It may generally be said that good ice chisels (tuks) and long helved axes and reserve helves for both of them are absolutely necessary tools for the limnologist in the arctic).

In the other two lakes plankton samples were occasionally taken; in the summer the samples were taken with the net tied to the catcher bar by a short line; in this way it was hauled several times backwards and forwards after wading out as far as the long bluchers allowed. In the winter the samples were taken through holes in the ice, which had to be hewn anew each time.

The 66 plankton samples taken have recently been dealt with in two papers (POULSEN 1940 a and b) and will therefore only be mentioned in as far as they are of interest for the description of the lakes.

The thickness of the ice was measured by means of a two meter long standard with a bar (about 40 cm long) fixed at right angles to the zero end in order to ensure that the zero was held exactly at the lower edge of the ice during the measuring.

III. DESCRIPTION OF THE LAKES

1. Position.

The lakes dealt with in the present paper are only a few examples of the numerous small shallow lakes on Ella Island in the Franz Joseph Fjord District of North-East Greenland. They lie on Cape Oswald Peninsula or on the acclivity south of it; about 72°50' N. Lat. 25°00' W. Long. The Praecambrian and Cambrian layers, which constitute the surface here, incline sharply towards the south (BÜTLER 1937), and the lakes in question lie in the valleys running approximately NE—SW. which are formed by erosion of the heads of the lesser resistant layers. The climate of the region has been thoroughly described by SØRENSEN (1941, p. 28—47); it can be characterized as high arctic and continental.

2. Langsø (Long Lake).

Langsø is the best investigated of all the lakes. It lies on an under-layer of Eleonora Bay formation (Praecambrian slates and limestones) and has its biggest extension in a NE—SW. direction. At the southwestern end the soil consists of moving soil covered with mixed chamaephyte-vegetation. The north-western and south-eastern banks are formed by the almost naked heads of the layers, the only vegetation of which is scattered *Dryas* plants (the so-called fell-field vegetation). At the north-eastern end the bank again consists of moving soil covered with mixed chamaephyte-vegetation, but here intermixed with *Carex* and *Graminea*, and it is at this end that the water runs off during the short melting period. In the same period a diffuse afflux of melting water is found, but no fixed afflux is formed.

The form of the lake is shown on the map. It is about 650 m by 140 m and covers an area of about 5 ha. The greatest depth is 2 m and it can approximately be estimated that half of the bottom is more and half of it less than 1 m under the surface; reckoning with an average depth of 1 m, the water content of Langsø will amount to about 50,000 m³.

Table 1. Langsø 1933.

The series of samples was taken along 6 lines running between 8 points shown by the figures
For all chironomids the

Line	I—II					
Sample no.....	43	44	108	109	110	111
Date	22.	22.	6.	6.	6.	6.
Month	VIII.	VIII.	IX.	IX.	IX.	IX.
Depth (m).....	0.1	0.3	0.5	0.4	0.4	0.5
<i>Trichotanypus choreus</i>	6	5	27	12	11	6
<i>Chironomus hyperboreus</i>	..	12	4	28	2	62
<i>Pentapedilum coracinum</i>	1	1	..	..	..	12
<i>Ditanytarsus setosimanus</i>	..	7	4	14	31	9
<i>Tanytarsus niger</i>	10	12	1	..	..	..
<i>Phoenopelma</i> sp.....	..	..	..	..	..	12
<i>Cricotopus glacialis</i>	..	..	..	..	1	2
<i>Psectrocladius</i> spp.....	3	1	1	..	2	1
<i>Corynoneura scutellata</i>	..	..	..	7	..	..
<i>Orthocladius ?consobrinus</i>	3	..	..	..	..	..
<i>Hydracnidae</i>	..	..	..	..	..	..
<i>Lepidurus arcticus</i>	..	1	..	..	..	..
<i>Candona candida</i>	..	..	1	..	1	1

Line	VI—V							
Sample no.....	153	154	155	156	157	158	159	170
Date	22.	22.	28.	28.	1.	1.	1.	5.
Month	IX.	IX.	IX.	IX.	X.	X.	X.	X.
Depth (m).....	0.2	0.2	0.5	0.6	0.4	1.0	1.25	1.25
<i>Trichotanypus choreus</i>	3	4	30	21	7	1	11	..
<i>Chironomus hyperboreus</i>	6	5	18	2	..	7	22	..
<i>Pentapedilum coracinum</i>	..	3	1	..	..	..	..	..
<i>Ditanytarsus setosimanus</i>	8	2	4	..	1	1	21	1
<i>Tanytarsus niger</i>	..	..	..	..	..	..	..	4
<i>Phoenopelma</i> sp.....	..	..	..	..	..	6	..	..
<i>Cricotopus glacialis</i>	1	..	4	..	..	..	..	..
<i>Psectrocladius</i> spp.....	8	1	15	2	5	..	3	..
<i>Corynoneura scutellata</i>	5	14	15	..	..	..	..	..
<i>Orthocladius ?consobrinus</i>	..	..	3	2	..	..	..	..
<i>Hydracnidae</i>	..	..	..	..	..	..	..	..
<i>Lepidurus arcticus</i>	..	..	..	..	..	..	..	..
<i>Candona candida</i>	..	..	..	3	3	7	..	2

Number of Individuals.

I—VIII on the map. In the table the lines are marked by the figures of the termination points. number means larvae.

II—VIII								VI—IV			
112	116	117	118	119	182	181	180	149	150	151	152
6. IX.	7. IX.	7. IX.	7. IX.	7. IX.	10. X.	10. X.	10. X.	22. IX.	22. IX.	22. IX.	22. IX.
0.75	0.75	1.5	2.0	1.0	0.5	0.6	0.4	0.3	0.5	0.5	0.3
6	4	37	19	16	..	5	6	11	3	7	5
44	14	1	..	9	7	3	7	7	2	14	4
..	1	1	..	1	5	..	9	..	..	..	..
7	..	10	..	6	1	5	4	10	1	11	17
2	..	..	..	..	..	..	..	..	..	..	..
7	..	3	1	..	..	7	..	..	..	..	..
..	..	..	..	..	..	2	2	3	..	6	5
1	..	1	..	3	..	5	4	3	2	3	7
..	..	..	..	..	..	6	65	..	3	10	4
2	..	..	..	..	..	..	..	..	..	3	..
1	..	1	..	1	..	..	1	..	..	..	1
..	..	..	..	..	..	..	..	1	..	..	..
2	..	..	1	..	..	1	2	..	..	..	..

VII—VIII							VIII—III						
171	172	173	176	177	178	179	191	192	193	195	196	203	204
5. X.	6. X.	6. X.	9. X.	9. X.	9. X.	9. X.	12. X.	12. X.	12. X.	15. X.	15. X.	20. X.	20. X.
1.5	1.5	1.75	1.75	1.25	0.75	0.5	0.75	1.0	1.5	1.75	1.75	1.75	1.25
3	9	21	4	12	2	1	11	27	18	11	..	..	26
..	..	..	..	1	..	2	5	25	..	..	..	..	1
..	..	..	2	..	..	3	6	4	..	..	..	..	..
..	11	..	..	..	2	6	5	20	..	..	..	..	..
7	..	17	12	12	3	..	..	40	12	3	2	..	18
..	..	..	6	2	..	..	3	27	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	32	6	6	4	..	..	..	..	7
..	..	..	..	..	4	2	..	..	..	..	..	..	..
..	..	..	..	1	..	..	..	..	..	..	..	..	..
..	..	..	..	..	5	4	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..
..	..	1	..	..	..	..	4	3	1	..	..	..	..

[illegible]

Number of Individuals.

I—VIII on the map. In the table the lines are marked by the figures of the termination points. gyttja; (bg) = mixed with black gyttja; d = detritus; gg = grey gyttja; l = lime concretions; number of chironomids is given by a fraction, the numerator means larvae and the denominator of chironomids always means larvae.

II—VIII								VI—IV			
582	583	584	588	589	590	625	626	554	557	565	566
23.	23.	23.	26.	26.	26.	7.	7.	13.	15.	16.	16.
VI.	VI.	VI.	VI.	VI.	VI.	VII.	VII.	VI.	VI.	VI.	VI.
0.6	1.4	1.1	1.3	1.0	1.0	0.8	0.7	0.4	0.5	0.4	0.4
B l	bg	s st l	s (bg)	s (bg)	s (bg)	s st l	mv	l m	bg l	l	st l B
37	37	16	48	7	3	10		21	22	12	8
31	1	18	..	8	8	3		4	10	18	2
3	14	6/3	6/1	1/1	..	1		..	..	..	..
34	4/1	2	..	8	..	3/2		6	9	44	3
0/1	6/15	..	6/19	0/1	1	..		..	..	..	..
..	4	3	6	3	..	..		..	..	..	..
1	..	..	..	1	..	10		7	9	97	4
..	..	2	4	2	..	..		10	4	13	5
..	..	1	..	2	1	0/1		..	7	8	18
..	..	..	..	..	..	2/1		..	..	..	..
1	..	..	..	1	1	1		..	2	1	..
..	..	..	..	..	..	1		..	..	..	..
2	..	..	..	..	..	..		..	..	..	..

VII—VIII							VIII—III						
738	737	736	735	734	733	732	707	708	711	712	713	714	715
VIII.	VIII.	VIII.	VIII.	VIII.	VIII.	VIII.	VII.	VII.	VIII.	VIII.	VIII.	VIII.	VIII.
14.	14.	14.	14.	13.	13.	13.	31.	31.	3.	3.	3.	3.	3.
1.7	1.7	1.5	1.2	1.5	1.0	0.7	0.5	0.8	0.5	1.0	2.0	1.75	1.75
bg	bg	bg	bg	gg	bg l	l	l P	bg l	l	bg l	bg	bg	bg
8	7	5	7	17	10	22	9	7	1	11	7	14	13
..	..	..	..	..	9	7	12	4	2	5	..	..	..
..	..	..	1	..	2	1	..	1	3	2	..	..	..
..	..	..	..	..	34	60	14	1	15	3	1	..	..
25	17	17	33	17	1	..	..	..	..	..	..	23	16
..	..	..	..	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	75	28	4	9	4	..	..	..
2	..	1	3	2	19	12	21	2	2	5	1	2	1
..	..	..	..	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	2	..	..	2	..	..	..
..	..	..	..	..	..	3	3	..	2	..	..	2	2
1	..	..	1	1	2	..	..	..	..	2	1	..	1
..	..	..	..	..	..	..	..	..	..	..	..	..	..

The surface temperature of the water rises in summer to 10° (on 8.VIII.1933 12.5° was measured).

Regarding the cover of ice the following information can be given: in 1933 the shallow ends of the lake were first frozen, and on 19.IX. the ice here was thick enough to bear, while there was still open water over the deeper parts of the lake. On 1.X. the ice here was also thick enough to bear. About 1.II.1934 the ice was 1 m thick, and from then onwards the increase in thickness was slow; in April it attained its greatest thickness (1.25 m), and then it became thinner: 1 m about 1.VI., and 0.85 m on 10.VI. The melting of course took place in the reverse order, the shallow parts, particularly the western end, being thawed first.

Thus the lake was completely covered with ice from about 25.IX.1933 until about 20.VI.1934, that is 9 months, and for 4 of these the ice was 1—1.25 m thick. Reckoning approximately that where the lake is more than 1 m deep the average depth is 1.5 m, the non-frozen water is calculated to amount to about $12,500 \text{ m}^3$, when the ice is 1 m thick. This mass of water receives no supply of oxygen from the air for 9 months, and for 4 months it is the only source of oxygen supply for the bottom below it. Thus, half the bottom consumes in 4 months the oxygen contained in one fourth of the water of the lake, after it has already been used by plankton and the bottom for 4—5 months. Moreover, the oxygen production by the CO_2 assimilation during most of this time is very small owing to lack of light. From the first week of November to the beginning of February the sun is not above the theoretic horizon, and in the time before and after this period the days are of course very short and the sun very low. The 1 m-thick ice and a layer of about 20—40 cm snow on it contribute further to the reduction of light.

Bearing these facts in mind it is not astonishing that all oxygen was consumed; on 19.III.1934 the water smelt slightly of H_2S , and on 25.III. the smell was intense and the water yellow brown. (From that date onwards we began fetching the drinking-water from Rundsø; we had hitherto used the Langsø water, but it smelt so intensely that it poisoned the air in the house when it stood in the water barrel).

On 9.V., that is a month before there was any open water on the lake, the smell had disappeared, and the water could again be used as drinking-water. This change was surely due to CO_2 assimilation, owing to the sun being higher and the days longer and to the wet snow allowing more light to pass through.

In Langsø 80 bottom samples were taken, 40 samples between 22.VIII. and 20.X.1933 (table 1) and 40 samples between 12.V. and 14.VIII.1934 (table 2).

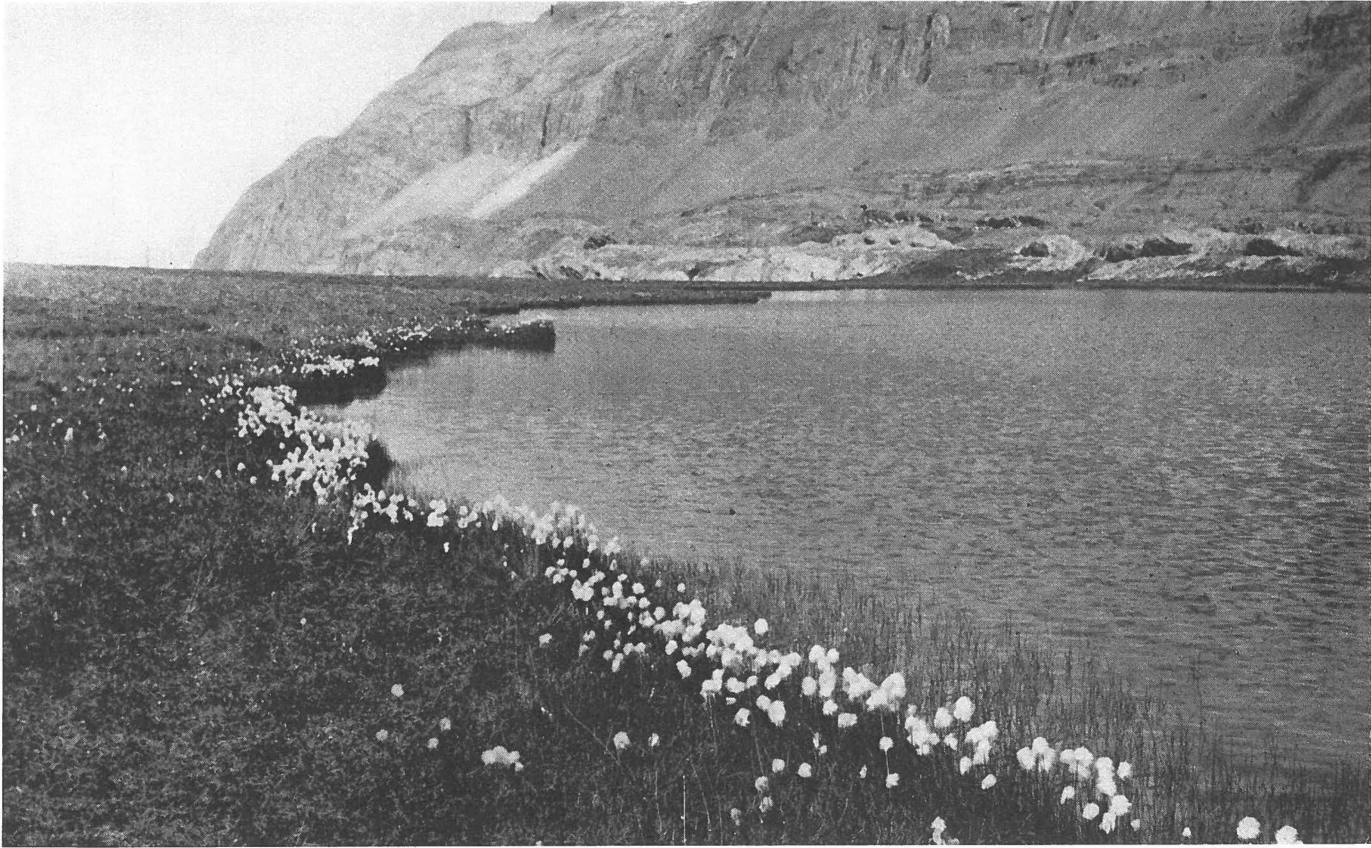


Fig. 1. Langsø (about 1.VIII.1933). Eastern end seen from the west. G. SEIDENFADEN fot.

The kind of bottom material was noted only in 1934 and is shown in table 3. The figures in this table give the number of samples, out of 40, in which the various kinds of bottom material were present. It will be seen in table 2 that one sample may contain two or three kinds of bottom material, e. g. no. 625: sand, stone and lime concretions.

As it appears from the table, the predominant sediment at depths less than 1 m was lime concretions; they were grey, porous and fragile and their size varied from a few mm to about 5 cm.

Table 3. Kind of bottom material.

Depth (m)	0.1—0.9	1—1.25	1.3—2	total
Number of samples	22	7	11	40
Lime concretions	19	3	..	22
Gyttja (black and grey)	2	5	10	17
Stones or sand and stones	4	1	..	5
Sand mixed with black gyttja	..	2	1	3
Sand and detritus	2	..	..	2
Turf	1	..	..	1
<i>Potamogeton</i> and <i>Batrachium</i>	3	..	..	3
Moss	1	..	..	1

These lime concretions were rare at depths of more than 1 m, and they were not found at depths greater than 1,1 m. This is due to the fact that the acid, CO₂-saturated water will dissolve any lime in winter, but at the time when the water turns acid, the upper 1 m of the bottom is protected against dissolution by the ice, which at this time is about 1 m thick. Gray and black gyttja is as characteristic of the depths greater than 1 m, as lime concretions are of lesser depths. Finally it may be seen from table 3 that higher plants and mosses are present only in 4 samples, all from depths less than 1 m.

As shown in the above a limit at about 1 m is marked both by the thickness of the ice and the benthic distribution of the various kinds of bottom material. It is natural therefore that this limit is well marked in the benthic distribution of the chironomids. This is shown in table 4, which is based on tables 1 and 2. From table 4 it appears that 3 forms are indifferent with regard to depth, viz. *Trichotanytus choreus*, *Phenopelma* sp. and *Pentapedilum coracinum*, while the remaining 7 forms mark the limit distinctly, 1 form, viz. *Tanytarsus niger*, being favoured by the conditions at a depth of more than 1 m, the other 6 preferring lesser depths. 3 of these 6, viz. *Ditanytarsus setosimanus*, *Psectrocladius* spp. and *Orthocladius ?consobunus*, are equally distributed over depths of less than 1 m; the remaining 3, on the other hand, mark a limit at

Table 4. Benthic distribution of *Chironomidae* in Langsø.
The table shows the average number per sample of individuals (larvae + pupae).

Depth (m)	0.1— 0.3	0.4	0.5	0.6— 0.8	1.0— 1.25	1.3— 1.5	1.7— 1.75	2.0
Number of samples	11	9	12	13	14	8	11	2
Indifferent forms:								
<i>Trichotanytus choreus</i>	10.8	14.8	11.2	15.0	10.9	21.8	11.7	13.0
<i>Phenopelma</i> sp.	..	0.7	1.1	1.5	2.9	1.6	0.6	0.5
<i>Pentapedilum coracinum</i>	0.5	1.0	2.0	1.0	1.9	2.8	0.2	..
Forms preferring depths > 1 m:								
<i>Tanytarsus niger</i>	2.0	0.2	0.1	0.5	8.0	12.4	17.3	..
Forms preferring depths < 1 m:								
Forms indifferent at depths < 1 m:								
<i>Ditanytarsus setosimanus</i>	17.1	12.3	6.2	18.2	6.9	3.3	..	0.5
<i>Psectrocladius</i> spp.	5.1	4.6	5.9	5.8	3.4	1.0	0.5	0.5
<i>Orthocladius ?consobrinus</i>	0.2	..	0.6	0.5	0.2	..	..	..
Forms preferring depths of 0.5—1.0 m								
<i>Chironomus hyperboreus</i>	6.8	7.2	12.1	12.1	8.1	0.3	..	..
Forms preferring depths < 0.5 m:								
<i>Cricotopus glacialis</i>	14.0	12.6	5.3	7.6	0.4	..	..	..
<i>Corynoneura scutellata</i>	4.4	11.3	4.1	0.9	0.3	..	..	..

0.4—0.5 m. This is not so distinct as the 1 m limit, but still it is obvious that *Chironomus hyperboreus* prefers depths of 0.5—1.0 m, while *Cricotopus glacialis* and *Corynoneura scutellata* attain the greatest density at lesser depths. Which factors determine this latter limit cannot be said with certainty, but it is likely that the temperature is of some consequence, the shallow water being more quickly warmed by the insolation and therefore providing higher temperature in the summer.

In view of the two ecological depth limits, it is natural to divide the bottom settlements into 4 benthic zones as shown in table 5, viz. 0.1—0.4 m, i.e., above the upper limit, 0.5—0.8 m, i.e. between the two limits, 1.0—1.25 m, i.e. the boundary zone at the lower limit, and 1.3—2 m, i.e. below the lower limit. Apart from the ubiquitous *Trichotanytus* two animal communities can be distinguished, viz. a *Tanytarsus niger* community at 1—2 m and a *Ditanytarsus setosimanus* community at 0—1 m. The *Tanytarsus* community is a real profundal community with its monotony, 2 forms constituting 86 % of all individuals. The *Ditanytarsus* community is a littoral community with great heterogeneity, no form reaching 25 %. By the upper limit this community is divided into two zones: a *Chironomus* zone at 0.5—1 m and a *Cricotopus* zone at 0—0.5 m.

Table 5. Langsø. Animal Communities.
Number of individuals in percentages of all individuals.

Depth (m)	0.1—0.4	0.5—0.8	1.0—1.25	1.3—2.0	Total
Number of samples	20	25	14	21	80
<i>Trichotanypus choreus</i>	20	23	25	46	26
<i>Pentapedilum coracinum</i>	1	3	4	3	3
<i>Phoenopelma</i> sp.	0.5	2	7	3	3
<i>Tanytarsus niger</i>	2	0.5	18	40	11
<i>Ditanytarsus setosimanus</i>	24	22	16	4	18
<i>Psectrocladius</i> spp.	8	10	8	2	8
<i>Chironomus hyperboreus</i>	11	21	19	0.3	14
<i>Cricotopus glacialis</i>	21	11	0.8	..	11
<i>Corynoneura scutellata</i>	12	4	0.7	..	5
<i>Orthocladius ?consobrinus</i>	0.2	0.6	0.5	..	0.5
Other animals	1	3	1	2	2
Total number per sample...	63	58	44	34	50

In addition to the animals present in the bottom samples the following animals have been found in Langsø:

Turbellaria (sp. indet.)

Nematoda

Mermis sp.

Rotatoria

Loricata (*Anuraea* sp.)

Illoricata A (conf. *Polyarthra*)

Illoricata B.

Entomostraca

Lepidurus arcticus

Daphnia pulex

Simocephalus vetulus

Chydorus sphaericus

Cyclops strenuus.

3. Rundsø (Round Lake).

Rundsø, like Langsø, lies on the slates and limestones of the Eleonora Bay formation. On three sides the surrounding land is covered with fell field vegetation, only on the eastern bank is the adjoining land covered with mixed chamaephyte vegetation (see the map). In the period when

the snow melts, the outlet is at the western edge; at the same time a diffuse afflux is found particularly at the eastern bank. Rundsø is by no means as long, relatively, as Langsø, the length being about 340 m and the breadth about 270 m. Its area is about 7.4 ha, and the greatest depth is 11 m. In its broad features the bottom profile is characterized by a slight slope from 0 to 1 m, an abrupt decline from 1 to 5 m, and from this depth it slopes slightly down to the greatest depth. The distribution of the area at the various depths can approximately be given as follows: one-third of the lake has depths less than 1 m, one half of it depths greater than 5 m, and in the remaining one-sixth the depths lie in between. In accordance herewith the water content can approximately be calculated; reckoning with 2.5 ha having an average depth of 0.5 m, 1.2 ha having an average depth of 3 m, and 3.7 ha an average depth of 8 m, the water content is calculated at about 345,000 m³. According to these figures 62,000 m³ or about $\frac{1}{6}$ of the water was less than 1 m under the surface and consequently frozen in winter. In 1933—34 Rundsø was ice-bound from about 1.X.1933 until 2.VII.1934. Thus the length of this period hardly differs from that of Langsø.

As already mentioned the surface water was free of H₂S during the whole winter (as distinct from that of Langsø). Nevertheless, there must have been a considerable decrease of oxygen in the deeper parts of the lake, as may be judged from a note made on the bottom sample no. 463 taken on 23.V.1934 through the plankton hole: the gyttja in this sample contained many sulphur bacteria and smelt strongly of H₂S.

The water in Rundsø was very limpid: on 6.II., at a time when there is not much light, the plankton net could distinctly be seen at a depth of 10 m.

In Rundsø three series of bottom samples were taken with a total number of 76 samples. The first series (table 6) was taken in August (10.VIII—1.IX.) 1933 and consisted of 25 samples along 3 lines from bank to bank. The second series (table 7) was taken in the last part of May and the beginning of June (20.V—5.VI.) 1934 and consisted of 9 × 3 samples along a single line. The samples of this series were taken through holes in the ice, and as this was about 1 m thick, the holes were the result of hard work; three samples were therefore taken through each hole; for the first sample in every hole the sampler was dropped direct to the bottom, but for the second and third the sampler was swung about, after having passed through the ice, in order to prevent it from going down on to the same spot as the first time. The third series (table 8) was taken in July (11.-22.VII.) 1934; it consisted of 24 samples along two lines from bank to bank. (The ostracod *Candona candida* was present in some samples, but as no distinction was made between living and dead animals, the frequency is not known).

[illegible]

Number of Individuals.

the map. In the table the lines are marked by the figures of the termination points. For the kind gm = glimmer sand; l = lime concretions; m = moss; mv = moving soil; n = *Nostoc*. All larvae.

III—V				II—V										
64	65	66	67	74	75	76	77	78	79	80	81	82	83	84
30. VIII.	30. VIII.	30. VIII.	30. VIII.	1. IX.	1. IX.	1. IX.	1. IX.	1. IX.	1. IX.	1. IX.	1. IX.	1. IX.	1. IX.	1. IX.
7.75	9	6.5	5.5	0.25	0.75	1	8	8	10	5	1	1	1	1
				mv										
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	1	..	..	..
..	..	..	1	..	..	..	..	..	..	1	2	..	6	2
..	..	..	..	..	1	..	..	..	..	..	..	..	..	..
..	..	..	..	..	3	1	..	..	..	..	..	5	..	1
..	..	..	..	..	1	3	..	..	..	..	..	3	..	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

Number of Individuals.

through 9 holes in the ice, 3 samples through each hole. For the kinds of bottom the following mv = moving soil; n = *Nostoc*. All figures mean larvae.

II—IV														
482	483	484	498	499	500	501	502	503	519	520	521	522	523	524
28.V			31.V.			1.VI.			5.VI.			5.VI.		
8.5			6.75			4			2.5			1		
g	m	n	g n			g	m	n	g	m	n	mv		
..	..	..	..	..	..	..	1	..	..	1	..	..	..	..
1	2	1	2	..	..	..	3	3	1	2	..	..	..	..
..	..	1	2	1	..	1	2	2	..	..	..	..	1	..
..	..	..	..	..	..	4	..	..	1	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	3	..	..	..	..

Table 8. Rundsø 1934 B.

The series of samples was taken along 2 lines marked in the table by the figures of the ter-
used: gg = grey gyttje; l = lime concretions; m = moss; mv = moving soil; st = stones. Simple

Line	III—V								
Samples no.	632	634	635	636	638	639	640	642	643
Date	11.	12.	12.	12.	14.	14.	14.	15.	15.
Month	VII.	VII.	VII.	VII.	VII.	VII.	VII.	VII.	VII.
Depth (m).....	0.7	1.5	2.5	7	8	10	8	6	6.5
Kind of bottom sediment	1	m gg	gg	gg	gg	gg	gg	m gg	m gg
<i>Trichotanypus choreus</i>	..	..	..	..	..	..	..	..	..
<i>Pentapedilum coracinum</i>	..	3	..	..	..	..	..	..	..
<i>Tanytarsus niger</i>	..	1	..	..	..	..	..	..	..
<i>Cricotopus glacialis</i>	1/1	..	..	..	..	..	..	..	..
<i>Corynoneura scutellata</i>	0/2	..	..	..	..	..	..	..	..
<i>Orthocladius ?consobrinus</i>	..	2	..	..	..	..	..	..	..

The composition of the bottom material is seen in table 9. The figures in this table give the number of samples in which the various kinds of bottom material were present; it will be seen that one sample may contain more than one kind.

Table 9. Bottom material.

Depth (m)	< 1	1—1.5	2—5	5.5—11
Number of samples	5	7	16	31
Gyttja	..	2	15	31
Moss	..	3	13	10
<i>Nostoc</i>	..	1	10	9
Lime concretions	2	2	1	..
Moving soil	2	3	..	..
Stones	..	2	4	..
Glimmer sand	1	..	..	..

The depths are classified in accordance with the bottom profile:
1) less than 1 m, i. e. the upper flat littoral zone which in winter is frozen to the bottom, 2) a boundary zone of 1—1.5 m, 3) 2—5 m, i. e., the steep sub-littoral zone and 4) 5.5—11 m, i. e. the plain profundal zone. In the latter the bottom material is very homogeneous, gyttja being the main component in all the 31 samples; the gyttja is of a grey-

Number of Individuals.

mination points shown on the map. For the kinds of bottom the following abbreviations are figures always mean larvae; in fractions the numerator means larvae and the denominator pupae.

			I—III												
	644	645	661	662A	662B	663	664	665	667	668	669	670	671	672	673
	15. VII.	15. VII.	19. VII.	19. VII.	19. VII.	19. VII.	19. VII.	19. VII.	20. VII.	20. VII.	20. VII.	21. VII.	21. VII.	21. VII.	22. VII.
	6.5	0.8	1	2	7	9	10	11	9.5	9.5	5	4	2	1	0.5
	m gg	mv	m l	st m l	m gg	gg	gg	gg	gg	gg	gg	m gg	m gg	m st gg	1
	..	..	..	1	..	1	..	..	..	..	..	..	..	..	..
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..
	..	..	4	..	..	..	..	..	..	..	..	..	..	..	4
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3
	..	..	..	..	..	..	..	..	..	..	..	..	..	1/1	3

green colour; moss and *Nostoc* were present in one-third of the samples. In the sub-littoral zone the bottom material was much the same as in the profundal zone, but in addition stones (or rock) were found in 4 samples, which is rather significant for this steep part of the bottom, and lime concretions, a littoral component, were present in one sample from 2 m. In the boundary zone gyttja, moss and *Nostoc* were still present beside the typical littoral kinds of material, i. e. lime concretions and moving soil. The glimmer sand found in one sample is presumably disintegrating products of an erratic block.

In order to see whether the chosen depth limits are ecological limits, table 10 has been worked out on the basis of tables 6—8.

From this table it is seen that the limit between the littoral and sublittoral is very well marked: five forms, viz. *Cricotopus*, *Psectrocladius*, *Corynoneura*, *Chironomus* and *Ditanytarsus* are present at depths of 1.5 m or less, but are not found in the deeper parts of the lake; two forms viz. *Phenopelma* and *Trichotanypus*, are only found at greater depths than 1.5, and one form, viz. *Tanytarsus*, has its main area of distribution in the deeper parts, while it is found in a few specimens in the boundary zone and is entirely lacking in the littoral zone proper (i. e. less than 1 m). The limit between sub-littoral and profundal (between 5 and 6 m) is marked by the *Orthocladinae* not going deeper than that limit and by the average number of animals per sample, the profundal showing less than one individual per sample.

Table 10. Number of *Chironomidae* found.

Depth (m).....	1	1-1.5	2-3	4-5	6-7	8-9	10-11	total
Number of samples	9	12	7	10	13	10	15	76
<i>Pentapedilum coracinum</i>	6	13	3	8	3	4	..	37
<i>Tanytarsus niger</i>	..	3	..	30	3	1	10	47
<i>Phoenopelma</i> sp.	..	..	1	22	..	..	2	25
<i>Trichotanypus choreus</i>	..	..	2	2	..	1	..	5
<i>Orthocladius ?consobrinus</i> ...	4	4	3	24	..	..	..	35
<i>Cricotopus glacialis</i>	21	11	..	..	..	..	..	32
<i>Psectrocladius</i> spp.....	12	6	..	..	..	..	..	18
<i>Corynoneura scutellata</i>	5	..	..	..	..	..	..	5
<i>Chironomus hyperboreus</i>	..	1	..	..	..	..	..	1
<i>Ditanytarsus setosimanus</i> ...	1	..	..	..	..	..	..	1
Number of individuals	49	38	9	86	6	6	12	206
Number of forms.....	6	6	4	5	2	3	2	10
Number of individuals per sample.....	5.4	3.2	1.3	8.6	0.5	0.6	0.8	2.7

The three series of samples yield no ground for assuming an essential difference in the benthic distribution of the animals at various seasons. On the other hand, the average number of animals per sample shows obvious differences between the three series, as shown in table 11. As however, the second series contains no samples from the littoral zone (owing to the zone being frozen up at this time) and the three samples available from the boundary zone are from the same spot on moving soil, where there are very few animals, these two zones were left out in preparing the table.

Table 11. Number of individuals found in the sub-littoral and profundal zones.

Date	12.VIII— 1.IX.1933	20.V— 5.VI.1934	11—21.VII. 1934
Number of samples.....	13	24	18
<i>Trichotanypus choreus</i>	1	2	2
<i>Pentapedilum coracinum</i>	2	16	..
<i>Tanytarsus niger</i>	..	44	..
<i>Phoenopelma</i> sp.....	..	25	..
<i>Orthocladius ?consobrinus</i>	..	27	..
Total number of individuals	3	114	2
Number of individuals per sample ...	0.2	5	0.1

Table 12. Rundsø. Animal communities.
Number of individuals in percentages of all individuals.

Depth (m)	0.25—0.8	1—1.5	2—5	5.5—11
Number of samples	9	12	17	38
<i>Pentapedilum coracinum</i>	12	34	12	29
<i>Tanytarsus niger</i>	..	8	32	58
<i>Phenopelma</i> sp.	..	..	24	8
<i>Trichotanytus choreus</i>	..	..	4	4
<i>Orthocladius ?consobrinus</i>	8	11	28	..
<i>Cricotopus glacialis</i>	43	29	..	..
<i>Psectrocladius</i> spp.	24	16	..	..
<i>Corynoneura scutellata</i>	10	..	..	..
<i>Chironomus hyperboreus</i>	..	3	..	..
<i>Ditanytarsus setosimanus</i>	2	..	..	..
Average number per sample...	5.4	3.2	5.6	0.6

The table shows that a month before the lake was free of ice a relatively great number of animals was found in the series taken on 20.V—5.VI., but only a fortnight after the lake was free of ice very few animals were found in the series taken from 11.—21.VII, and one and a half months later (in the preceding year) the number was not greater in the series taken from 12.VIII—1.IX. The number of samples in the series being small, conclusions drawn from the figures should be handled with caution. The table shows, however, quite clearly that the number of animals decreased very much from one month before until a fortnight after the lake was free of ice; thus the majority of the chironomids in the sub-littoral and profundal zones of Rundsø hatch during or immediately after the period of ice-melting. The table further suggests that no great increase in the number of larvae has taken place for one and a half months after the time when the chironomids fly; there is thus reason to believe that in the sub-littoral and profundal zones of Rundsø the larvae from the eggs laid in the beginning of July have not grown big enough to be found in the samples at the end of August. Finally the table shows that the larvae are able to continue their growth under the ice during winter.

In order to study the animal communities table 12 has been worked out on the basis of tables 6—8. It shows the percentage of the settlement constituted by each form in each zone. According to this table an *Orthocladinae* community is found in the littoral zone, this sub-family constituting 75 % of all animals found in the zone. In the profundal zone a *Tanytarsus niger* community is found, which shows

Table 13. Ulvesø.

All samples (except no. 28) were taken through holes in the ice, 2 or 3 through each hole.
m = moss; mv = moving soil; n = *Nostoc*;

Year.....	1933								
Sample no.	28	263	264	265	351	352	370	371	372
Date.....	15.VIII.	21.XI.			23.III.		7.IV.		
Depth (m).....	0.5	5			5		4.5		
Kind of bottom sediment.....	mv	m			m		m		
		gg			g		g		
		n							
<i>Trichotanypus choreus</i>	..	8	6	10	1	1	..	1	2
<i>Tanypus ?melanosoma</i>	..	..	9	1	..	..	..	..	..
<i>Pentapedilum coracinum</i>	..	..	..	..	..	..	..	..	..
Sand tubes of this species	..	..	..	..	..	..	..	..	1
<i>Micropsectra groenlandica</i>	}	2	2	20	4	..	1	3	4
<i>Tanytarsus niger</i>									
<i>Phoenopelma</i>	..	7	2	25	5	5	1	2	3
<i>Psectrocladius</i> spp.....	..	..	..	..	..	..	..	..	..
<i>Orthocladius ?consobrinus</i>	..	..	..	3	..	..	..	..	..
Total...	..	..	..	..	..	..	..	..	..

its profundal character by two forms making 87 % of all the animals. The average number of animals per sample in this community is small (0.6). In the sub-littoral zone three forms are found to have about the same percentage, viz., two forms (*Tanytarsus* and *Phoenopelma*), which are likewise present in the profundal zone, and one form (*Orthocladius ?consobrinus*), which is also found in the littoral zone. I have chosen the name *Phoenopelma* for this community, in spite of it being the less frequent of the three, for two reasons, firstly, the two other forms have given name to a community each while only very few specimens of *Phoenopelma* are found outside the sub-littoral zone, and secondly, *Phoenopelma* is predominant at the same depth in Ulvesø. In the boundary zone both the littoral and the sub-littoral-profundal elements decrease with the result that the indifferent *Pentapedilum* attains the highest percentage.

In addition to the animals found in the bottom samples, the following were likewise found in Rundsø.

Rotatoria

- Loricata (*Anuraea* sp.)
- Rizota (conf. *Conochilus*)

Number of Individuals.

For the kinds of bottom the following abbreviations are used: g = gyttja; gg = grey gyttje; st = stones. All figures mean larvae.

1934											profundal zone		
373	374	375	376	381	389	390	391	404	405	406	18 samples		
9.IV.		11.IV-12.IV.		14.IV.	15.IV.			26.IV.			21.XI.33-26.IV.34		
4		4		1.25	4			4			4-5 m		
m g		m g		st	m g			m g			total num- ber	average no. per sample	%
18	9	6	2	no sample	..	3	3	3	2	3	78	4	11
..	..	..	..		..	..	..	..	..	..	10	0.6	1.5
..	..	..	..		..	..	..	..	..	1	1	0.1	0.1
4	..	1	..		..	1	..	..	..	..	..	..	..
30	16	10	27		5	2	3	7	5	6	147	8	22
107	68	42	47		16	29	33	13	19	13	437	24	64
1	..	..	2	..	..	..	..	..	2	..	5	0.3	1
..	..	..	..		..	..	..	..	..	..	3	0.2	0.4
..	..	..	..		..	..	..	..	..	..	681	38	100

Entomostraca

Bosmina longirostris var. *cornuta*

Cyclops strenuus

Maraeonobiotus danmarki

Insecta, Coleoptera

Colymbetes dolobratius

Vertebrata, Pisces

Gasterosteus aculeatus.

4. Ulvesø (Wolf Lake).

Ulvesø lies on Subcambrian tillit. As may be seen on the map the lake is flanked on the north-western and south-eastern sides by steep slopes, which rise to a height of 50 and 100 m respectively above the level of the lake. On the north-western side the border is formed by the rock, which from a height of 1—1.5 m runs almost vertically down to the lake; above these vertical slopes lies a stripe of land covered with mixed chamaephyte vegetation. On the south-eastern side the border is

formed by the débris from the steep rocky slope that bounds the valley. Between the big stones of the débris the lake forms small lagoons, and at a small distance from the lake the spaces between the stones are here and there filled with moving soil, on which *Dryas* plants may be found. At the south-western end there is moving soil without any vegetation (the mixed chamaephyte vegetation shown on the map is 1 m from the lake). At this end and from the slopes on the north-western and south-eastern sides a diffuse afflux takes place in the period, when the snow is melting. At the north-eastern end the mixed chamaephyt vegetation goes right down to the water. The outlet is at this end; as shown on the map it is more permanent than the outlet from Langsø and Rundsø; it dries up, however, in the middle of summer like most of the other water courses on Ella Island.

Ulvesø is about 550 m by about 200 m and covers an area of about 8.4 ha; the greatest depth measured was 5 m; assuming an average depth of 3 m we get a water content of about 252.000 m³. As only a very small part of the lake has depths of less than 1 m, it may be assumed that $\frac{2}{3}$ of the water were more than 1 m under the surface and consequently not frozen in winter.

The period in which the lake was ice-bound hardly differs from that of Langsø and Rundsø.

The decrease in oxygen under the ice was not so big during the winter that the water smelt of H₂S; but some of the bottom samples taken in April had a distinct H₂S odour.

19 bottom samples were taken in this lake (see table 13); one (no. 28) near the shore while wading in long bluchers; the remaining 18 were taken through the ice, 2 or 3 through each hole as shown in the table.

Information is thus available on the bottom material at 8 places in the lake; moreover it is known from no. 381, where no samples could be taken owing to a stony bottom. Apart from the two places at 0.5 and 1.25 m, where the bottom material consisted of moving soil and stones respectively, the sediment was in all cases gyttja with moss and *Nostoc*. The samples containing such sediment were all from depths between 4 and 5 m.

The bottom samples give no information of the fauna in shallow water, but the following forms have been caught with a catcher (15.VIII. 1933) and on various occasions with the plankton net:

Trichotanypus choreus
Tanypus ?melanosoma
Chironomus hyperboreus
Cricotopus glacialis

Psectrocladius spp.

Ostracoda (*Prionocypris glacialis*)

Hydracnida

Turbellaria

Regarding the fauna at a depth of 4—5 m, however, the bottom samples give good information. From these depths 18 samples are available. In the three last columns of table 13 the following facts are given about each form present in these 18 samples: the total number of individuals, the average number of individuals per sample and its percentage in relation to the total number of individuals. The samples contained 8 forms; among these *Micropsectra* and *Tanytarsus* were not kept apart during the investigation. With regard to the percentage composition of the fauna, it appears as a real profundal community with one form, *Phoenopelma* sp., constituting 64 % of all animals. Next comes *Micropsectra groenlandica* + *Tanytarsus niger* with 22 % and *Trichotanytus choreus* with 11 %. This *Phoenopelma* community differs from the sub-littoral *Phoenopelma* community at about the same depth in Rundsø in that *Orthocladinae* is almost completely lacking and *Tanytarsus niger* is far less important.

In addition to the animals already mentioned the following were found in Ulvesø:

Rotatoria

Rhizota (conf. *Conochilus*)

Entomostraca

Cyclops strenuus

Daphnia pulex

Chyderus sphaericus

Bosmina longirostris var. *similis*

Polyphemus pediculus

Insecta, Coleoptera

Colymbetes dolobratus

5. Bjørnesø (Bear Lake).

Bjørnesø is of about the same size as the other lakes. It lies in a valley wider and more luxuriant than the valleys around the other lakes. In conformity with the form of the valley the lake is very shallow, hardly more than 0.5 m deep, and big parts of it are not more than 0.1—0.2 m. In the shallow water there are growths of *Hippuris*, which is

the only vascular plant of any importance in this lake, while it is absent in the three other lakes.

Bjørnesø has only been very superficially investigated; quantitative bottom samples have not been taken, but a sample of the bottom was taken with the catcher on 25.X.1933 the depth was 0.5 m (of which 0.3 m was ice), the bottom material was gyttja and moss, and the sample contained larvae of the following species:

Chironomus hyperboreus
Trichotanytus choreus
Cricotopus glacialis
Corynoneura scutellata

Furthermore the following animals were found in the lake:

Turbellaria (sp. indet.)
Rotatoria
 Loricata (*Anuraea* sp.)
 Illoricata A (conf. *Polyarthra*)
Entomostraca
 Lepidurus arcticus
 Cyclops strenuus
 Daphnia pulex
 Chyderus sphaericus
 Simocephalus vetulus
 Prionocypris glacialis var. *albida*
Insecta, Coleoptera
 Colymbetes dolobratus

IV. REMARKS ON THE ANIMALS

In the present chapter a list is given of the animals found in the lakes. For every species or form some biological remarks are given together with their ecological claims as far as they are known from other places where the species has been investigated; in the case of the chironomids this ecological information is also given when it concerns other species of the same larval group. It is of interest when we consider the fact that species belonging to the same larval group are often to some extent ecologically equal.

The species are arranged in four sections according to the method by which information about them has principally been gained during the investigation in question.

As some years have elapsed since the appearance of my earlier paper, some of the metamorphoses described in that paper have been referred to by other authors; reference to these authors is made, in parenthesis, immediately after the name of the species.

To facilitate the work with this paper, the larval groups, to which the chironomids belong, are given for each species. For further information about the larvae and pupae the reader is referred to the earlier paper (ANDERSEN 1937).

1. Forms found in the bottom samples.

Trichotanypus choreus MEIGEN. The larva of this species (belonging to the *culiciformis* group) was found in all the lakes and at all depths. As it is carnivorous, feeding partly on other chironomid larvae, it is most frequent where the settlement of these is most dense. This is shown in the following table where the figures indicate that the number of *Trichotanypus* increases more quickly than that of other chironomids.

The high percentage of *Trichotanypus* found in Ulvesø and Langsø suggests that these larvae not only feed on chironomid larvae, but that they also take plankton animals, especially the biggest of them, viz., *Daphnia pulex*, which is not found in Rundsø, but is present in Ulvesø and is especially common in Langsø.

	Rundsø	Ulvesø	Langsø
Average number of chironomids per sample .	3	34	50
Average number of <i>Trichotanypus</i> per sample	0.07	4	13
<i>Trichotanypus</i> in percentage of all chironomids	2	11	26

Table 14. Occurrence in the lakes of the forms found in the bottom samples.

Lake	Rundsø	Ulvesø	Langsø	Bjørnesø
Number of samples	76	20	80	¹⁾
<i>Trichotanypus choreus</i>	+	+	+	+
<i>Pentapedilum coracinum</i>	+	+	+	?
<i>Phoenopelma</i> sp.	+	+	+	?
<i>Tanytarsus niger</i>	+	+	+	?
<i>Cricotopus glacialis</i>	+	+	+	+
<i>Psectrocladius</i> spp.	+	+	+	?
<i>Corynoneura scutellata</i>	+	+	+	+
<i>Orthocladius</i> ? <i>consobrinus</i>	+	+	+	?
<i>Hydracnidae</i>	..	+	+	?
<i>Chironomus hyperboreus</i>	(+)	(+)	+	+
<i>Ditanytarsus setosimanus</i>	(+)	+	+	?
<i>Tanypus melanosoma</i>	..	+	..	?
<i>Micropsectra groenlandica</i>	..	+	..	?
<i>Candona candida</i>	+	?	+	?

¹⁾ catcher.

From its benthic distribution in Langsø it appears that the *Trichotanypus* larva can hibernate in a frozen-up state (see p. 46) as well as in the water under the ice in Langsø, in spite of the lack of O₂ and the high concentration of H₂S in this water (see p. 16). On the whole *Trichotanypus* cannot be used for characterization of the biotope, because it is highly indifferent to almost every ecological factor (see a. o. LENZ 1927, p. 153) except of course to food as just shown.

In Langsø, where this species was most frequent, it was often seen swimming round, holding the thorax and the front abdominal segments stiffly slanting downwards, with the head and thorax bent slightly towards the back and throwing the rest of the abdomen from side to side; in this way it swims in a direction opposite to the head. If it is frightened, the larva is able for a short time to swim backwards very rapidly, in a way not unlike a lobster, beating the hind part of the abdomen against the fore part.

It is primarily on account of its great ability in swimming that this carnivorous larva is able to live in Rundsø, where there is a long way

from one prey to another, and it is owing to this same ability that the larva is so equally distributed in all depths.

Pentapedilum (Sergentia) coracinum ZETT. (see LENZ 1941, p. 35). The larva of this species was found in all the lakes except Bjørnesø and here it may have been overlooked owing to the superficial investigation of this lake. In Langsø and Rund sø it is equally distributed in the various depths (see p. 19 and 26), but the part it plays in the various lakes is quite different as may be seen from the following table:

	Rund sø	Langsø	Ulvesø
<i>Pentapedilum</i> in percentage of all chironomids..	18	3	0.1
Number of <i>Pentapedilum</i> per sample.....	0.5	1.5	0.05

In Ulvesø only one specimen was found, but 7 pupa tubes (see LENZ 1941, fig. 43) were present in the samples.

The *Sergentia* larva is stated by LENZ (1927, p. 160) and others to be an indicator of mesotrophic lakes and (loc. cit. p. 153) to avoid those with a certain content of humus, but according to BRUNDIN (1942, p. 98) *Sergentia* larvae may also be found in polyhumose lakes.

Unfortunately the latter author did not rear his larvae, and so it is unknown to which species they belong. It is, at any rate, highly probable that *P. coracinum* in Langsø has to live for a couple of months under conditions somewhat like those of the polyhumose lake (see p. 56).

The vivacity of this larva, which permits of its equal distribution in all depths, has been described in the earlier paper (ANDERSEN 1937, p. 32).

Phoenopelma sp. (see THIENEMANN 1941, pp. 79, 197 and 238). The larva of this species (belonging to the *Attersee-Tanytarsus* group) was found in all lakes except Bjørnesø. Its frequency was as follows:

	Langsø	Ulvesø	Rund sø
Percentage of all chironomids	2.5	64	12
Average number per sample	1.3	22	0.3

It is seen that the larva is most frequent in Ulvesø as regards both the percentage and actual number; in the two other lakes it attains the highest percentage in Rund sø, but the highest actual number is in Langsø. In Rund sø the larva was only found in the sample series taken from 20.V—5.VI and almost exclusively at a depth of 4 m; that is about the same depth as the profundal in Ulvesø; this in connection with the fact that most of the samples in Ulvesø were also taken in the spring

provides some explanation of the overwhelming part played by the *Phoenopelma* larva in this lake. In Langsø the larva was caught during all months of the year, when samples were taken, but in August only one specimen was present in 15 samples. It can thus be stated that *Phoenopelma* completes its development in one year and that the development from the egg is slow, slower of course in the deeper and colder lake than in the shallower and warmer one.

From other sources nothing is known of the ecology of this species.

Tanytarsus niger ANDERSEN. The larva of this species (belonging to the *gregarius* group) was found in all lakes except Bjørnesø. Its frequency in Langsø and Rundso was a follows:

	Langsø	Rundso
Percentage of all chironomids	11	23
Number per sample	5.4	0.6

(Frequency in Ulvesø is not known, because this species and *Micropsectra groenlandica* were counted as one, the presence of the latter not being recognized until the species was described in Copenhagen). As this larva is only occasionally found at depths less than one meter, these figures are accidental and dependent on the relation between the number of samples from depths less than or more than one meter. The frequency of the larva at depths of one meter or more was:

	Langsø	Rundso
Percentage of all chironomids	30	30
Number per sample	11	0.7

Thus this larva plays a very important part in the chironomid settlements of these lakes.

Tanytarsus niger is able to hibernate in a frozen state as was found in sample no. 447 (see p. 46), but as it is mostly found at depths greater than one meter, it hibernates as a rule under the ice.

Tanytarsus niger has not been recorded from other lakes, but larvae of the *Tanytarsus gregarius* group were once taken (by THIENEMANN and others) as indicators of oligotrophy. Later investigations, however, have shown that this was due to the fact that *Lauterbornia* and *Tanytarsus gregarius* groups had not been kept apart. PAGAST writes (1940, p. 397): "Für das mitteleuropäische Gebiet kann zusammenfassend festgestellt werden, dass die Leitform der Tiefe der sog. *Tanytarsus*-See nicht die Angehörigen der Gattung *Tanytarsus* sind, sondern diese sind Bewohner von Seen verschiedenster Art." This holds good for *Tanytarsus niger*, which cannot be steno-oxybiont, since, in Langsø, it is able to live for months in the almost O₂-free water under the ice.

Cricotopus glacialis EDW. The larva of this species was found in all the lakes. As it was never found at depths greater than one meter, its frequency is given only for depths of one meter or less (in Ulvesø the larva was caught only by a catcher).

	Langsø	Rundsø
Percentage of all chironomids	21	40
Number per sample	8	1.6

The larva of the sub-family Orthocladinae is generally stated to be steno-oxybiont, and so it is with this species, since it only lives at depths where it is frozen up in winter, thus avoiding the lack of O₂ under the ice.

This species shows a striking increase in number in Langsø from the first to the second series of bottom samples. In the series taken in September—October 1933, 26 specimens only were found, as compared with 408 specimens in the series from June and July 1934. This shows that the species completes its development in one year and that the growth takes place in early summer.

Psectrocladius spp. 2 species of *Psectrocladius* were caught as imagines in the lakes, namely *Ps. armatus* ANDERSEN (see THIENEMANN 1941, p. 177) and *Ps. limbatellus* (HOLMGR.) EDW., the latter in two varieties. As these species were not kept apart during the sorting of the samples, they have to be dealt with collectively. Larvae belonging to this genus were found in all lakes except Bjørnesø. The frequency was as follows:

	Langsø	Ulvesø	Rundsø
Percentage of all chironomids	8	0.7	9
Number per sample	4	0.3	0.2

In Langsø they were found at all depths (0.1—2.0 m), in Ulvesø only at a depth of 4 m, lesser depths being only slightly investigated, and in Rundsø it was found only at depths of 1 m or less.

Judging from their occurrence larvae of this genus are able to hibernate under the ice as well as frozen up.

Corynoneura scutellata WINN. Larvae of this species were present in all the lakes; in Ulvesø and Bjørnesø they were only caught with the catcher. In Langsø and Rundsø this larva was found down to a depth of 1.25 and 1 m respectively; it is therefore natural to compare its frequency in these two lakes only at lesser depths. The frequency was:

	Langsø	Rundsø
Depth (m).....	≤ 1.25	≤ 1
Percentage of all chironomids	6	10
Number per sample	4	0.6

This larva was only found at depths, where it was frozen up before the great O_2 decrease in the winter.

The *Corynoneura* larva is able to swim in two ways like that of *Trichotanypus*, but owing to its smaller size its swimming does not carry it very far.

Orthocladius ?consobrinus (HOLMGR.) EDW. The determination of the larvae registered under this name is doubtful in two respects, firstly, because the larvae were not reared, but determined by means of a hypopygium found in a pupa, and secondly, because *O. consobrinus* was not the only species of this genus found in the neighbourhood of the lakes; some of the larvae may consequently belong to some other species (see ANDERSEN 1937). Larvae, probably belonging to this species, were found in all the lakes except Bjørnesø. In Langsø and Rundsø they were present only in the littoral and sub-littoral zones; in Ulvesø they were found in the profundal. They were always found in very small numbers, but in Rundsø they constituted a good part of all chironomids, above all in the sub-littoral zone. The small part played by them in Ulvesø is partly due to the fact that here only the profundal zone was

	Langsø	Ulvesø	Rundsø
Percentage of all chironomids	0.3	0.2	0.5
Average number per sample	0,5	0,4	17

investigated. The ecological claims of this species are unknown from other places, but like other *Orthocladinae* it may be considered to be steno-oxybiont to some extent.

Hydracnidae were found only in Langsø and Ulvesø; accordingly they are lacking or very rare in Rundsø; this is probably due to the fact that they feed on chironomid larvae, and these are comparatively rare in Rundsø (compare *Trichotanypus*). The fact that they were found in sample no. 477 (see p. 46) shows that *Hydracnidae* are able to hibernate frozen up.

Chironomus hyperboreus STÆGER (THIENEMANN 1941, pp. 192 and 233). The larva of this species was found in Langsø and Bjørnesø and a single specimen in Rundsø. It prefers depths less than 1 m; in Langsø only a few were found at depths greater than 1.25 m. Accordingly the larva hibernates in a frozen up state; 4 specimens were found frozen up in sample no. 477 (see p. 46).

Chironomus hyperboreus belongs to the *Ch. salinarius* group, the larvae of which, according to LENZ (1927 a. o.), are characteristic of water rich in oxygen. This larva of the *Ch. salinarius* group in fresh water is undoubtedly an arctic type; outside East Greenland it is found in Nowaja Semlja (LENZ and THIENEMANN 1922), in the Norwegian mountains (LENZ 1927) and in Swedish Lapland (THIENEMANN 1941).

(The larvae of the *Ch. salinarius* group found in European rivers and in Finnish lakes will probably prove to be another type).

Ditanytarsus setosimanus GOETGH. (see THINEMANN 1941, p. 197). The larvae of this species (belonging to the *lauterborni* group) was found in Langsø and a single specimen in Rundsø. In Langsø it is most frequent at depths less than 1 m, where it predominates, but it is not rare at greater depths, and one specimen was caught at a depth of 2 m.

Ditanytarsus is a littoral species, but it does not like the extreme oligotrophic conditions under which the *Orthocladinae* predominate.

Tanytus melanosoma GOETGH. Larvae (of the *costalis* group) probably belonging to this species were found in Ulvesø; they were present only in two bottom samples (from 5 m), but some larvae were also caught by the catcher in shallow water.

Micropsectra groenlandica ANDERSEN. Larvae of this species (belonging to the *inermipes* group) were found among larvae of *Tanytarsus niger* from Ulvesø, when the animals were examined after our return to Copenhagen. As larvae of these two species were not kept apart during the investigation in Greenland, nothing is known about their relative frequency.

M. groenlandica has not been found outside Greenland, but larvae of the *inermipes* group are generally taken as indicators of oligotrophy; according to VALLE (1927, p. 106) they are less fastidious than the larvae of the *gregarius* group. On the other hand PAGAST (1940) states that this group is typical of the depths of the deep oligotrophic lakes.

Candona candida (MÜLLER)¹. This ostracod was found in Langsø and Rundsø, but not in Ulvesø, which is undoubtedly due to the fact that the samples from Ulvesø were all taken during winter, and *Candona* is found in summer only.

2. Forms found in the preserved plankton

(determined by POULSEN 1940 a).

Simocephalus vetulus MÜLLER was found in Langsø and Bjørnesø, and in the former only one cast of *ephippia* was found, and that on 12th of June, the only time when a sample was taken in the shallow, western end of the lake. This occurrence is in conformity with the ecology of the species as it is known from Europe. It is here found to prefer alkaline reaction (POULSEN 1928, p. 213 and LUYTEN 1934, p. 91) and temperatures above 13° (LUYTEN 1934, p. 115); and it occurs near the shore and never as a plankton form (BERG 1930, p. 45). Thus, it

¹) Determined by POULSEN (1940 a).

Table 15. Occurrence in the lakes of forms found in the preserved plankton samples.

Lake	Rundsø	Ulvesø	Langsø	Bjørnesø
Number of samples	27	9	27	3
<i>Simocephalus vetulus</i>	..	..	(NB)	+
<i>Daphnia pulex</i>	..	+	+	+
<i>Chyderus sphaericus</i>	..	+	+	+
<i>Cyclops strenuus</i>	(NB)	+	+	+
<i>Polyphemus pediculus</i>	..	+	..	..
<i>Bosmina longirostris</i> var. <i>similis</i>	..	+	..	..
<i>Bosmina longirostris</i> var. <i>cornuta</i>	+	..	..	..
<i>Maraenobiotus danmarki</i>	+	..	..	..
Number of forms present	2	5	3	4

prefers shallow water and a relatively high summer temperature, as found in the shallower lakes Langsø and Bjørnesø, but it is only found at depths, where it becomes frozen up in winter, thus avoiding the acidity caused by the high H_2S tension.

Daphnia pulex DE GEER was found in all the lakes except Rundsø. The ecological claims of this species seem to be different in Europe and America. In Europe it is most frequently found in shallow water (POULSEN 1928, p. 209) in ponds, often more or less contaminated¹⁾, and in lakes only near the edge (BERG 1931, p. 57), never planktonic (POULSEN 1928, p. 209). NORDQVIST (1921) mentions it as "planktonic" in oligotrophic pools (loc. cit. p. 80) and eutrophic ponds (loc. cit. p. 87) and as lacking in oligotrophic ponds and lakes of every trophy²⁾. In America, on the other hand, FORBES (1893, pp. 225 and 242) and JUDAY (1915, p. 237) found *D. pulex* as a pelagic form in big, deep lakes. Since, however, the animal found by FORBES was not typical, but var. *pulicaria*, and JUDAY found the species as a pelagic form in tropical lakes only, the presence of the typical form in the shallower East Greenland lakes may be taken as a sign of a certain eutrophy of these lakes, both absolutely and compared with Rundsø.

Chyderus sphaericus MÜLLER was also found in all lakes except Rundsø. From Europe this species is known to be highly independable on ecological factors (BERG 1930, p. 94, POULSEN 1928, p. 225, and LUYTEN 1934, p. 103 and 126) but it is not pelagic in deep lakes (RYLOV 1935, p. 149). POULSEN (1928, p. 225) found it less frequently in waters more than 4 m deep³⁾, LUYTEN (1934, p. 156) states it to be a transitional form

¹⁾ See also RYLOV 1935, p. 115.

²⁾ See also HABERBOSCH 1920, p. 89.

³⁾ See also HABERBOSCH 1920, p. 89.

between planktonic and littoral forms, and NORDQVIST (1921) even lists it among the species present in pools but lacking in (certainly oligotrophic) ponds and lakes. Thus, it is obvious why it is not found in the plankton of Rundsø, the deepest of the lakes.

Cyclops strenuus FISCHER was found in all the lakes (see POULSEN 1940a, p. 46 and table 2, p. 63), but since it was only present in 2 samples out of 27 from Rundsø, the species was in this, the deepest lake, no doubt a littoral form, only occasionally drifting out into the plankton; it is therefore listed as lacking in the plankton from Rundsø.

As shown by POULSEN (loc. cit.) the breeding begins earlier in Ulvesø than in Langsø: in Langsø the first females with eggsacs were found on 29.V., while in Ulvesø they were found on 22.III.; as that was the earliest sample taken that year, they may have been present earlier. This big difference cannot be due to a difference in temperature; it therefore seems probably that it is lack of oxygen that prevents the Langsø population from breeding as early as the Ulvesø population.

Another fact of ecological interest can be learnt from the list giving the occurrence of *Cyclops* in the plankton samples from Langsø: 12.VI. 1942 I could not take the sample in the deep part of the lake, as it was covered with melting ice. I therefore took it in the western, shallow part of the lake west of the small peninsula (see the map). In this sample no *Cyclops* were present. As the deepest sounding in that part of the lake is about 0.6 m, it had been frozen to the bottom. This proves that the adult *Cyclops* cannot hibernate frozen up. It is, however, likely that eggs had wintered in this part of the lake and had not yet been hatched, since the presence of the species in Bjørnesø shows that it can survive in a lake, which is frozen to the bottom in winter.

On the ecology of *Cyclops strenuus* NORDQVIST writes (1921, p. 83) that it plays a much greater part in eutrophic than in oligotrophic ponds and (p. 87) that it belongs to the eutrophic forms, which are found both in ponds and in lakes, but (p. 74) it is also characteristic of the spring plankton in oligotrophic ponds. RYLOV writes (1935, p. 205) that *C. strenuus* (above all the typical form) is very resistant and that it is able to live even in water containing H_2S . That is, no doubt, the case with the East Greenland population, and, although our biological picture of this species is very vague owing to the confounding of the various *strenuus* forms (RYLOV 1935, p. 204), the presence of *C. strenuus* in the East Greenland lakes may well be taken as a sign of a certain eutrophy, and it is in conformity herewith that it was present in 2 samples only out of 27 in Rundsø, the deepest and therefore most oligotrophic of the lakes.

Polyphemus pediculus LINNÉ was found in Ulvesø only. The occurrence of this species cannot be explained by its claims on pH or vege-

tation (POULSEN 1928, p. 226: euryionic, perhaps more frequently found in acid waters, and LUYTEN 1934, p. 105: acidophilous, and p. 157: in lakes with some vegetation at the banks). On the other hand the occurrence may be explained by its claims on temperature: LUYTEN has shown (loc. cit. p. 127) that the species has its optimum at 18°, and POULSEN (1940a, p. 45) says that it cannot be regarded as a true arctic species; this may explain its absence in Rundsø, and its presence in the more favourably situated and less exposed, shallower Ulvesø; moreover, it is no typical plankton form (see POULSEN 1928, p. 226, and HABER-BOSCH 1920, p. 89) NORDQVIST (1921) calls it a pronounced littoral form (p. 81), and lists it among the forms in the plankton of oligotrophic pools and ponds, but not of oligotrophic lakes (p. 80). As only one specimen of this species was caught, no conclusions can be drawn from its occurrence.

Bosmina longirostris (Müller) was found only in the two deeper lakes, Rundsø and Ulvesø, and in two varieties, viz. var. *cornuta* in Rundsø and var. *similis* in Ulvesø. As this species with its many varieties is able to live under much varying conditions, no conclusions on the ecology of the two varieties in question can be drawn from their occurrence recorded in literature, but judging from their occurrence in the East Greenland lakes the two varieties prefer lakes with more than 1 m average depth (compare HABERBOSCH 1920, p. 97).

Maraenobiotus danmarki Brehm was found in Rundsø only. Nothing was previously known about its ecological claims.

3. Forms found by examination of the living plankton.

Rotatoria were found in all the lakes. Only on a few occasions, when the plankton was examined before its preservation, rough sketches of and notes on the *Rotatoria* were made. As only one or two samples from every lake were examined, conclusions drawn from them are of no real value, and they are mentioned only because the investigation has shown that a more detailed study of these forms in the East Greenland lakes will be profitable.

Table 16. Occurrence in the lakes ascertained on the living plankton.

Lake	Rundsø	Ulvesø	Langsø	Bjørnesø
Number of observations	2	1	2	1
<i>Loricata</i> (<i>Anuraea</i> sp.)	+	..	+	+
<i>Rhizota</i> (conf. <i>Conochilus</i>)	+	+	..	..
<i>Illoricata</i> A (conf. <i>Polyarthra</i>)	..	..	+	+
<i>Illoricata</i> B	..	..	+	..

Loricata (*Anuraea* sp.) were found in all the lakes except in Ulvesø (where it may be present).

Rhizota (conf. *Conochilus*) was found in Rundsø and Ulvesø; it is seemingly lacking in the shallow lakes.

Illoricata A (conf. *Polyarthra*) was found in Langsø and Bjørnesø and is thus lacking in the deeper lakes.

Illoricata B was found in Langsø only.

Thus, of the four forms found, one preferred the deeper lakes, two preferred the shallower ones, while one was indifferent.

4. Forms caught occasionally by catcher or other gear.

Gasterosteus aculeatus L. was found in Rundsø only. The gear mostly used during the investigation in question was not suitable for gathering information about this animal, but the following facts can be given: on 13.VIII.1933 it was found clustered in dense masses in the shallow warm water at the edge. (The fact that 250 were captured at one stroke of the catcher may give an idea of the density). The biggest specimen measured was about 6 cm long and weighed 1.8 g; 9 out of 250 specimens weighed 1 g or more each. On 11.I.1934 one specimen was caught in the plankton hole.

In East Greenland *Gasterosteus* can only be found in deep lakes, since it cannot, of course, live at low O_2 tensions or survive being frozen up.

Colymbetes dolobratius PAYK was found in all the lakes investigated. The imagines hibernate: 2 specimens were caught on 1.IV.1934 in the plankton hole on Langsø and 2 in the same place on 29.V.1934; thus it seems able to survive the lack of O_2 and the high tension of H_2S in Langsø during winter. Its occurrence in Bjørnesø suggests that it can likewise hibernate frozen up. One specimen was caught flying on 7.VI.1934 at a little pond near Rundsø. Larvae were caught in Langsø on 17.VI. and on 18.VII.1934.

Lepidurus arcticus PALLAS was found only in Langsø and Bjørnesø (POULSEN 1940a) and thus seems to avoid lakes more than 3 m deep; this is in accordance with the fact that OLORSSON (1918) failed to find it in Relict Lake, the only one of the lakes investigated by him that was more than 3 m deep.

Prionocypris glacialis SARS¹⁾ was found in Ulvesø and the variety *albida* ALM in Bjørnesø. The specimens from Ulvesø were taken with the catcher, and those from Bjørnesø with a cast net and with the

¹⁾ Determined by POULSEN (1940 a).

plankton net on the bar (see p. 10). As these methods of sampling were very rarely or not at all used in Langsø and Rundsø (the plankton here being taken from the boat), the species may well occur in these lakes without being found.

Turbellaria were found in all the lakes except Rundsø; they have not been determined.

?*Mermis* sp. A parasitic worm (*Gordius* or *Mermis*) was found in *Chironomus hyperboreus* larvae from Langsø (ANDERSEN 1937, p. 29); it has not been determined.

V. HIBERNATION OF THE CHIRONOMIDS

Hibernation conditions are of course of great importance among the factors determining which species are able to live in the lakes, and the information about hibernation gained during the investigation in question is therefore collected below.

As already mentioned the lakes were ice-bound for about 9 months of the year; consequently the oxygen supply constitutes a problem. In Langsø the lack of oxygen was so pronounced during a certain period that the water smelt intensively of H_2S (see p. 16). In the two deeper lakes, Rund sø and Ulvesø, the lack of oxygen was not so pronounced; the presence of *Gasterosteus* in Rund sø shows that there must be a relatively high O_2 tension in the water of this lake; but both in Rund sø and in Ulvesø some bottom samples smelt of H_2S ; they were taken in the spring at places where there was a thick gyttja layer, which at these places must have been almost free of oxygen. In most samples, however, the gyttja did not smell of H_2S , and the water never smelt at all.

Thus it may be concluded that the bottom animals in Langsø wintering at depths greater than 1 m must be able to stand the lack of O_2 and a high H_2S tension. The following forms are regularly found at these depths and can be supposed to hibernate there (see table 4):

Trichotanypus choreus,
Pentapedilum coracinum,
Phoenopelma sp.,
Tanytarsus niger,
Ditanytarsus setosimanus and
Psectrocladius sp.

On the other hand, the animals in the two deeper lakes are not as a rule exposed to these conditions, but hibernate under conditions very much like those of summer except perhaps for somewhat lower temperatures. Under these conditions the larvae continue their growth as can be seen when comparing the three sample series from Rund sø (see

p. 27). The species found wintering under the ice in the two deeper lakes are:

Trichotanypus choreus
Tanypus melanosoma
Pentapedilum coracinum
Micropsectra groenlandica
Tanytarsus niger
Phoenopelma sp.
Psectrocladius sp.
Orthocladius ? *consobrinus*

At depths of less than 1 m the hibernating conditions are quite different. The bottom at these depths freezes before the oxygen of the shallower lakes has been used up, and after that time practically no oxygen is consumed owing to the low temperature.

The fact that chironomid larvae are able to hibernate frozen up is shown by the bottom sample no. 447. It was taken on 12.V.1934 in the following way: at first 20 cm snow over the ice was dug away; then 40 cm ice was hewn away, and finally a block of 15×12 cm² was hewn out of the bottom and thawed, and the animals were picked out. The bottom material was sand and gyttja, and the sample contained the following forms:

- 53 *Trichotanypus choreus* larvae
- 4 *Chironomus hyperboreus* larvae
(one of these with a parasitic worm, ? *Mermis*)
- 6 *Ditanytarsus setosimanus* larvae
- 2 *Tanytarsus niger* larvae
- 6 *Phoenopelma* sp. larvae
- 2 *Psectrocladius* larvae
- 1 *Hydrocnidae*
- 2 small Ostracoda.

All the larvae were swimming briskly about and did not differ in behaviour from those taken in ordinary bottom samples. The larvae just mentioned had survived being frozen up for about 5 months, since the ice had attained a thickness of 40 cm not later than in the middle of December.

Among the chironomid larvae not found in sample no. 447, *Cricotopus glacialis* and *Corynoneura scutellata* are able to winter frozen up, as they have never been found at depths greater than 1.25 m. The same can be said of *Orthocladius* ? *consobrinus* judging from its benthic distribution in Langsø.

As to *Pentapedilum coracinum*, it cannot be stated with certainty whether it is able to hibernate frozen up or not. In Langsø the larvae

of this species were found in almost equal numbers at all depths, but as it is the most agile swimmer of all the larvae found in the lakes, it is not sure that it has wintered at the depths where it was captured. It may be right in this connection to mention a difference found in the benthic distribution of this species in the two series of samples from Langsø, as is shown in table 17. The two series were taken between 22.VIII. and 20.X., i. e., after the period of flying, and between 11.VI. and 14.VIII., i. e., before and during the period of flying. In the first series the highest average number of *Pentapedilum* is found at 0.4—0.8 m, in the second series the highest number is found at 1—1.5 m.

Table 17.

(Single figures always mean larvae, in fractions the numerator means larvae and the denominator pupae).

Depth (m)	0.1— 0.3	0.4	0.5	0.6— 0.8	1.0— 1.25	1.3— 1.5	1.7— 1.75	2.0
Number of samples:								
22.VIII—20.X.	5	4	7	6	7	4	5	1
11.VI—14.VIII.	6	4	5	7	7	4	6	1
Average number of <i>Penta-</i> <i>pedilum</i> per sample:								
22.VIII—20.X.	0.8	2.3	3.0	1.2	0.7	0.3	0.4	..
11.VI—14.VIII.	..	..	0.6	0.9	2.4/0.6	5.0/0.3	..	..
Average number of <i>Tany-</i> <i>tarsus</i> per sample:								
22.VIII—20.X.	3.7	..	0.1	0.8	10.6	4.8	6.8	..
11.VI—14.VIII.	..	..	..	/0.1	5.3/0.2	11.5/8.5	26	..

These changes may be explained in three ways: 1) Emigration from the shallow water as the ice grew thicker (the first series was taken before the ice reached a thickness of 30 cm, and the second after the ice has melted). 2) Extinction of the larvae, as they get frozen up. 3) Owing to a higher temperature in the shallow than in the deeper water, a quicker development of the imagines in early summer, and a quicker growth of the young larvae in late summer.

If the first or second explanation is right, it means that *Pentapedilum* does not winter frozen up; if the third is right, the contrary is the case. An examination of these explanations gives the following results: 1) Emigrations of a similar kind were assumed for the larvae of other species of chironomids by LUNDBECK (1926), LANG (1931) and BERG (1938), and *Pentapedilum* might be able to carry out such an

emigration, being a good and willing swimmer; but the fact that *Tanytarsus niger* shows the same change, speaks against this explanation, since *Tanytarsus* is no good swimmer and does not spontaneously leave its tube. 2) This fact also contradicts the second explanation, since *Tanytarsus* is known to be able to winter frozen up. 3) It must therefore be assumed that the third explanation is the most probable, and consequently that *Pentapedilum coracinum* is in all probability able to hibernate frozen up.

Tanypus melanosoma is likewise probably able to hibernate frozen up, since it was once taken in shallow water.

As to *Micropsectra groenlandica*, there is no possibility whatever of knowing whether it is able to winter frozen up or not, as it was only caught at 4—5 m.

Thus among the 12 species of chironomids found in the lakes 9 are certainly able to winter frozen up, 2 are probably able to do so, and the ability of one in this respect is unknown.

In table 18 a survey is given of the way in which the chironomid larvae hibernate in the lakes.

Table 18.

Wintering conditions	frozen up	under the ice	
		In the water of Langsø lacking in O ₂	In the water of Ulvesø and Rundsø containing O ₂
<i>Trichotanypus choreus</i>	+	+	+
<i>Pentapedilum coracinum</i>	+	+	+
<i>Phenopelma</i> sp.	+	+	+
<i>Tanytarsus niger</i>	+	+	+
<i>Psectrocladius</i> spp.	+	+	+
<i>Ditanytarsus setosimanus</i>	+	+	..
<i>Orthocladius ?consobrinus</i>	+	..	+
<i>Chironomus hyperboreus</i>	+	..	..
<i>Cricotopus glacialis</i>	+	..	..
<i>Corynoneura scutellata</i>	+	..	..
<i>Tanypus melanosoma</i>	?+	..	+
<i>Micropsectra groenlandica</i>	?	..	+

As already mentioned the hibernation at depths of less than 1 m has the advantage of the oxygen supply ceasing to be a problem, but there is also the disadvantage that the development of these animals is interrupted for 5—9 months, while animals at greater depths are able

to continue their growth all through the winter. As a counter-balance the animals in the shallows have the chance of a quick development owing to the higher temperature in the period when the lakes are free of ice.

As most of the chironomid larvae are able to winter frozen up and conditions in most respects are more favourable in shallow water, it is easily understood that most of the larvae attain their greatest density at depths of less than 1 m; exceptions (see table 4 and 10) are *Tanytarsus niger* with its maximum in Langsø at about 1.7 m and in Rundsø at 4—5 m, and *Phoenopelma* sp. and *Orthocladus ?consobrinus* with their maxima in Rundsø at 4—5 m.

VI. DURATION OF DEVELOPMENT OF THE CHIRONOMID LARVAE

Owing to the short vegetation period and the low temperature, it was to be expected that chironomid larvae would need more than one year for their development in high arctic lakes, the more so as a two-year cycle has been seen in the case of a species of *Chironomus* in a temperate lake (R  MP  L 1936). This was, however, not proved, even for a single species; on the contrary, it was proved that five species complete their development in one year: in Runds  , *Pentapedilum coracinum*, *Phoenopelma* sp., *Tanytarsus niger* and *Orthocladius ?consobrinus* (see table 11, p. 26) and in Langs   *Pentapedilum coracinum* and *Tanytarsus niger* (see table 17, p. 47) and *Cricotopus glacialis* (see p. 37). As far as the remaining species are concerned, it cannot be ascertained how long they require for their development.

VII. COMPARISON OF THE LAKES

The factors determining the composition of the animal communities in a lake may be divided into two categories: 1) qualities of the lake, such as form, size and depth, and 2) qualities of the surroundings, such as climatic factors, the shape and nature of the surrounding land and the position of the lake in relation to the zoogeographical regions. For the three lakes, Langsø, Ulvesø and Rundsø, the animal communities of the bottom of which were investigated, the factors of the second category are almost equal; perhaps Ulvesø receives more afflux and is better protected against wind owing to the greater depth of the surrounding valley.

Thus, most of the differences between the animal communities of these lakes have to be explained by the form, size and depth of the lakes. These qualities can be compared by means of table 19: 1) The areas are within the same order of magnitude and consequently cannot be supposed to have any influence on the differences in the animal communities. 2) The ratio length: breadth varies considerably, as can be seen on the map. For lakes with the same surface area, it can be taken as a (certainly inaccurate) measure of the length of the coast line and of the average distance from all points in the lake to the nearest coast; the greater the ratio length: breadth, the longer the coast line and the shorter the average distance to the coast. This must be of some importance to the animals, because a longer coast line will give a higher temperature in the water, and a short average distance to the coast will give greater probability for all parts of the lake to receive plankton plants and animals drifting out from the warmer littoral zone. 3) The water content also varies considerably. Its importance is most easily recognized in watching the ratio shown next in the table. 4) Water content: surface area = average depth. This factor must necessarily be of the greatest importance to the animals, as it is a measure of insolation per unit of water content and thus determines the production of phytoplankton and the temperature of the water. 5) Compared with the factor just mentioned, the greatest depth is of very little importance except

Table 19.

Lake	Langsø	Ulvesø	Rundsø
1) surface area (ha).....	5	8.4	7.4
2) length : breadth.....	4.6	2.8	1.3
3) water content (m ³).....	50,000	250,000	350,000
4) average depth (m)	1	3	4.7
5) greatest depth (m).....	2	5	11
6) water content more than 1 m under the surface (m ³)	13,000	170,000	290,000
7) area of bottom more than 1 m under the surface (ha).....	2.5	6.7	5.0
8) average height of water over the non-frozen bottom, when the ice is 1 m (m)	0.5	2.5	5.8
conditions for phytoplankton production and high temper- ature	good	middling	poor
oxygen supply in the winter..	poor	middling	good
littoral zone:			
depth (m).....	0—1	?	0—1
bottom community.....	<i>Ditanytarsus</i> (<i>Trichotanypus</i>)	..	<i>Cricotopus</i> a. o. <i>Orthocladinae</i>
average number of animals per sample.....	60	..	5.4
sub-littoral zone:			
depth (m).....	..	?	2—5
bottom community.....	..	..	<i>Phoenopelma</i> (<i>Tanytarsus</i> and <i>Orthocl. ?consob.</i>)
average number of animals per sample.....	..	..	5.6
profundal zone:			
depth (m).....	1.3—2	4—5	5.5—11
bottom community	<i>Tanytarsus</i> (<i>Trichotanypus</i>)	<i>Phoenopelma</i>	<i>Tanytarsus</i>
average number of animals per sample.....	34	38	0.6

as the lower limit of the profundal zone. 6) The next figure in the table gives the portion of the water content that lies more than 1 m under the surface; this mass of water is of particular interest, containing as it does the oxygen reserve for the lake during the winter (when the ice is 1 m). To compare the three lakes, the size of this mass of water

must be taken in relation to that part of the bottom, using the oxygen, viz. the part lying more than 1 m under the surface; 7) this figure is shown in the next line. 8) The ratio between these two figures

non-frozen water : non-frozen bottom = average height of water over the
non-frozen bottom

is shown in the next series of figures; 0.5 m water proved to be too little for the oxygen supply, while 2.5 m in Ulvesø was enough to keep the water free of H_2S .

Comparing the three lakes, it is obvious that the ratio length : breadth and the average depth make possible the highest phytoplankton production and temperature in Langsø and the lowest in Rundsø; on the other hand, the oxygen reserves are biggest in Rundsø and smallest in Langsø; in both these respects Ulvesø is intermediate.

These facts give some explanation of the composition of the various animal communities in the lakes (see the continuation of table 19):

For the littoral zone (0—1 m) the oxygen supply in the winter is without interest, and the phytoplankton production and temperature are therefore the deciding factors. In Rundsø, where the phytoplankton production and the temperature are lowest, the littoral bottom community is dominated by the *Orthocladinae*, which are generally known to be predominant under extreme oligotrophic conditions; 75 % of all *Chironomidae* found belong to *Orthocladinae*. In Langsø, where the phytoplankton production and the temperature are highest, a *Ditanytarsus* community is found, in which the *Orthocladinae* constitutes only 35 %; moreover, the number of animals per sample in Rundsø is 5.4 and in Langsø 60.

In the profundal zone of Langsø and Rundsø the same species predominates, viz. *Tanytarsus niger*, but there is a striking difference in the number of animals per sample, viz. 60 times as many in Langsø as in Rundsø, which shows, that Langsø is more eutrophic than Rundsø. Furthermore, it is curious to find that *Pentapedilum coracinum* constitutes 29 % in Rundsø and only 3 % in Langsø, curious, because there is reason to believe that this species prefers a certain mesotrophy. When *Tanytarsus* is found to be predominant in the profundal zone of Langsø and Rundsø, it is to be expected that it predominates in the intermediate Ulvesø too; but here *Phoenopelma* is predominant, and *Tanytarsus*, together with *Micropsectra*, has only one third of the frequency of that species. Moreover, the number of individuals per sample in Ulvesø does not lie between that of Rundsø and Langsø. These facts can, to some extent, be explained by comparing the profundal of Ulvesø with the sub-littoral of Rundsø, which include about the same depths, and the latter is inhabited by a community, of which *Phoenopelma* is the most

Table 20. Benthic distribution of the chironomids in the lakes.
Average number of individuals (larvae + pupae) per sample.

Depth (m).....	< 1		1-1.5		2	2-3	4-5	6-7	8-9	10-11
Lake (L = Langsø, R = Rund- sø, U = Ulvesø).....	L	R	L	R	L	R	U	R	R	R
Number of samples.....	45	9	22	12	13	7	18	10	13	10
<i>Trichotanypus choreus</i>	13	..	15	..	12	0.3	4	0.2	..	0.1
<i>Tanypus ?melanosoma</i>	..	..	..	..	..	..	0.6	..	..	..
<i>Chironomus hyperboreus</i>	10	..	5	0.1	..	..	..	..	..	..
<i>Pentapedilum coracinum</i>	1.1	0.7	2.2	1.1	0.2	0.4	0.1	0.8	0.2	0.4
<i>Ditanytarsus setosimanus</i>	14	0.1	6	..	0.1	..	..	..	..	..
<i>Tanytarsus niger</i> + in Ulvesø. } <i>Micropsectra groenlandica</i> }	0.7	..	10	0.4	15	..	3	3	0.2	0.1
<i>Phoenopelma</i> sp.....	0.8	..	2.5	..	0.6	0.1	24	2.2	..	0.1
<i>Cricotopus glacilis</i>	10	2.3	0.2	0.9	..	..	..	..	..	..
<i>Psectrocladius</i> spp.....	5	1.3	2.6	0.5	0.5	..	0.3	..	..	..
<i>Corynoneura scutellata</i>	5	0.6	0.2	..	..	..	..	..	..	..
<i>Orthocladius ?consobrinus</i>	0.4	0.4	0.1	0.3	..	0.4	0.2	2.4	..	..
Total...	60	5.4	43	3.3	28	1.3	38	8.6	0.5	0.6

characteristic member, since the two other species present in almost equal numbers are more characteristic of the littoral or profundal zone. This is more clearly understood when considering table 10, in which it is shown that *Phoenopelma* is found in Rundsø in the greatest number at a depth of 4—5 m, this being the same depth as the profundal zone in Ulvesø. At the same depth the highest total number of animals per sample was found; this seems to show that the depth 4—5 m is a particularly profitable depth for the chironomids in the lakes in question, and that explains also why the number of animals per sample is so big in the profundal of Ulvesø. (This, however, is no doubt partly due to the fact that all samples in Ulvesø were taken at the “best” time of the year (see p. 27)). The fact that *Orthocladius ?consobrinus* is present in a greater number in Rundsø than in Ulvesø is undoubtedly explained by this species preferring extreme oligotrophy, as most other species of this family do.

Thus the differences between the bottom animal communities in the three lakes are almost entirely explained by means of the differences in form and depth of the lake.

This is further confirmed by table 20, which shows that a fairly continuous picture of the benthic distribution of the various species is gained, when facts from all three lakes are put together.

Comparing the bottom fauna of the lakes, it is further noticed that the same species are found in all the lakes, apart from *Tanytus melanosoma* and *Micropsectra groenlandica*, the presence in Ulvesø of which is most probably due to this lake having a somewhat more favourable exposure than the other lakes. The difference between the bottom fauna of Langsø and Rundsø is, therefore, only demonstrated by a quantitative investigation. In sharp contrast hereto stand the plankton crustaceans, of which Langsø and Rundsø have no form in common, and the same can be said of Rundsø and Ulvesø, as *Bosmina longirostris* is found in different varieties in these two lakes. The distribution of the plankton crustaceans in the lakes may be described in the following way (see table 15): One littoral form, *Simocephalus vetulus*, was only found in water less than 1 m deep, viz. in Bjørnesø and in the shallow, western end of Langsø. Three shallow-water forms, *Daphnia pulex*, *Chydorus sphaericus* and *Cyclops strenuus*, were found in the plankton of all the lakes except Rundsø, and they may be present in the shallow parts of this lake too (see *Cyclops strenuus* p. 41); in Europe these forms are also lacking in the plankton of deep lakes. Two forms, *Polyphemus pediculus* and *Bosmina longirostris* var. *similis*, were found in Ulvesø only, and two forms, *Bosmina longirostris* var. *cornuta* and *Maraenobiotus danmarki*, were found in Rundsø only.

VIII. COMPARISON WITH OTHER LAKES

1. Types of lakes.

A comparison of the bottom fauna of the lakes described in the present paper and that of other lakes is very difficult, because most of the species, constituting the bottom fauna in East Greenland lakes, are different from those of other lakes. This is due to the fact that the lakes dealt with here are the first arctic lakes in which the bottom fauna has been subjected to a quantitative investigation.

A comparison of the other aspects of the lakes is also very difficult, owing to the lack of hydrographic measurements. It is possible, however, to place our lakes with some degree of certainty in the main system of types of lakes, as may be seen in the following.

It can primarily be stated that none of them are dystrophic, because the water in them is never brown in summer. In Langsø, however, the water was yellow-brown for about two months in winter. This colour can hardly be due to anything but humus, and it is most probable that the conditions for the animals under the ice at this time resemble, to some extent, those of a dystrophic lake, but as the humus is autochthonic (due to insufficient oxydation of dead plankton organisms) and seasonal, it is misleading to call the lake dystrophic.

Finally, we have to decide whether the lakes are eutrophic or oligotrophic. They are found to have the following in common with eutrophic lakes (see THIENEMANN 1925, p. 199): 1) In the depth of the lakes the bottom is covered by a thick layer of decaying gyttja. 2) In all the lakes gyttja, smelling of H_2S , was found in the winter, which shows that a distinct decrease of oxygen has taken place under the ice. In Langsø the decrease was violent. 3) There is reason to believe that electrolytic nourishment for plants is present. 4) The fauna decreases towards the depth in the deepest lake, quantitatively as well as qualitatively.

On the other hand, our lakes have the following in common with oligotrophic lakes: 1) The littoral plant production is small. 2) The profundal fauna is dominated by *Tanytarsus*, and in Rundsø, the deepest and therefore the most oligotrophic of the lakes, 3) the transparency is great and 4) only a little suspended detritus is found in summer.

Finally the number of animals per sq.m. in the profundal zone is medium in the two lakes; the number in Langsø and Ulvesø is 1500 and 1700 respectively. (THIENEMANN gives 300—1000 for the oligotrophic and 2000—10,000 for the eutrophic lake). Only in Rundso the number (27) is even lower than in oligotrophic lakes.

Thus our lakes have some qualities in common with eutrophic and some in common with oligotrophic lakes, and one quality lies in between. At first sight that seems rather puzzling, but closer consideration shows that they possess most of the conditions of eutrophic lakes, but as they are free of ice only for 3 months (compared with about 8 months in the case of central European lakes), they have not enough time for a rich development of the phytoplankton. This explains: 1) The great transparency and 2) the small amount of suspended detritus. 3) The small littoral plant production is likewise due to the short vegetation period. 4) The *Tanytarsus* fauna in the depth is not at all a sign of oligotrophy, as *Tanytarsus niger* is able to live under the ice in Langsø in the winter (see p. 16) and thus cannot be stenooxybiont.

It is therefore clear that if the vegetation period had been longer, the lakes would have been eutrophic.

From the point of view of the bottom fauna, however, two qualities in a lake are of predominant importance, viz. the amount of oxygen and the amount of food. The amount of oxygen in our lakes is midway between oligotrophic and eutrophic lakes, as there is a decrease in the oxygen tension in winter but not in summer. The amount of food is also medium, since this is the case with the number of animals. From the point of view of the bottom fauna, the lakes can therefore be characterized as mesotrophic. This agrees well with the presence of *Pentaptilum* (*Sergentia*) in the profundal of the lakes. Rundso should undoubtedly be placed somewhere between the mesotrophic and oligotrophic types, since transparency is great, and the number of animals per sq.m. is only 27.

Above it is shown that the arctic climate, viz. the short vegetation period excludes eutrophy in the lakes. JÄRNEFELT (1935) has shown that another aspect of the arctic climate, viz. the small precipitation, excludes dystrophy even in a region with many moors. Thus in the arctic there is only a possibility of oligotrophic and mesotrophic lakes, (setting aside the rare cases of lakes eutrophied by manuring etc. see JÄRNEFELT 1935, p. 656) and, moreover, the latter type is typical only of shallow lakes like Langsø and Ulvesø¹⁾.

¹⁾ Altogether it is important to remember, when discussing the type of these lakes, that the classic types were set up on the basis of investigations of big, deep lakes. On the whole the East Greenland region must therefore undoubtedly be characterized as oligotrophic.

In this connection it is worth mentioning some observations made in a little lake from the late glacial period (ANDERSEN 1937). In this lake a rich Cyanophycean gyttja was sedimented in Allerød time, showing that the lake was eutrophic, while in the lower and upper Dryas time a grey gyttja was sedimented. This latter gyttja was very much like that found in our East Greenland lakes and shows that meso- to oligotrophic conditions have prevailed in the arctic climate before and after the warmer Allerød time.

2. Zonation of the bottom.

A good compendium and appraisal of the zonation used in descriptions of temperate lakes is given by BERG (1938, p. 178). He shows that three zones are generally accepted, viz. the littoral, the sub-littoral and the profundal zone, and that the boundaries ordinarily used to mark these zones are the extreme limit of the vegetation (as the lower boundary of the littoral zone) and the extreme limit of the molluscs apart from *Pisidia* (as the lower boundary of the sublittoral zone). These two limits, however, cannot be used in the East Greenland lakes as higher plants are very scarce in them (they were present in 3 samples only—see table 3) and molluscs are entirely lacking. For the same reasons, the way in which LUNDBECK marks the lower boundary of the sublittoral zone (1926, p. 112, and 1936, p. 216) cannot be used. He marks this boundary by means of the lower limit of the littoral sedimentation, but as this sedimentation is due to molluscs shells and littoral vegetation, it is not found in the East Greenland lakes. In these lakes it is therefore necessary to find another basis for the zone division.

As the lower boundary of the littoral zone in the East Greenland lakes the depth of 1 m was chosen for the following reasons: 1) it is a well-marked faunistic limit (see tables 4 and 11), 2) it is also marked in the benthic distribution of the various kinds of bottom material, and these two facts are due to the circumstance that 3) the ice in winter reaches this depth. In this connection it should be noted that the ice is supposed to reach almost the same thickness every year, as it was 1 m as early as on 1.II. (after 55 month degrees below zero), and did not grow more than 0.25 m thicker during the following two and a half very cold months (further 67 months degrees below zero)¹⁾. In tempered lakes no such constant thickness of the ice is found and that is no doubt the reason why it does not mark any fixed ecological limit in these lakes.

¹⁾ That the ice on shallow lakes never grows thicker than about 1.5 m is further backed up by the fact that the two-year-old ice measured by Johansen (1911) on Sælsøen and Annekssøen was only about 2 m thick.

A sub-littoral zone was not found in Langsø. (The boundary zone here and in Rundsø was only introduced by the description of the animal communities, in order to exclude samples taken in the area, where both the littoral and the profundal (or the sublittoral) communities are represented). In Rundsø a sublittoral zone was described as reaching from the littoral zone down to a depth of 5 m. This limit was chosen for the following reason: 1) it is the lower limit of the Orthocladinae, 2) at this limit the number of animals suddenly drops to less than one per sample, and 3) 5 m marks the boundary between the steep slope (1—5 m) and the plain bottom (6—11 m).

A profundal zone was found in all three lakes, which were quantitatively investigated, but at quite different depths, viz. in Langsø 1—2 m and in Rundsø 6—11 m; in Ulvesø the profundal zone was only investigated at a depth of 4—5 m.

In order to see whether it is right to use the names preoccupied by the zones in temperate lakes for the quite differently defined zones in the arctic lakes, it is of interest to try to compare these zones.

The lower boundary of the littoral zone is fixed at a depth, where a phenomenon working from the surface is weakened to such a degree, that it is manifested in the form of a faunistic limit. In the temperate lakes this phenomenon is the light manifesting itself through the plants; in the arctic lakes it is the refrigeration manifesting itself through the ice; but in both cases it is the effect on the fauna in the form of a faunistic limit, which is of interest to the zoologist. In the arctic, as in the temperate lakes, the littoral zone is that of the oxybionts (i. e. in the arctic lakes the chironomids without haemoglobin). In the temperate lakes the danger of an O_2 -decrease is greatest in the summer and is counteracted by the CO_2 -assimilation of the vegetation, which, according to the definition, is present in the zone, and diminished by the proximity of the surface. In the arctic lakes the danger of an O_2 -decrease is greatest under the ice in the winter, but in the littoral zone the animals are protected against a lack of O_2 in being frozen up according to the definition of the zone. Both in the temperate and in the arctic lakes gyttja is scarce in the littoral zone and that brings about a scarcity in this zone of animals, requiring a low O_2 -tension and therefore gyttja to hide in during critical periods (see LANG 1931, p. 103).

Thus the littoral zone in the temperate lakes and in the East Greenland lakes play an equal part in the ecology of the animals in the lakes to such a degree that they are considered directly comparable.

With regard to the sub-littoral zone things are more difficult, because the ecological factors determining the depth to which the molluscs descend in the temperate lakes, and the change of the composition and

density of the fauna at the lower boundary of the sub-littoral zone in Rundsø are not known. It is, however, not improbable that the profile of the bottom is the deciding factor in both cases. In Rundsø the boundary between the sub-littoral and the profundal was fixed at the foot of a steep slope, and it is clearly seen on BERG's map (1938, fig. 1, p. 5) that the foot of the slope lies at 15 m, i. e. at the lower boundary of the sub-littoral zone. This seems to indicate that the sub-littoral zone is in fact that part of the steep slope not occupied by the littoral zone. This supposition is further supported by the fact that on this steep slope solid bottom is common (as distinct from the gyttja plains of the profundal zone), and this solid bottom is for many molluscs "a suitable substratum", which according to BERG (1938, p. 185) "may be of importance" to them. Thus, there is some resemblance between the lower limit of the sub-littoral zone in Esrom lake and in Rundsø, and as this zone in both lakes is, moreover, clearly transitional between the littoral and profundal zones, they are without doubt comparable.

With regard to the profundal zone, that of Rundsø may be compared to that of Esrom lake, since their upper limits are comparable. In Langsø the upper limit of the profundal zone is identical with the lower limit of the littoral zone. This is, however, also found to be the case in small, shallow lakes in a temperate climate (see c. g. LUNDBECK 1926, p. 113). There is, therefore, no doubt that the profundal zone of Langsø is comparable to that of shallow, tempered lakes. As the fauna of the profundal zone, moreover, shows pronounced monotony both in the East Greenland lakes and in the tempered lakes (and this likewise holds good for the investigated part of the profundal in Ulvesø) there is no reason to doubt the profundal zone of the East Greenland lakes being directly comparable to the profundal zone of temperate lakes.

IX. MAIN RESULTS

The chief value of the present paper consists in quantitative investigations of the bottom fauna in high arctic lakes being for the first time published here (tables 1, 2, 6, 7, 8 and 13). Moreover, most of the chironomid larvae, composing this bottom fauna, were determined as to species by rearing and by collecting exuvia of the pupae on the surface of the lakes and imagines in the surroundings (ANDERSEN 1937). These lakes will, therefore, be a good subject for comparison to future investigators of arctic lakes; the more so as the plankton of these lakes is the best investigated of any arctic lake (POULSEN 1940 a and b), and the topography (see the map), geology (BÜTLER 1937) and meteorology (SØRENSEN 1941) of the place have been very closely investigated.

The main results of the investigation were:

A. Hydrography.

1) In the two lakes, in which samples were taken in the shallow water, an ecological limit was found at about 1 m. This limit is due to the ice being 1 m thick most of the winter.

2) In the shallowest lake, Langesø, a high concentration of H_2S was found in the water under the ice from the middle of March until the first part of May. This shows that the water was almost free of oxygen.

3) In the deepest lake, Rundsø, *Gasterosteus aculeatus* is found as a sign of a relatively high oxygen tension also in winter.

B. Hibernation.

4) The animals wintering at depths less than 1 m are frozen up for months. This was shown by hewing out a sample of the frozen bottom (p. 46). Thus, the oxygen supply is no problem to them. All this time they are, however, unable to grow and develop. On the other hand, they have the chance of a quick growth, when the shallow water is warmed in the early summer.

5) The animals wintering at depths greater than 1 m are able to continue their growth all through the winter (see p. 27). On the other

hand, they are, in Langsø, exposed to a lack of oxygen in winter and in Rundsø to a low temperature in the summer.

6) The conditions in which the Chironomid larvae hibernate are seen in table 18, which shows that all the larvae properly investigated in this respect are able to winter frozen up.

7) Furthermore, as the conditions in most respects are more favourable in shallow water, most of the larvae attain their greatest density at depths less than 1 m; exceptions are (see table 4 and 10) *Tanytarsus niger* with its maximum in Langsø at about 1.7 m and in Rundsø at 4—5 m, and *Phoenopelma* sp. and *Orthocladius ? consobrinus* with their maxima in Rundsø at 4—5 m.

C. Zonation.

8) The 1 m limit is taken as the lower boundary of the littoral zone. In Rundsø, the only lake in which a sub-littoral zone was found, its lower boundary was fixed at the depth where the steep slope is followed by the plain bottom. On pp. 58—60 it is shown that the zones delimited by these boundaries are quite comparable with the corresponding zones in temperate lakes.

D. Animal communities.

9) The littoral zone in Rundsø is inhabited by an *Orthocladinae* community (75 % *Orthocladinae*) and in the more eutrophic Langsø by a *Ditanytarsus setosimanus* community (with only 33 % *Orthocladinae*).

10) The profundal zone of both these two lakes is inhabited by a *Tanytarsus niger* community, but with 60 times as many animals per sample in Langsø as in Rundsø.

11) In the profundal zone of Ulvesø a *Phoenopelma* community is found, the type of which is also the most characteristic animal in the sub-littoral zone of Rundsø. This is explained by the two zones covering almost the same depth (4—5 m).

12) While the various lakes show only quantitative differences in their chironomid fauna, differences in their plankton fauna are distinctly shown even by a qualitative investigation (see table 15).

13) The differences in the animal communities of the three lakes are mostly due to the qualities of the lakes themselves (above all the average depth), since the surroundings are to a high degree equal (p. 51).

E. Type of lakes.

14) The lakes would have been eutrophic had it not been for the short vegetation period. From the point of view of the bottom fauna they are mesotrophic (pp. 56—57).

F. Other biological results.

15) In the deepest lake, Rundsø, it was shown: a) that the major part of the chironomids in the sub-littoral and profundal zones hatch during or immediately after the period of ice-melting; b) that in these zones the larvae from the eggs laid in the beginning of July have not grown so big by the end of August that they are found in the samples, and c) that the larvae are able to continue their growth under the ice during the winter (p. 27).

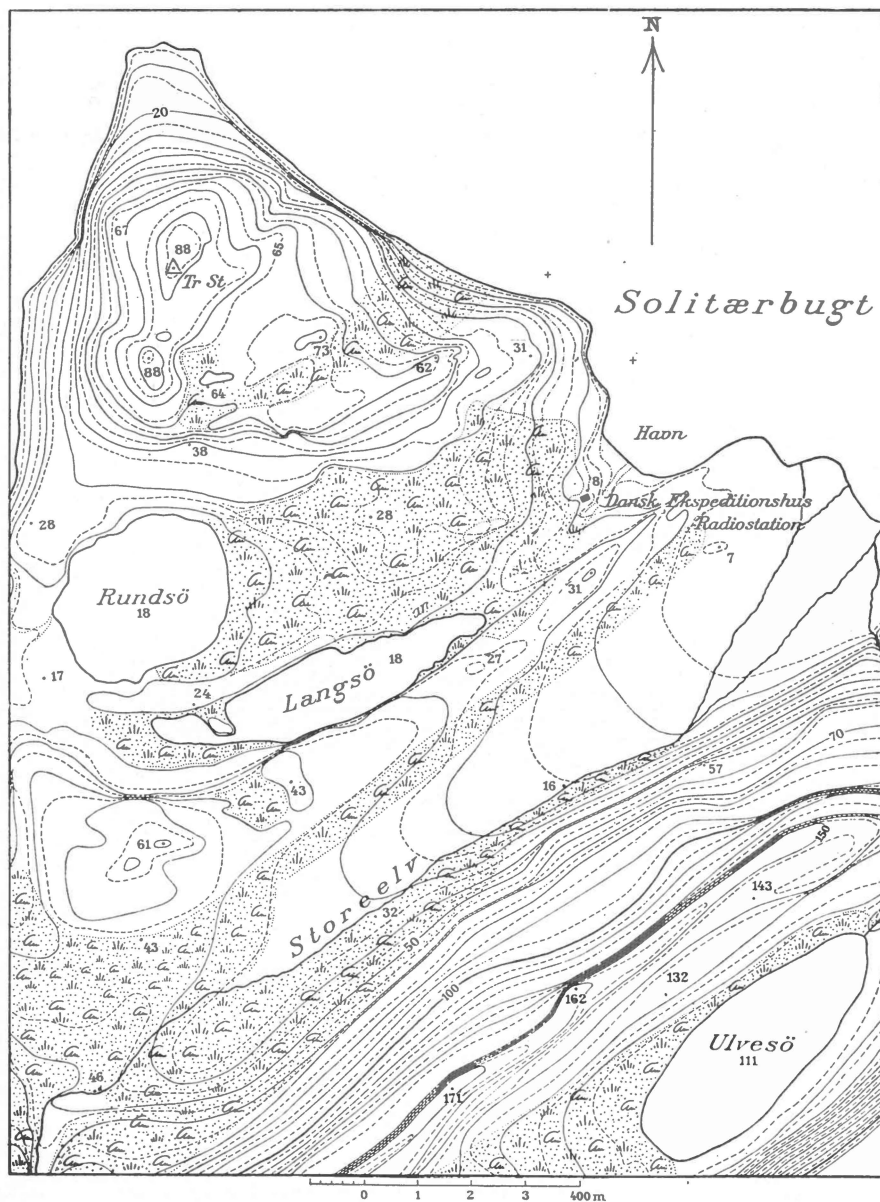
16) The two species *Pentapedium coracinum* and *Tanytarsus niger* show in Langsø a different benthic distribution in the two sample series (see table 17, p. 47). This is not explained by emigration, as *Tanytarsus* is dull and does not spontaneously leave its tube, but by earlier hatching in the shallows, owing to a higher temperature in the early summer.

17) The following species were found to complete their development in one year: *Pentapedium coracinum*, *Phoenopelma* sp., *Tanytarsus niger*, *Orthocladius ? consobrinus* and *Cricotopus glacialis* (see p. 50).

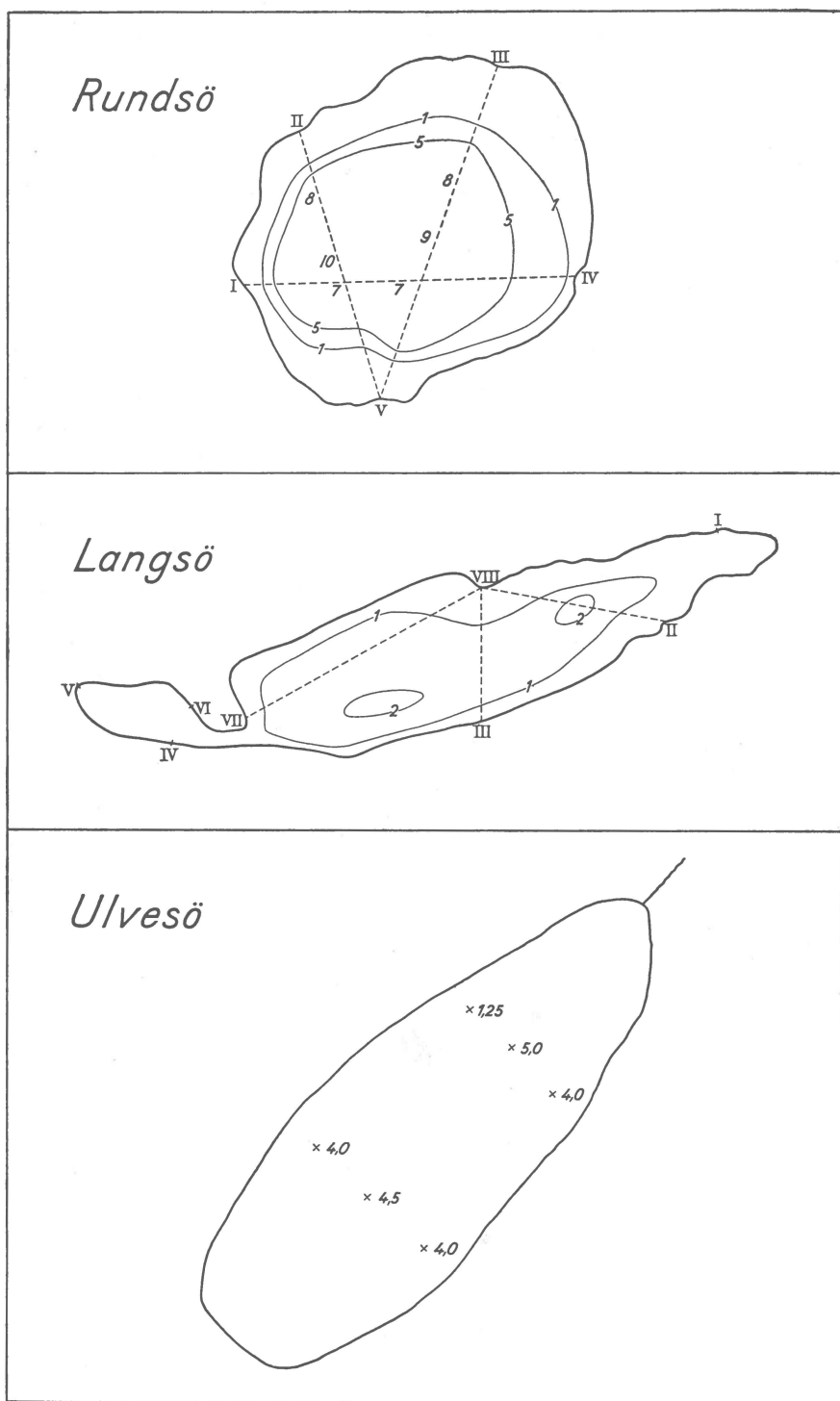
X. LITERATURE

- ANDERSEN, SØGAARD, 1937. Ueber die Metamorphose der Ceratopogoniden und Chironomiden Nordost-Grönlands. — Medd. Grønland, Bd. 116, Nr. 1.
- 1938. Spätglaciale Chironomiden. — Medd. Dansk Geol. Foren., Bd. 9, p. 320.
- 1943. Dryadotanytarsus edentulus. — Entom. Medd. (København), Bd. 23, p. 174.
- BERG, K., 1929. A faunistic and biological study of Danish Cladocera. — Vidensk. Medd. Dansk Naturh. Foren. Bd. 88, p. 31.
- 1931. Studies on the genus Daphnia with special reference to the mode of reproduction. — Ibid. 92, p. 1.
- 1938. Studies on the bottom animals of Esrom lake. — Mém. l'Acad. Roy. Sci. Lettr. Danemark. Sec. Sci., 9. ser., t. 8., p. 1.
- BRUNDIN, L., 1942. Zur Limnologie Jämtländischer Seen. — Medd. Stat. Undersök. Forsöks. Sötvattensfisk. Stockholm, Nr. 20, p. 1.
- BÜTLER, H., 1937. Erläuterungen zu einigen Bildern der Ellainsel in Ostgrönland. — Mitt. d. Naturf. Ges. Schaffhausen, Hefte 13, Nr. 2, p. 9.
- FORBES, S. A., 1893. A preliminary report on the aquatic invertebrate fauna of the Yellowstone National Park, Wyoming, and the Flathead region of Montana. — Bull. of the U. S. Fish Comm. for 1891.
- HABERBOSCH, P., 1920. Die Süßwasserentomostracen Grönlands. — Zeitschr. f. Hydrologie 1, 1920.
- JÄRNEFELT, H., 1935. Die regionale Verteilung der Gewässertypen in Finland. — Verh. Intern. Verein. theor. angew. Limnol., Bd. 7.
- JOHANSEN, F., 1911. Freshwater life in Northeast Greenland. — Medd. Grønland, Bd. 45, p. 321 (1912).
- JUDAY, C., 1915. Limnological studies on some lakes in Central America. — Transact. Wisconsin Acad. sc., vol. 18, part 1, p. 214.
- LANG, K., 1931. Faunistisch-ökologische Untersuchungen in einigen seichten oligotrophen bzw. dystrophen Seen in Südschweden. — Lunds. Univers. Årsskr. N. F. Avd. 2. Bd. 27. Nr. 18.
- LENZ, FR. und A. THIENEMANN, 1922. Chironomidenlarven aus Nowaja Semlja. — Report of the scientific results of the Norwegian expedition to Novaya Zemlya 1921, No. 3.
- LENZ, FR., 1927. Chironomiden aus norwegischen Hochgebirgsseen. — Nyt Mag. f. Naturv. Bd. 66, p. 111.
- 1928. Ökologische Chironomiden-Typen. — Biol. Listy 14, p. 413. (Sep. p. 1).
- 1941. Die Jugendstadien der Sectio Chironomariae (Tendipedini) connectentes. — Arch. Hydrobiol. 38, p. 1.
- LUNDBECK, J., 1926. Die Bodentierwelt norddeutscher Seen. — Arch. Hydrobiol. Suppl. Bd. 7, p. 1.
- 1936. Untersuchungen über die Bodenbesiedelung der Alpenrandseen. — Arch. Hydrobiol. Suppl. Bd. 10, p. 207.

- LUYTEN, M., 1934. Over de oecologie der Cladocera van België. — Biol. Jaarb. Antwerpen.
- NORDQVIST, H., 1921. Studien über das Teichzooplankton. — Lunds Univers. Årsskr. N. F. Avd. 2. Bd. 17. Nr. 5.
- OLOFSSON, O., 1918. Studien über die Süßwasserfauna Spitzbergens. Beitrag zur Systematik, Biologie und Tiergeographie der Crustaceen und Rotatorien. — Zool. Bidrag från Uppsala. Bd. 6.
- OLSTAD, O., 1925. Ørretvand i Guldbrandsdalen. — Nyt Mag. f. Naturv. 63, p. 1.
- PAGAST, F., 1940. Ueber Zusammensetzung und Verteilung der Bodenchironomidenfauna mitteleuropäischer Seen. — Schr. physik.-ökon. Ges. Königsberg, Bd. 71, p. 387.
- POULSEN, E. M., 1929. Faunistische und biologische Untersuchungen über die Cladocerenfauna von Dänemark. — Vidensk. Medd. Dansk Naturh. Foren. Bd. 86, 1928, p. 203.
- 1940 a. Freshwater Entomostraca. — Medd. Grønl. Bd. 121. Nr. 4.
- 1940 b. Biological remarks on *Lepidurus arcticus* Pallas, *Daphnia pulex* de Geer and *Chydrus sphaericus* O. F. M. in East Greenland. — Medd. Grønl. Bd. 131. Nr. 1.
- REMPEL, J. G., 1936. The life-history and morphology of *Chironomus hyperboreus*. — J. Biol. Can. 2 (2), p. 209.
- RYLOV, W. M., 1935. Das Zooplankton der Binnengewässer. — Die Binnengewässer 15.
- SORENSEN, Th., 1941. Temperature relations and phenology of the Northeast Greenland flowering plants. — Medd. Grønl. Bd. 125, Nr. 9.
- THIENEMANN, A., 1925. Die Binnengewässer Mitteleuropas. — Die Binnengewässer 1.
- 1928. Chironomiden Metamorphosen II. — Arch. Hydrobiol. 20, p. 93.
- 1941. Lappländische Chironomiden und ihre Wohngewässer. — Arch. Hydrobiol. Suppl. Bd. 17. Heft 1—2.
- VALLE, K. J., 1927. Ökologische-limnologische Untersuchungen über die Boden- und Tiefenfauna in einigen Seen nördlich vom Ladogasee. — Acta. Zool. Fennica 2.
- ZAVREL, J., 1926. Chironomiden aus Wigry-See. — Arch. Hydrobiol. et Ichtyol. tom. 1, p. 197.
-



Map of Cape Oswald, about $72^{\circ}50'N$. $25^{\circ}W$. The figures give the height in metres. The dotted areas are covered with a dense or an almost dense vegetation.
(Published by permission of Geodætisk Institut).



Detailed maps of the lakes. The Roman numerals mark the terminal points of the sample lines. The Arabic numerals indicate the depths in metres.