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STUDIES ON THE VEGETATION AND HYDROCHEMISTRY OF SCANIAN LAKES II

ION DETERMINATIONS IN LAKE WATERS

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II

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BY

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Introduction.

In connexion with the investigation of the aquatic vegetation in several lowland lakes in Scania performed by **Asta Lundh** (1951), the author on several occasions collected water samples both from the lakes and their tributaries in order to determine the concentrations of a number of common ions.

The main part of the analytical work was carried out in the summers of 1946 and 1947, but some supplementary analyses were made in the summer of 1948. As the investigation closely accompanied that performed by **Lundh** in her study of the same lakes during the same periods the reader is referred to her description of the development of the investigation (**Lundh** 1951 pp. 7 and 9).

The analyses were performed in 1946 in the laboratory of the purification plant for sewage of Lund at Källby, in 1947 at the soil laboratory of the Botanical Museum in Lund and in 1948 mainly at Källby.

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When the collecting of the samples was commenced in the spring of 1946, the aim of the investigation was to obtain information of the characteristic features of the concentrations of electrolytes in the waters of Scanian lakes and, moreover, to study whether there was any correlation between the concentrations of ions and the distribution of the higher aquatic plants. Naturally it is impossible, even if such a correlation were discovered, to discuss the growth requirements of the plants.

There are very few investigations on the water chemistry of Scanian lakes, but some authors have made determinations of the general limnological factors. Thus **Thunmark** (1945 b) has published some determinations of colour, potassium permanganate-consumption, hydrogen ion concentration, total hardness and specific conductivity from Häckebergasjön. **Lillieroth** (1949 and 1950) has reported the same analyses

Table 1. Survey of the localities for the water samples.

Lake	Map Figure no. (in Lundh 1951)	Maximum number of localities	Name of the tributaries	Notation on the map.
1. Yddingen	9	3	—	1, 2, 3, 4
2. Fjällfotasjön	9	4	—	—
3. Börringesjön	9	4	—	—
4. Havgårdssjön	9	2	—	—
5. Björkesåkrasjön	14	2	—	—
6. Häckebergasjön	14	3	—	—
7. Svaneholmssjön	14	3	—	—
8. Krageholmssjön	16	3	Vistorpsbäcken	1
9. Ellestasjön	16	3	Ebbetorpsbäcken Snogarpsbäcken	2 3
10. Snogeholmssjön	16	3	Outflow from Ellestasjön Assmåsabäcken	4 5
11. Sövdeborgssjön	16	1	—	—
12. Sövdesjön	16	3	Outflow from Snogeholmssjön Frihultsbäcken	6 7
13. Heljesjön	21	1	—	—
14. Vombsjön	21	3	Täpperödsbäcken Övedsbäcken Björkaån	7 8 9
15. Krankesjön	21	5	Sjötorpsbäcken Silvåkrabäcken	5 6
16. Gyllebosjön	29	2	—	—
17. Tunbyholmssjön	29	2	—	—
18. Western Ringsjön	30	1	—	—
Eastern Ringsjön	30	1	—	—
19. Dagstorpssjön	33	1	—	—
20. Kvesarumssjön	35	2	—	—
21. Tjörnarpssjön	35	2	—	—
22. Bosarpssjön	35	2	—	—
23. Finjasjön	37	1	—	—
24. Araslövssjön	38	1	—	—
25. Hammarsjön	38	3	—	—
26. Råbelövssjön	39	3	Råbelövsbäcken Ekestadsbäcken Österlövsbäcken	1 2 3
27. Oppmannasjön	39	3	—	—
28. Levrasjön	50	3	—	—
29. Siesjön	50	2	—	—
30. Västersjön	51	3	—	—
31. Rösjön	51	3	Lärkesholmsån	1

from some lakes in the north-western part of the province but has added determinations of potassium, nitrogen and phosphate. ANDERSSON (1948) published some ion determinations from four Scanian lakes as a part of the present investigation.

More extensive ion determinations from Swedish lakes have been carried out by LOHAMMAR (1938) and his large material has subsequently been treated by IVERSEN and OLSEN (1943) and RODHE (1949). LOHAMMAR's investigation also included the lowland lakes of Uppland, the vegetation of which seems to be very similar to that of Scanian lakes. THUNMARK (1948) has published some results from lake investigations in Södermanland and Småland but of the ions only chloride is discussed. Very detailed studies on the concentrations of cations and sulphate and chloride have been performed by WITTING (1947, 1948 and 1949) in Swedish mire-waters.

In Denmark IVERSEN (1929) has published some studies on the relations between the hydrogen ion concentration and the occurrence of water plants. NYGAARD (1938) made rather close investigations on the hydrochemistry of Danish ponds and lakes, also including the seasonal variations in the contents of nitrogen and phosphorus but he did not discuss the plants. OLSEN (1950 a and b) has recently carried out an investigation in order to find correlations between some ions and the distribution of water plants and divided them into groups according to the concentrations of ions.

This paper is not intended to give a comprehensive solution of the problem of the relationships between ion content and the distribution of plants, nor a limnological classification of the lakes, but to contribute to the always actual discussion of the causes of the differences between the vegetation of various lakes. Very often the total content of electrolytes, *i.e.,* the specific conductivity is regarded as a measure of the nutrients, in spite of the fact that the proportions of the components can vary considerably in different cases. It has been impossible to publish the whole extensive material, which contains about 4800 determinations from lake waters and 1500 values from waters from tributaries, and only surveys are given here. Naturally this material can be treated in many other ways than has been done here and there are also many examples in the literature of a much smaller material which has been studied more closely and from which more far-reaching conclusions have been drawn.

General remarks.

As the lakes studied here are the same as those which have been discussed by Lundh (1951), no general descriptions or maps of the lakes are given in this report. Such information is to be found in her work, where also the localities for the collecting of the water samples are given for both the lakes and the tributaries. Moreover the hydro-

Table 2. Survey of the number of the water analyses of the investigated lakes.

Lake	1946	1947	1948	Total
1. Yddingen	12	8	2	22
2. Fjällfotasjön	6	8	2	16
3. Börringesjön	8	8	2	18
4. Havgårdssjön	2	4	2	8
5. Björkesåkrasjön	—	4	—	4
6. Häckebergasjön	—	3	1	4
7. Svaneholmssjön	1	4	2	7
8. Krageholmssjön	4	6	2	12
9. Ellastasjön	4	6	2	12
10. Snogeholmssjön	6	6	2	14
11. Sövdeborgssjön	—	1	2	3
12. Sövdesjön	6	6	2	14
13. Heljesjön	—	2	2	4
14. Vombsjön	11	7	3	21
15. Krankesjön	15	6	2	23
16. Gyllebosjön	—	4	2	6
17. Tunbyholmssjön	—	4	2	6
18. Western Ringsjön	—	2	1	3
Eastern Ringsjön	—	1	1	2
19. Dagstorpssjön	—	1	2	3
20. Kvesarumssjön	—	2	2	4
21. Tjörnarpssjön	—	2	2	4
22. Bosarpssjön	—	2	2	4
23. Finjasjön	—	—	1	1
24. Araslövssjön	1	—	—	1
25. Hammarsjön	1	2	—	3
26. Råbelövssjön	20	—	1	21
27. Oppmannasjön	—	4	3	7
28. Levrasjön	2	6	2	10
29. Siesjön	—	4	2	6
30. Västersjön	—	5	3	8
31. Rösjön	—	5	3	8

Table 3. Survey of the number of water analyses from the tributaries.

Tributary	Corresponding lake	No. on the map	Map fig. no.	1946	1947	1948	Total
Brook 1	Yddingen	1	9	4	1	—	5
Brook 2	»	2	9	3	—	—	3
Brook 3	»	3	9	1	—	—	1
Brook 4	»	4	9	3	1	4	4
Vistorpsbäcken	Krageholmssjön	1	16	3	1	—	4
Ebbetorpsbäcken	Ellestasjön	2	16	2	1	—	3
Snogarpsbäcken	»	3	16	2	—	—	2
Outflow from Ellestasjön	Snogeholmssjön	4	16	3	2	—	5
Assmåsabäcken	»	5	16	3	1	—	4
Outflow from Sövdeborgssjön	Sövdesjön	6	16	2	—	—	2
Frihultsbäcken	»	7	16	2	1	—	3
Täpperödsbäcken ...	Vombsjön	7	21	4	1	—	5
Övedsbäcken	»	8	21	4	1	—	5
Björkaån	»	9	21	4	2	—	6
Sjötorpsbäcken	Krankesjön	5	21	3	1	—	4
Silvåkrabäcken	»	6	21	4	1	—	5
Råbelövsbäcken	Råbelövssjön	1	39	7	—	—	7
Ekestadsbäcken	»	2	39	7	—	—	7
Österslövsbäcken	»	3	39	7	—	—	7
Lärkesholmsån	Rösjön	1	51	—	1	—	1

logical conditions of the years of the investigation are not discussed here (*cf.* LUNDH 1951 p. 30 *et seq.*).

Naturally the localities in the lakes have not always had exactly the same position, nor has the same number of samples been collected at all visits to the lakes. The localities in the outflows and in the tributaries have always had the same position.

Table 1 is a survey of all stations for sample collecting. Altogether 31 lakes have been studied. The number of stations has varied from one to five according to the area of the lake.

Table 2 gives a survey of the total number of analyses series from the lakes for the different years of the investigation and thus shows its development.

Table 3 illustrates the number of analyses from the tributaries. As is evident the number was greater in 1946 than in 1947, because most of the brooks were completely dried up in the summer of 1947, a year very deficient in precipitation (*cf.* LUNDH 1951 p. 35).

Methods.

The water samples were collected in the surface water down to 0.5 m. Common one litre bottles with cork stoppers were employed. Samples for determinations of oxygen and carbon dioxide were collected in bottles with glass stoppers but these analyses will not be discussed here.

For most of the chemical analyses the methods described in »Anvisningar för Bakteriologiska och Fysikalisk-kemiska Vattenanalyser» have been used and references are given below to this publication. As this book is written in Swedish and the author has made some modifications of the methods brief summaries are given below.

Hydrogen ion concentration. The pH was determined in some analyses in the spring of 1946 colorimetrically by using a Hellige comparator and phenol red, pH range 6.8—8.4, as the indicator. Generally, however, the determinations were made by a Radiometer potentiometer. The pH was always determined the same day as the samples were collected and as soon as possible thereafter. Some experiments employing a portable pH-meter in field failed as the apparatus did not stand the transportation on a motor cycle.

Potassium permanganate-consumption, mg. $KMnO_4$ per litre. The analysis was made in the following manner. To 100 ml. of the water sample 1 ml. of concentrated H_2SO_4 and 10 ml. of 0.1 N $KMnO_4$-solution were added in a wide test tube. This was then placed in a water bath for 20 minutes and then 10 ml. of 0.1 N $Na_2C_2O_4$-solution were added and the $KMnO_4$-consumption was determined by titration with 0.1 N $KMnO_4$-solution.

Specific (electrical) conductivity ($\varkappa_{18} \cdot 10^6$) was determined by a conductivity apparatus, made by Trüb Täuber & Co, Zürich and a dip electrode, type Philips, with a cell constant of about 0.66. The electrode was kept in 96 per cent alcohol.

Total solids, mg. per litre. 100 or 200 ml. of a thoroughly shaken sample were evaporated to dryness on a water bath in a tared crucible of porcelain (platinum or quarz crucibles were not available). Since the amount of total solids in waters rich in plankton generally could be regarded as large, in such cases only 100 ml. were used. After evaporating the crucibles were dried at 100 to 105 °C for three hours. The increase in weight was taken as the total solids.

Non-volatile solids, mg. per litre. The dried residue from the preceding analysis was ignited in an electric oven at 600 to 650 °C. The difference in weight between the crucible after ignition and the empty crucible is the non-volatile solids.

Total hardness, German degrees, °DH, was determined by titration with a soap solution according to KLUT (1927 pp. 111 to 113).

Calcium, mg. per litre. The method is given on pp. 68 to 69. Calcium was precipitated with ammonium oxalate, and after dissolving the precipitate in sulphuric acid, the free oxalic acid was titrated with 0.05 N $KMnO_4$-solution. Generally 250 ml. of water were used for these analyses.

Magnesium, mg. per litre, was determined by the method given on pp. 69 to 70, in the filtrate from the calcium analysis when the calcium oxalate was separated. Magnesium was precipitated with ammonium phosphate and then determined gravimetrically in the ignited precipitate. The values are rounded off to 0.5 mg. per litre.

Iron, mg. per litre. During 1946 iron was determined by the method given on pp. 70 to 71, by colouring with potassium thiocyanate and colorimetric determination. From 1947 the analyses were performed according to SAYWELL and CUNNINGHAM (1937) with o-phenantroline. 100 ml. of water were evaporated to dryness and then the residue was dissolved in hydrochloric acid. After addition of hydroxylamine and o-phenantroline the colour was measured in a photocolorimeter.

Potassium, mg. per litre. The determinations were performed by Lantbrukskemiska Kontrollstationen in Kristianstad by using a flame photometer after the precipitation of the calcium by a mixture of salammoniac and oxalic acid.

Chlorides, mg. per litre, were determined according to the method given on pp. 78 and 79 by titration according to MOHR with a silver nitrate solution, of which one ml. corresponded to one mg. chlorine. In the calculations the results have been corrected for the quantities of silver nitrate necessary to colour the potassium chromate according to OHLMÜLLER-SPITTA (1931 p. 70).

Sulphate, mg. per litre. The method is to be found on pp. 79 and

80. The sample volume was generally 250 ml. After precipitation with barium chloride the determinations were made gravimetrically.

Nitrate, mg. per litre. In 1946 the method including colour development with brucine sulphate, given on pp. 80 to 82 was used, but it proved to be somewhat unsatisfactory. From 1947 the analyses were performed according to the method with phenole disulphonic acid, *cf.* BURSTRÖM (1942). 100 or 200 ml. of water were evaporated to dryness after the addition of potassium hydroxide. The residue was treated with hydrogen peroxide and the phenol disulphonic acid and ammonia were added. The colour was measured in a photocolorimeter.

Silicon dioxide, mg. per litre, in water soluble silica, was determined according to WERESCAGIN (1931 p. 183). The colorimetric determination was made in a common Lunzer colorimeter with tubes of 30 cm. in height.

Phosporus, γ P per litre. Some results from 1946 obtained with the method given by LOHAMMAR (1938) seemed to be unsatisfactory, as the blue colour was not stable and therefore they are not included here. From the autumn of 1946 the method of SCHEEL (1936) has been used. 500 ml. of water were evaporated to dryness and then the residue oxidized with hydrogen peroxide in order to destroy organic material. In some cases it proved to be necessary to remove silica by evaporation with hydrochloric acid. The developed colour was determined in a photocolorimeter and the experiments were carried out by the Lantbrukskemiska Kontrollstationen in Kristianstad.

Bicarbonate, mg. HCO_3 per litre, was determined according to the method given on p. 78 by titration with hydrochloric acid and methyl orange as the indicator.

Colour, given as mg. Pt per litre, was determined according to the method given on p. 58, which is the general method given by HAZEN (1892). A Lunzer colorimeter with 30 cm. tubes was employed.

Results.

A survey of all analyses from the lakes is given in table 4 and from all tributaries in table 5. The discussion below is mainly founded upon these surveys. Both maximum and minimum values and the averages are presented. In those cases where only one determination has been made it is given as the average.

Hydrogen ion concentration. Since the variation of the pH due to the photosynthesis of the plankton organisms is affected by *e.g.*, weather and plankton content, no averages have been calculated. The method given by Iversen (1929) for determining the maximal pH variation of a water has not been employed, but since the determinations have been carried out on various occasions, it is likely that the extreme values are also represented. The pH in all lakes lay above the neutral point, with a few exceptions as regards Västersjön and Rösjön. It is apparent that the pH varies in about the same manner in all the lakes, even if the general electrolyte content is different as well as the vegetation. Any significant differences did not seem to occur. Thus it is impossible to establish a correlation between pH and the qualitative composition of the lake vegetation as has been made by Iversen (1929) for some waters in Denmark. In spite of the fact that the vegetation of such lakes in Scania as for example Yddingen and Rösjön has entirely different character, the reactions of the waters are rather similar. This seems to indicate that a factor other than pH regulates the distribution of the plants.

Potassium permanganate-consumption. The $KMnO_4$-consumption is commonly employed for the estimation of the content of such factors as humus, organic substances in plankton, detritus and so on. It generally varies in such a manner that brown and turbid lakes have a relatively large consumption, for example Börringesjön and Krankesjön, while lakes with transparent, uncoloured water have low values, for example Heljesjön and Levrasjön. No apparent correlation between the qualitative composition of the vegetation and the $KMnO_4$-consumption naturally can be found. In turbid lakes, however, the quantitative development of the vegetation seems to be less than in transparent lakes, a fact already observed by IVERSEN (1929). Thus Levrasjön and Heljesjön have a very rich bottom vegetation. This also holds true for Råbelövssjön and Western Ringsjön. Turbid lakes on the other hand, for example Fjällfotasjön and Börringesjön, have very insignificant submerged vegetation. No determinations of the light intensities on the bottoms have been performed by the author, but ÅBERG and RODHE (1942) established a high extinction in the lake Växjösjön, which probably has the same richness in plankton as the most plankton-rich Scanian lakes, *e.g.*, Vombsjön and Sövdesjön. These authors, however, have not studied the distribution of plants in relation to light.

In connexion with the $KMnO_4$-consumption the water colour will also be discussed. Levrasjön has the least colour of all the lakes, not exceeding 8 mg. Pt per litre, followed by Havgårdssjön, Heljesjön, Gyllebosjön and Råbelövssjön, all with richly developed bottom vegetation. On the other hand, the brownest waters are to be found in Fjällfotasjön, Kvesarumssjön, Tjörnarpssjön and Araslövssjön. These conditions are related to the supply of water to the lakes (*cf.* LUNDH 1951). The remaining lakes are more or less randomly distributed between these two groups. It is apparent that all combinations between the salt concentration and the humus content can exist. On the whole it is possible just by measuring the lake colour (*cf.* LUNDH 1951, table 3 p. 24) to obtain an idea of the relative content of humus, even if there are exceptions.

Specific conductivity. This factor is used as a measure of the total salt content and in limnological literature it is very often regarded as identical with the content of nutrients. As already mentioned it is a very complex property which is not as significant as is generally considered. In the lakes studied here the conductivity of the hydrogen ions might be disregarded as the pH is above 7. According to RODHE (1949) the following ions mainly constitute the specific conductivity in lake waters: Ca, Mg, Na, K, Cl, SO_4 and HCO_3.

A survey of the values is given in the diagram in figure 1, which shows that if the lakes are arranged according to increasing specific conductivity a relative smooth curve is obtained from Västersjön to Yddingen. According to this curve the lakes cannot be divided in well delimited classes as far as this factor is concerned. The main part of the lakes had a specific conductivity between 200 and 300. Only four exceeded this value and those are situated on the southwestern plain and the Kristian-

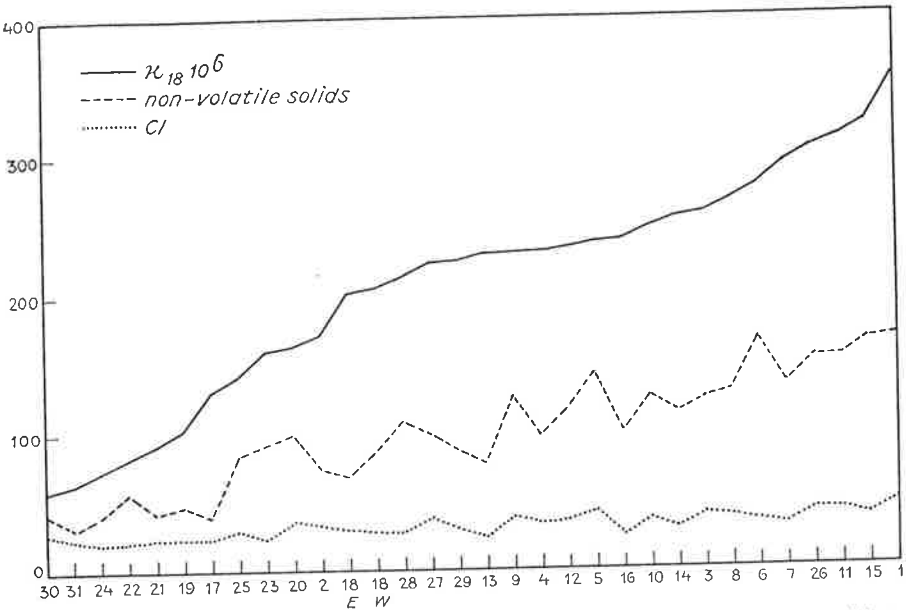

Fig. 1. The variation of the specific conductivity, non-volatile solids (mg. per litre) and chloride (mg. per litre) in the lakes arranged according to increasing specific conductivity. The lakes are represented by number (cf. table 1) instead of names.

stad plain. The remaining lowland lakes belonged to the group 200 to 300. The group between 100 and 200 contained two lakes on the ridge Linderödsåsen (Dagstorpssjön and Kvesarumssjön), Tunbyholmssjön, Fjällfotasjön and Hammarsjön. The group below 100 included two lakes on Linderödsåsen (Tjörnarpssjön and Bosarpssjön), Araslövssjön, Västersjön and Rösjön. The two last-mentioned have apparently abberant vegetation in comparison to all the remaining lakes. The lake Araslövssjön is supplied with water from the Småländska Högland and thus is relatively deficient in electrolytes (*cf.* ÅBERG and RODHE 1942).

Total solids. The content of total solids is likewise a complex factor, which contains *i.a.* salts, clay particles, dry substances from algae and humic substances. Thus it differs in many ways according to the local variations of these factors.

Non-volatile solids. The amount of non-volatile solids followed in general features the specific conductivity, but it deviated somewhat, depending upon, for example, the content of clay particles.

In the studies of the cations there is a gap in the analyses as no determinations of sodium have been performed at all, because this ion is not regarded as an essential nutrient. However, this ion naturally may be present in relatively large quantities (*cf.* LOHAMMAR's analyses from the lowland lakes in Uppland, 1938).

Calcium and bicarbonate. Figure 2 illustrates the variations in the calcium and bicarbonate contents in the lakes, which are arranged in the same order as in figure 1. It is very apparent that these qualities vary in the same manner as the specific conductivity, and that these two ions are quantitatively predominating. The amount of calcium was generally equivalent to that of HCO_3 (figure 2). The quotient $\frac{Ca}{HCO_3}$ varies mostly between 0.7 and 1.3. Some marked exceptions were found in Tjörnarpssjön and Araslövssjön with 0.5 and Hammarsjön, Västersjön and Rösjön with about 2. Probably the aberrations were partly due to the fact that the method for determinations is not quite accurate for small quantities of HCO_3 (*cf.* STEEMANN-NIELSEN 1944).

As regards the calcium content of different lakes it may be noted that Vombsjön and Krankesjön, which are situated in sandy areas with acid leached grounds were rich in calcium. Gyllebosjön, which lies in a district generally regarded as deficient in this substance, had also a high concentration. The same held true for Kvesarumssjön, which in comparison to the other lakes on Linderödsåsen was rich in calcium.

Magnesium. Compared with calcium the quantities of magnesium and also of potassium are small. The former varies between 9.5 (Yddingen) and 1.0 (Araslövssjön). Thus the concentration was highest in the real lowland lakes and lowest in the water from the Småländska Högland.

Iron. This element showed an irregular variation both within a lake and between different lakes. The most prominent aberrations were found between Araslövssjön-Hammarsjön and the remaining lakes, thus demonstrating a difference between the lakes. The same was also applicable to a certain extent as regards magnesium, but here Hammarsjön was richer.

Potassium. The variation was comparatively slight between 1.1 and 6.0 mg. per litre. As regards the soils surrounding the lakes LUNDH (1951) has found that no regional differences can be established. It seems to be very striking that Heljesjön, which according to the usual terminology must be regarded as a typical eutrophic lake, had an average potassium content of only 1.5 mg. per litre, which is about the same concentration as that of Västersjön and Rösjön, both with a divergent vegetation.

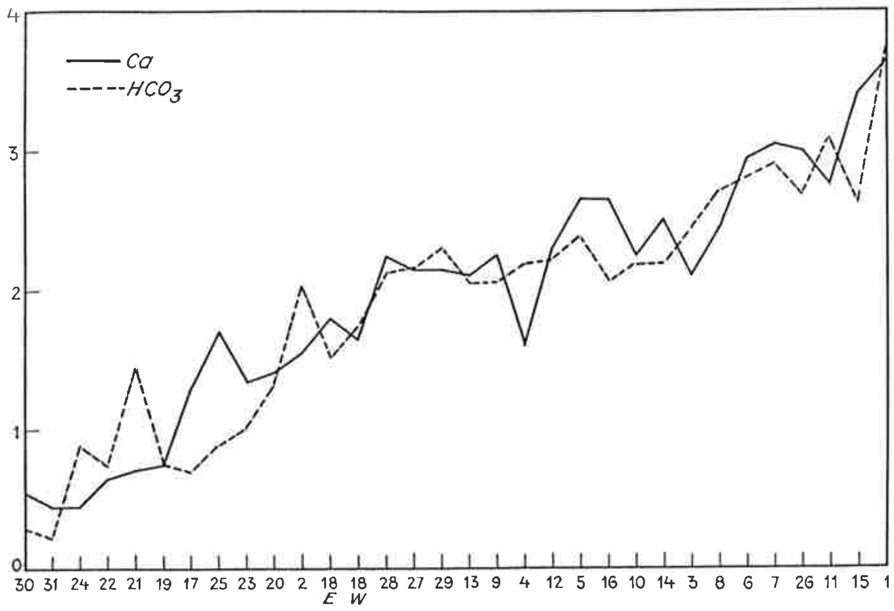

Fig. 2. The variation of calcium and bicarbonate (mEq. per litre) in the lakes arranged according to increasing specific conductivity.

Chloride. The chloride generally follows the variation of the specific conductivity. The quotient of the lakes richest and those poorest in this element is about 2. No lake showed such a high content as has been found in the polluted Scanian rivers (*cf.* ANDERSSON and LUNDH, 1948), which is due to the fact that the degree of contamination by sewage is lower in the lakes. THUNMARK's investigations in the so-called nutrient-rich lakes in Södermanland established that these lakes have the same chloride content as the lakes on Linderödsåsen and somewhat lower values than Västersjön and Rösjön on Hallandsåsen, though containing a vegetation of the same species as the pronounced Scanian lowland lakes. Perhaps the Scanian lakes have throughout a higher concentration of chloride because of their situation near the Swedish west-coast. Such a relation has been observed by WITTING (1948) in mire-waters as regards sodium and magnesium. The lakes in Uppland richest in chlorides had about the same concentrations as the richest lakes in Scania, probably due to their position in areas previously transgressed by the sea.

Sulphate. Among the anions this ion showed the most apparent variation in addition to bicarbonate. The concentration was highest in the most typical lakes on the plains with the highest specific conductivity, namely Yddingen, Krankesjön and Råbelövssjön, but also Vombsjön and Gyllebosjön were included in this group with average concentrations varying between 37 and 44 mg. per litre. The content was lowest in Araslövssjön, Västersjön and Rösjön, which, as already mentioned, have a deviating vegetation. Sövdeborgssjön is uncertain as only one determination is available.

Nitrate. The nitrate concentration was low in comparison to the anions mentioned hitherto. Sometimes in spring, however, higher values have been found, perhaps due to effects from manuring the fields in winter and spring (*cf.* Yddingen, Börringesjön, Snogeholmssjön and Vombsjön). High values have also been found in spring in Ringsjön (according to a private communication from civil engineer ERIC BENGTSSON, Hälsingborg). During the summer the nitrate content does not generally exceed 1 mg. per litre and no significant differences seem to prevail.

Silicic acid. The concentration of soluble silicic acid was also relatively low and of about the same order of magnitude in all the lakes.

Phosphorus. Unfortunately comparatively few values are available and they often showed a strong variation even in the same lake. In the autumn of 1947 with an extremely low water-level prevailing, the phosphorus content in all the lakes was high, perhaps depending upon a leaching from the sediments near the shore and a concentration by evaporation of water. From the mean values it is impossible to obtain a clear picture of the variation in the phosphorus content in the different lakes. It seems, however, as if the most salt-rich lakes have the highest concentration, even if there are exceptions.

Lake	1. Yddingen	2. Fjällfotasjön	3. Börringesjön	4. Havgårdssjön	5. Björkesåkrasjön	6. Häckebergasjön	7. Svaneholmssjön	8. Krageholmssjön	9. Ellestasjön	10. Snogeholmssjön	11. Sövdeborgssjön
Number of analyses	22	16	18	8	4	4	7	12	12	14	3
pH	7.7—8.7	7.4—9.2	7.5—8.8	8.0—8.6	8.2—8.8	7.6—8.3	7.6—8.9	7.6—8.8	7.7—9.2	7.7—9.3	7.9—8.3
$KMnO_4$	98—164 119	147—234 179	87—204 132	42—204 109	139—149 145	111—145 123	89—117 100	49—88 66	79—135 92	78—122 100	54—95 71
$\varkappa_{18} \cdot 10^6$	214—438 355	152—197 171	217—357 257	208—254 230	228—242 237	246—288 277	282—313 294	241—304 266	171—303 230	214—296 247	308—316 311
Total solids	264—357 317	165—261 201	212—328 242	145—269 187	215—247 232	223—256 241	193—285 245	199—268 232	204—297 236	216—273 234	119—243 181
Non-volatile solids	123—191 166	65—95 74	95—184 123	95—101 97	99—204 144	102—219 167	111—154 133	101—180 128	96—166 126	97—177 125	152
Total hardness °DH	6.7—12.9 10.9	3.5—5.9 4.5	3.7—9.0 7.2	3.4—7.3 5.7	6.5—7.4 7.0	5.9—10.2 8.0	6.8—9.6 8.4	5.6—10.9 8.1	4.0—8.7 6.9	5.6—9.6 7.1	6.3—8.0 6.9
Ca	66—83 73	26—36 31	20—58 43	20—45 32	44—62 53	54—67 59	46—72 61	40—57 49	27—78 45	37—58 45	36—66 55
Mg	4.0—9.5 7.5	3.5—5.5 4.8	1.0—8.5 6.0	4.5—8.0 6.8	4.5	2.5—4.0 3.2	4.0—5.5 4.6	2.5—6.0 4.9	1.5—6.0 4.7	3.5—6.0 5.0	2.5
Fe	0.0—0.37 0.09	0.0—0.50 0.20	0.0—0.73 0.15	0.0—0.16	0.01—0.60 0.31	0.25—0.92 0.47	0.0—0.40	0.0—0.37 0.05	0.0—0.26 0.06	0.0—0.35 0.08	0.10—0.17 0.14
K	5.0—6.0 5.5	3.7—5.0 4.4	4.6—7.0 5.2	3.0—4.3 3.7	3.3—3.9 3.7	3.4—3.8 3.6	2.1—3.9 3.2	2.9—5.3 4.2	3.4—4.7 4.3	3.3—5.6 4.4	2.6—2.9 2.8
Cl	17—31 24	14—22 17	17—24 20	13—18 17	19—25 21	16—19 17	13—20 16	15—26 19	15—22 19	15—23 18	21—22 21
SO_4	37—67 44	14—34 19	18—38 25	10—22 15	15—17 16	11—41 20	17—25 20	24—38 29	23—44 30	20—33 24	7
NO_3	$<$1—6.0	0.3—1.7	trace—4.7	0.2—0.9	0.0—0.3 0.2	0.0—0.7 0.4	0.0—0.5	0.1—0.4	0.2—1.2	0.3—5.5	0.2—0.4 0.3
SiO_2	0.1—3.6 1.1	0.1—1.6 0.7	0.0—3.8 0.8	0.0—3.4 1.2	1.2—3.2 2.2	0.2—2.6 1.2	0.2—4.2 1.7	0.0—4.0 1.6	0.0—3.4 1.1	0.0—3.2 1.4	0.1—2.2 1.2
Soluble P	8—280 76	16—320 112	10—226 84	20—268	130—198 152	92—240 117	20—320 139	10—220 73	8—136 60	16—130 60	160
HCO_3	165—477 227	71—215 124	122—171 149	110—153 132	140—149 145	154—184 171	159—201 177	141—249 165	85—146 125	110—149 133	184—194 188
Colour	30—80 52	60—160 91	28—68 42	10—30 18	50—80 63	50—65 59	30—50 43	18—35 27	30—63 45	16—97 54	16—22 19

Table 4. Continued.

Lake	12. Sövdesjön	13. Heljesjön	14. Vombsjön	15. Krankesjön	16. Gyllebosjön	17. Tunbyholmssjön	18. Western Ringsjön	Eastern Ringsjön	19. Dagstorpssjön	20. Kvesarumssjön	21. Tjörnarpssjön
Number of analyses	14	4	21	23	6	6	3	2	3	4	4
pH	7.7—9.2	8.0—8.6	8.1—8.9	7.7—8.6	7.7—8.8	7.1—7.9	7.8—8.6	7.8—8.4	7.1—7.9	7.5—8.6	7.4—7.9
$KMnO_4$	67—120	23—59	40—105	61—104	32—57	41—82	40—50		60—63	95—139	74—177
	89	40	55	82	49	66	45	48	62	125	123
$\varkappa_{18} \cdot 10^6$	196—282	170—288	221—298	266—388	206—275	102—165	202—207		95—110	152—182	85—102
	233	229	254	322	238	131	205	202	103	163	91
Total solids	124—328	65—191	131—268	128—326	76—201	48—123	138—173				95—96
	224	140	210	272	171	99	156	134	91	189	96
Non-volatile solids	52—173	30—108	20—167	131—209	46—140	31—49	68—103			96—101	36—49
	116	78	114	164	99	40	86	68	48	99	43
Total hardness °DH	5.6—14.8	5.2—7.0	4.8—9.0	7.1—11.7	6.2—7.4	1.6—4.0	3.9—5.8		1.6—2.7	3.0—4.3	1.4—4.0
	7.9	6.0	7.5	9.8	6.9	3.0	4.6	3.8	2.1	3.5	2.7
Ca	32—53	39—46	40—57	56—78	50—57	21—34	31—36	34—38	14—16	27—28	13—14
	46	42	50	68	53	26	33	36	15	28	14
Mg	2.5—5.0	2.5—4.0	2.0—6.5	4.0—8.0	2.0—5.0	1.5—3.0			2.0—3.0	3.5—4.5	1.5—2.5
	4.5	3.0	4.9	5.6	3.1	2.4	2.5	2.5	2.5	4.1	2.3
Fe	0.0—0.29	0.0—0.11	0.0—1.0	0.0—0.33	0.03—0.12	0.0—0.45	0.08—0.11	0.08—0.11	0.10—0.17	0.09—0.72	0.14—0.25
	0.07	0.06			0.08	0.19	0.09	0.10	0.13	0.44	0.22
K	3.2—5.0	0.9—2.0	3.4—4.7	2.9—5.8	1.4—2.6	0.9—2.1	3.0—3.9	2.9—3.2	1.4—2.3	2.3—2.7	1.2—1.9
	4.1	1.5	4.0	4.2	1.9	1.6	3.5	3.1	1.8	2.5	1.6
Cl	17—20	10—13	13—16	16—21	9—15	11—14	13—14	14—15	11—13	16—19	11—13
	18	12	15	19	12	12	14	15	12	18	12
SO_4	19—32	19—21	31—66	30—82	31—53	11—37	17—37		12—17	21—31	11—17
	26	20	41	48	37	21	27	35	15	27	13
NO_3	0.1—2.5	0.2—0.4	0.1—1.7	0.2—8.5	0.0—0.2	trace—0.1	<0.1—0.2	0.1—0.2	0.2—2.2	0.3—1.6	0.3—1.3
		0.3						0.2	1.3	1.1	1.0
SiO_2	0.0—4.0	0.1—2.8	0.4—4.2	0.0—0.6	0.3—2.4	0.3—1.8			0.6—2.2	0.5—3.6	0.4—1.2
	1.5	1.3	1.5	0.4	1.1	0.9	3.8	—	1.5	1.6	1.0
Soluble P	18—140	12—92	12—156	14—65	10—280	12—280				126—136	82—92
	65	52	45	30			140	—	100	131	87
HCO_3	116—1[illegible]	[illegible]04—153	110—[illegible]59	139—192	116—134	35—46	92—116		43—49	73—85	37—49
	135	124	1[illegible]	159	126	42	106	9[illegible]	45	82	44
Colour	17—70	10—12	16—38	22—50	8—24	22—65	17—22	18—22	38—85	45—110	38—95
	47	11	24	32	18	39	20	20	55	78	70

Table 4. Continued.

Lake	3osa jön	'injasjön	ıraslövssjön	lammarsjön	åbelövssjön	ppmannasjön	evrasjön	iesjön	ästersjön	ösjön

Colour	17—70 47	10—12 11	16—38 24	22—50 32	8—24 18	22—65 39	17—22 20	[illegible] 20	[illegible] 55	78	70

Table 4. Continued.

Lake	22. Bosarpssjön	23. Finjasjön	24. Araslövssjön	25. Hammarsjön	26. Råbelövssjön	27. Oppmannasjön	28. Levrasjön	29. Siesjön	30. Västersjön	31. Rösjön
Number of analyses	4	1	1	3	21	7	10	6	8	8
pH	7.1—8.1	8.8	7.1	7.2—7.8	7.0—8.5	8.1—9.5	8.0—8.7	7.9—8.4	6.9—8.7	7.0—8.5
KMnO$_4$	67—164 129	51	95	99—108 103	28—55 45	41—138 83	20—36 28	46—65 57	42—60 52	43—87 63
$\varkappa_{18} \cdot 10^6$	78—91 82	160	72	119—164 142	264—354 304	146—252 223	192—228 213	195—247 224	54—66 59	57—69 64
Total solids	92—279 186	169	98	124—170 144	209—266 241	177—277 195	154—259 179	174—186 179	60—169 81	58—71 65
Non-volatile solids	57—59 58	—	41	53—128 84	121—196 152	75—112 99	86—139 108	85—88 87	18—108 42	20—52 32
Total hardness °DH	1.4—3.2 2.0	2.7	1.7	1.7—4.4 3.0	8.1—10.8 9.6	4.0—7.0 5.6	4.7—7.6 6.2	4.6—7.1 6.3	0.6—1.4 1.2	0.7—2.0 1.5
Ca	12—14 13	27	8.7	25—62 34	44—68 60	27—50 43	35—56 45	38—49 43	6—21 11	7—14 9
Mg	1.5—2.5 2.0	3.5	1.0	3.7	1.0—6.5 4.0	4.0—5.0 4.7	2.5—4.0 3.0	2.5—9.0 4.1	2.5—3.0 2.6	1.5—3.0 2.7
Fe	0.08—0.65 0.33	0.15	1.0	trace—1.2	0.0—0.16 0.02	0.04—0.20 0.12	0.0—0.17 0.04	0.05—0.31 0.17	0.0—0.38 0.15	0.0—0.55 0.19
K	1.5—1.9 1.7	2.5	2.3	2.2—2.6 2.4	3.2—6.4 5.4	1.5—4.0 3.1	4.7—5.9 5.3	2.0—2.5 2.2	1.1—1.7 1.4	1.1—1.4 1.3
Cl	10—11 11	12	10	14—17 15	19—24 21	16—21 19	11—16 14	13—17 15	13—18 14	11—13 12
SO$_4$	10—15 13	25	11	14—27 20	34—44 39	15—23 20	15—30 20	14—34 20	7—9 8	5—12 9
NO$_3$	0.2—1.5 1.0	0.7	2.0	trace—1.0	trace—1.5	0.2—0.9 0.7	0.1—0.2 0.2	0.2—1.8 0.5	0.2—0.6 0.2	0.0—0.7 0.3
SiO$_2$	0.4—1.2 0.9	0.6	0.4	1.2	0.2—1.3 0.7	0.4—3.0 1.1	0.2—1.8 0.8	0.4—2.2 1.2	—	—
Soluble P	32—64 48	—	55	90—280 203	16—400 100	12—28 17	14—62 27	18—178	62—118 91	80—138 100
HCO$_3$	37—61 45	61	54	45—73 54	146—185 162	85—140 131	116—146 129	128—159 140	17—20 18	14—30 20
Colour	41—90 66	40	180	40—100 68	7—28 19	10—36 18	4—8 6	24—40 28	25—70 53	25—65 47

Table 5. Survey of the water analyses of the tributaries.

Name of the tributary	—	—	—	—	Vistorps-bäcken	Ebbetorps-bäcken	Snogarps-bäcken	Outflow from Ellestasjön	Assmåsa-bäcken	Outflow from Snogeholms-sjön
Lake	Yddingen	Yddingen	Yddingen	Yddingen	Krage-holmssjön	Ellestasjön	Ellestasjön	Snogeholms-sjön	Snogeholms-sjön	Sövdesjön
No. on the map in LUNDH (1951)	1	2	3	4	1	2	3	4	5	6
Fig. in LUNDH (1951)	9	9	9	9	16	16	16	16	16	16
Number of analyses	5	3	1	4	4	3	2	5	4	2
pH	6.9—7.6	7.3—7.8	7.5	7.4—7.8	7.9—8.5	8.1—8.2	7.7	7.5—8.1	7.3—7.6	7.3
KMnO₄	85—234	103—157		132—173	33—72	34—60	120—146	74—110	98—171	88—101
	158	132	129	156	56	47	133	98	152	95
$\varkappa_{18} \cdot 10^6$	545—635	463—505		490—595	366—473	346—414	421—473	240—293	251 —350	269—302
	582	490	522	527	408	389	447	265	306	286
Total solids	413—630	383—437		433—508	291—400	259—381	251—417	215—255	277—340	245—258
	513	406	401	466	347	334	334	234	313	252
Non-volatile solids ..	162—338	195—219		205—358	173—299	142—303	84—215	112—157	131—230	104—131
	259	209	199	260	229	231	150	134	190	118
Total hardness °DH	15.7—22.9	15.3—17.0		14.8—18.5	10.1—16.7	10.4—13.9	13.6—16.3	6.5—16.0	8.1—17.0	9.0—10.2
	18.2	16.1	14.7	16.8	13.4	12.7	15.0	9.7	11.3	9.6
Ca	55—142	51—100		100—122	75—99	66—86	54—99	33—57	52—73	54—59
	107	83	100	110	86	79	77	47	64	57
Mg	4.0—10.0	8.5—20.5		2.0—10.5	6.0—8.0	2.5—8.5	4.5—6.5	4.0—6.0	4.0—7.0	4.5—5.5
	7.8	12.8	7.5	6.1	6.6	5.8	5.5	5.2	6.0	5.0
Fe	0.0—1.3	0.0—0.2		0.0—0.62	0.0—0.50	trace—0.27	trace—0.10	0.0—0.36	0.0—0.48	0.4—0.5
		0.1	trace	0.35	0.19					0.5
K	3.9—7.5			1.1—5.5	2.9—6.3	4.3—5.5		3.6—5.4	1.8—4.1	
	6.0	4.0	—	3.5	4.1	4.9	8.0	4.7	2.2	4.3
Cl	21—40	19—34		18—45	16—22	17—19	21—21	14—18	19—29	
	31	25	24	33	19	18	21	16	22	22
SO₄	26—138	17—38		14—80	19—41	23—42	45—48	11—29	20—54	
	74	31	40	34	31	30	47	23	27	12
NO₃	<1—13.0	<1—5.0		<1—6.7	0.5—8.0	1.0—7.0	1.1—8.0	trace—9.0	trace—7.5	<1—5.0
			8.5		3.1	3.6	4.6			
SiO₂	0.2—2.4	0.0—1.2		0.2—1.6	0.2—3.8	0.0—5.0	0.0—1.6	0.0—4.0	0.1—4.6	0.8—2.4
	1.1	0.6	0.0	1.1	2.2	2.1	0.8	1.3	2.0	1.6
Soluble P	28—144			26—54	24—220	50—72		20—240	30—200	
		12	—	40	93	61	40	102	103	72
HCO₃	215—536	284—342		350—455	173—317	203—293	221—300	135—171	132—240	174—181
	349	311	284	410	243	257	261	152	184	178
Colour	110—280	65—110		95—170	20—44	37—50	115—117	40—95	100—290	60—120
	184		130	131	33	42	116		1[illegible]	90

Table 5. Continued.

Table 5. Continued.

Name of the tributary	Frihultsbäcken	Täpperödsbäcken	Övedsbäcken	Björkaån	Sjötorpsbäcken	Silvåkrabäcken	Råbelövsbäcken	Ekestadsbäcken	Österslövsbäcken	Lärkesholmsån
Lake	Sövdesjön	Vombsjön	Vombsjön	Vombsjön	Krankesjön	Krankesjön	Råbelövssjön	Råbelövssjön	Råbelövssjön	Rösjön
No. on the map in LUNDH (1951)	7	7	8	9	5	6	1	2	3	1
Fig. in LUNDH (1951)	16	21	21	21	21	21	39	39	39	51
Number of analyses	3	5	5	6	4	5	7	7	7	1
pH	7.3—7.9	8.3—8.7	7.8—8.6	7.7—8.3	7.7—8.1	7.5—8.1	7.4—7.8	6.9—7.6	7.6—8.4	7.3
KMnO$_4$	32—62	54—92	21—121	23—66	40—118	41—75	83—145	88—153	31—76	
	51	66	64	38	72	54	120	122	51	36
$\varkappa_{18} \cdot 10^6$	268—298	348—412	300—394	313—359	368—443	392—425	285—394	184—368	465—600	
	283	383	346	335	408	409	370	293	542	100
Total solids	216—277	265—315	230—296	219—270	302—414	251—394	299—348	209—471	320—469	
	247	299	269	261	340	328	319	273	389	97
Non-volatile solids	107—160	156—202	148—192	133—176	179—232	144—236	177—211	103—185	193—292	
	137	178	157	156	208	194	197	152	246	42
Total hardness °DH	7.0—13.9	10.5—13.6	8.2—12.8	8.3—12.9	10.4—12.6	12.0—13.6	10.1—13.9	6.4—12.2	16.0—21.3	
	9.6	12.1	10.4	10.5	12.0	12.7	11.6	9.5	18.4	4.4
Ca	52—60	55—85	53—78	54—79	65—108	79—110	61—78	35—77	104—124	
	56	71	61	66	84	90	64	57	115	15
Mg	3.0—5.0	5.5—7.0	6.0—10.5	1.5—7.0	4.5—6.5	5.0—7.5	3.0—4.5	3.0—6.0	4.0—9.0	
	4.2	6.0	8.4	5.3	5.7	6.1	3.7	4.3	5.3	4.0
Fe	0.04—1.2	0.0—0.05	0.0—0.05	0.0—0.35	0.0—0.1	0.0—0.2	0.1—0.8	0.2—1.3	0.0—1.1	
	0.6	0.01		0.06			0.3	0.6		0.0
K		3.0—6.2	5.1—5.8	2.8—5.0	3.1—7.9	2.7—5.0	3.3—5.3	1.7—4.5	2.2—17.0	
	3.3	5.1	5.5	3.6	5.5	3.6	4.5	2.8	5.9	1.5
Cl	21—23	14—24	16—20	14—20	17—32	18—20	17—25	14—24	18—22	
	22	19	18	17	24	19	20	18	20	15
SO$_4$	20—28	41—67	27—66	43—72	38—75	40—68	32—55	22—53	30—62	
	24	50	40	50	61	58	46	41	45	12
NO$_3$	<1—7.5	0.6—10.0	1.0—15.0	0.1—13.0	1.1—7.5	1.2—9.5	<1—13.5	1.0—8.5	<1—15.0	
		4.4	6.2	4.2	5.7	5.5		5.7		0.5
SiO$_2$	0.1—5.0	0.4—1.4	0.4—0.6	0.6—3.0	0.2—1.3	0.0—2.0	0.2—2.0	0.8—2.2	0.2—2.0	
	2.1	0.8	0.8	1.2	0.8	0.9	1.0	1.2	1.0	—
Soluble P	68—100	10—220	34—200	20—134	14—24	26—42	68—320	14—220	4—300	
	84			52	19	34	170			110
HCO$_3$	121—178	212—262	183—245	165—212	166—268	185—234	149—213	85—247	249—390	
	158	229	207	179	206	209	186	153	328	39
Colour	50—90	50—73	45—63	16—41	21—48	33—50	40—160	50—210	12—35	
	76	63	52	26	38	42	100	127	25	140

The relationships between water chemistry and geology.

Lundh (1951 p. 22) has summarized the characteristic geological features of the surroundings of the investigated lakes and expressed some assumptions about the dependence of the salt content upon the geological conditions. It may be of certain interest to discuss the question if these assumptions agree with the results of the water-analyses.

If the lakes situated on Archaean bedrock (Västersjön, Rösjön, Dagstorpssjön, Kvesarumssjön, Tjörnarpssjön, Bosarpssjön and Finjasjön) are compared with the remaining lakes, mostly situated on the plains, one finds a difference in the total content of electrolytes, which is gradual as already mentioned (p. 154). The lakes on the Archaean rocks have the lowest salt content. Araslövssjön and Hammarsjön are not included here, as they have special water conditions.

Of the Archaean lakes, however, two are divergent with higher concentrations of electrolytes, namely Kvesarumssjön and Finjasjön. The higher values are found as regards almost all the studied ions.

The lakes most deficient in salts of the Archaean lakes are Västersjön and Rösjön, which also have a divergent vegetation. Furthermore, they are situated in an area poorer in lime than the other lakes of this type, which are surrounded by more or less limy moraine (Lundh 1951, p. 17).

The lakes on the Kristianstad plain, Råbelövssjön and Levrasjön, the bottom of which sometimes is formed by cretaceous rocks, would *a priori* have a water richer in calcium than any of the remaining lakes. This is not the case, however, but on the south-western plains some lakes are to be found with the same high content. Thus Yddingen has the water which is richest in calcium. It is also impossible to establish whether Råbelövssjön and Levrasjön are richer in phosphate or more influenced by culture. The latter factor is very difficult to study exactly.

Of the lakes situated in the south-western Scania Börringesjön, Krageholmssjön and Ellestasjön should be those most influenced by culture, as they are mainly surrounded by fields, but this is also difficult to prove. The total salt content is almost the same as in the lakes on the Kristianstad plain.

The three lakes on the Vomb plain Heljesjön, Vombsjön and Krankesjön are all rich in lime, in spite of their position in a leached sand plain, and they are all rich in salts. This agrees with the statements made by LUNDH.

Gyllebosjön and Tunbyholmssjön, both lying in an area of sandstone moraine in south-eastern Scania, should according to their position have a relatively low content of calcium in their water, probably of the same degree as the lakes on Linderödsåsen. This holds also true for Tunbyholmssjön, which agrees with Kvesarumssjön and Finjasjön. Gyllebosjön, however, is a typical lime lake. This is probably due to the influences of lime occurrences in the moraine and the glaciofluvial deposits originating from the Kristianstad plain or the Baltic.

Finally, Ringsjön situated in the centre of the province, in the transition area between Archaean bedrock and the plains, also forms an intermediate in salt concentration.

The effects of outlets of sewage in the lakes.

As LUNDH (1951) already has discussed the Scanian lakes have been affected by culture in many respects. The problem is whether or not such influences can result in notable changes in the ion concentrations of the lake waters. In this connexion two sources of pollution will be discussed, namely the direct outlet of sewage in the lakes and the influences of manuring the fields.

An outlet of sewage into a lake is generally accompanied by an enormous development of plankton algae (*cf.* THUNMARK 1945 a and RODHE 1948) but the changes in the composition of the higher vegetation and in the salt concentrations of the water seem to have been less studied.

Only a few of the investigated lakes receive waste water from factories and communities namely the following.

Vombsjön: its tributary Björkaån is recipient for the communities Vollsjö, Lövestad and Sjöbo. This river had a relatively high specific conductivity (table 5) which is caused mainly by the high content of calcium bicarbonate, but the other ions seemed to be of the same concentrations as in Vombsjön.

Sövdesjön (the northern part): the village Sövde with a dairy.

Eastern Ringsjön: the river Hörbyån is recipient for the sewage from the market town Hörby. From the analyses performed by the water-works of Hälsingborg no marked differences in the ion concentrations of the different parts of Ringsjön were to be found (*cf.* ANDERSSON 1948). On the other hand there was a higher concentration of bacteria in Eastern Ringsjön than in Western Ringsjön.

Sätoftasjön (the northern part of Eastern Ringsjön) is polluted by water from the market town Höör.

Hammarsjön: recipient for the sewage from the city of Kristianstad.

Finjasjön: recipient for the sewage from the city of Hässleholm.

Moreover some lakes receive waste water from seasonal factories, *e.g.*, starch factories, namely Krankesjön, Råbelövssjön (at Råbelöv and Österslöv), Oppmannasjön (at Kiaby and Norregård) and Levrasjön.

Finally most lakes receive some polluted water from farms during all the year.

Usually it is not possible to study the changes in the ion content by pollution as no analyses are available from earlier times. A good object for such studies, however, is Hammarsjön, through which the river Helgeå flows. If no pollution had taken place it could be assumed that the river at the outlet from Hammarsjön would have a water similar to that above Kristianstad. Thus if the water of Helgeå is analyzed before the entrance into Hammarsjön and after passing the lake it should be possible to study the effect of pollution. Perhaps a reservation should be made here. The lake contains many reed swamps and it is possible that the water is not absolutely uniformly mixed, but larger concentrations of sewage may be found in well sheltered parts of the lakes especially at low water. Table 6 illustrates some values from a study from Helgeå and Hammarsjön. It proved that compared with Torsebro a marked increase in electrolytes was found at Pynten, where the sewage was mixed with a relatively small volume of lake water. At Kavrö, however, the increase was relatively insignificant, probably due to greater dilution. The most apparent feature was the increase in sulphate. Naturally if the conversion of water in Hammarsjön had been less it is probable that the increases in ion concentrations would have been stronger. Such large sources of pollution are not situated at the other lakes and for this reason they are not suited for studies of this type.

By rich precipitation a more or less strong leaching of the salts and organic substances from artificial manuring, natural manuring and the remains of animals and plants in decomposition takes place on the surface of the fields. The dissolved compounds are transported in the surface water by brooks and runnels into the lakes. It is impossible to calculate the amounts of such substances, as the leaching occurs mainly during rich precipitation and then the concentration of the salts in the brooks is very low. As regards the lakes on the plains, however, the quantity seems to be of a rather large order of magnitude, as they generally are surrounded of fields. From this leaching the high contents of nitrate in the lakes apparently originate.

A study of the values from the investigated tributaries (table 5), all of which belong to the plains with the exception of Lärkesholmsån, shows that the contents of electrolytes are generally higher than in the reci-

Table 6. Survey of water analyses from Helgeå and Hammarsjön.

Locality	Torsebro					Pynten					Hammarsjön			Kavrö		
Date	12.8 1946	18.4 1948	22.5 1948	12.6 1948	15.7 1948	6.6 1946	18.4 1948	22.5 1948	12.6 1948	15.7 1948	1.8 1946	29.7 1947	29.7 1947	22.5 1948	12.6 1948	15.7 1948
Hour	1730	1600	1915	1930	2015	—	1640	1800	1920	1945	1100	—	—	1715	1845	1910
Temperature	19.0	12.7	16.3	20.2	19.5	16.8	13.4	16.2	21.1	20.2	—	—	—	15.7	21.2	19.7
pH	7.2	6.9	7.4	7.4	7.2	7.0	6.9	7.3	7.2	6.9	7.3	7.8	7.2	7.3	7.4	7.1
$KMnO_4$	92	62	64	66	60	83	64	153	69	54	99	102	108	84	67	50
$\varkappa_{18} \cdot 10^6$	70	89	86	87	86	155	130	98	180	111	142	164	119	95	103	100
Total solids	94	—	83	82	—	—	—	318	135	—	170	138	124	111	90	—
Non-volatile solids	41	—	53	—	—	—	—	188	—	—	128	72	53	46	—	—
Total hardness °DH	1.6	1.7	1.1	1.2	1.2	—	2.2	1.2	2.2	1.4	1.7	4.4	2.8	1.5	1.4	1.5
Ca	9	—	10	12	10	—	—	14	20	12	14	62	25	10	13	11
Mg	3.0	—	3.5	3.5	1.0	—	—	3.5	4.0	2.0	3.0	3.0	5.0	3.5	4.3	2.1
Fe	0.8	—	0.4	0.8	0.8	—	—	1.1	0.6	0.8	trace	1.1	1.2	0.7	0.5	0.5
Cl	10	11	11	9	11	—	13	10	17	20	14	17	15	11	12	12
SO_4	12	—	14	14	—	—	—	29	45	—	14	18	27	32	31	—
NO_3	2	—	0.6	1.1	1.5	—	—	7.2	0.8	1.0	1.0	trace	trace	1.1	0.5	1.0
SiO_2	0.4	—	1.9	0.4	1.6	—	—	0.4	0.4	2.0	1.2	—	—	0.3	0.4	1.2
P	26	—	—	—	—	—	—	—	—	—	30	240	280	—	—	—
HCO_3	43	31	29	26	31	—	29	35	63	35	21	73	45	34	33	44
Colour	140	—	60	80	70	90	—	110	80	55	100	40	64	60	80	60

For the positions of the stations see LUNDH 1951 figure 38.

Torsebro is situated about 2.5 km. north of the mouth of Helgeå into Araslövssjön.

Pynten: about 100 m. eastwards the inlet of the sewage conduit of Kristianstad into Hammarsjön. It may be noted that only a part of the sewage is let out here. The rest runs out into the river at several points above Pynten.

Kavrö: at the bridge over Helgeå, 1 km. from its outflow from Hammarsjön.

pient lake. The amounts of calcium and bicarbonate predominate and are often present in large quantities. The magnesium and potassium contents deviate only slightly from those of the lakes. The chloride content is somewhat higher and the same is also true of sulphate. A very apparent feature is also the high content of nitrate and sometimes also the high phosphorus concentration.

The larger concentrations of electrolytes in the brooks do not evidently depend upon the leaching from the fields as most of the analyses have been made when the water flow has been slight, but it must be due to the fact that the brooks contain ground water, which on its way through the soil has leached salts. This is especially marked in Lärkesholmsån, running through a district poor in fields. The high concentration of nitrate and phosphorus are partly due to this leaching, partly to sewage from farms. The electrolyte content of the tributaries probably plays a rather unimportant part in the composition of the lake water, as the water supply from the brooks is insignificant in relation to the total water volume of the lake.

The lake contains a mixture of ground water and surface water, as it constitutes a reservoir for the large volumes of rain and melted snow which do not penetrate the soils. Consequently the lake water must be more diluted than the ground water and the tributaries when the precipitation is low or lacking. For the same reason the higher values of electrolytes in the brooks compared with the lake do not necessarily originate from a strong influence by culture.

As is evident from the discussion above it is very difficult to discover the influences of sewage on the concentrations of electrolytes in the lake waters. Since a great source of pollution is necessary only Hammarsjön is suitable for such a study, but the conditions in this lake do not quite agree with other lakes on account of the large variations in the water. A slight increase has, however, been discovered in Hammarsjön, and it is assumable that this would have been greater in a smaller lake with less conversion. As regards the influence of manuring it is impossible to study its effects by analyses of the water in the brooks.

Discussion.

It is clear from the table given by Lundh (1951, pp. 120 to 121), that the recorded water plants are not uniformly distributed over all the studied lakes. Only some have a ubiquitous distribution. Some are apparently restricted to the lakes on the plains and other to the lakes situated on Archaean rocks. The lakes thus differ in some of their vegetation.

The results from the chemical studies have also established that there is a variation in the concentrations of the ions, even if it is more or less marked. The differences are especially large for calcium, bicarbonate and sulphate, and less for magnesium, potassium and chloride. Exceptions, however, are encountered. On the other hand the contents of nitrate, phosphorus and iron and the hydrogen ion concentration do not show any significant differences.

If the total concentrations of the ions are calculated for the most electrolyte-rich lake Yddingen and for the most electrolyte-deficient, for example Rösjön, the following results are obtained:

	Yddingen	Rösjön
Cations mEq.	4.40	0.70
Anions mEq.	5.32	0.85

The differences between the cations and the anions are mainly due to the undetermined sodium. From these values it is evident that the salt content is about 6 to 7 times greater in a typical lowland lake than in a lake on Archaean rocks. Generally the quotient does not amount to this value as Yddingen is extremely rich in salts.

As regards nitrate, phosphorus and potassium, which belong to the most important nutrients for the plants, it may be stated that the differences between the lakes are less than would be expected *a priori*.

As already mentioned the variation is most pronounced in the content of calcium bicarbonate. By experimental investigations upon the effects of the pH and bicarbonate on the growth of *Ceratophyllum* and *Elodea* Steemann-Nielsen (1944) has shown that the content of bicarbonate is of decisive importance for the development of these two plants and not the pH. Perhaps the different contents of bicarbonate in the lowland lakes and in the Archaean lakes might partly explain the aberrations in the vegetation.

This investigation like LOHAMMAR's has established that it is impossible to draw any conclusions about the distributions of the species from the content of common ions in lake waters. Even if still more thorough analyses were performed it would be impossible to solve the problem in this way, as the ion content is only a small part of the big complex of mostly unknown factors which together constitute the environments. Furthermore only a vague idea of the total salt content and the metabolism in the lake is obtained from single analyses. On the whole information of the actual requirements of nutrients, trace elements and other growth factors cannot be achieved from an investigation of this type.

Summary.

In the summers of 1946, 1947 and 1948 the author has studied the concentrations of some ions together with some other factors in the water from 31 Scanian lakes, the vegetations of which at the same time were investigated by ASTA LUNDH. The problem was to establish the characteristic features of the electrolyte concentrations and if possible to study whether or not there is any simple correlation between the ion concentrations and the distributions of aquatic plants. The following ions have been studied: Ca, Mg, Fe, K, Cl, SO_4, NO_3, PO_4, SiO_2, and HCO_3 and of other factors: pH, $KMnO_4$-consumption, specific conductivity, total solids, non-volatile solids, total hardness and colour. The analytical methods are described.

The most striking result is the variation found in the concentrations of Ca and HCO_3 in the different lakes. The concentrations of the other ions agree more or less or the variation is heterogeneous. No significant differences seem to occur. As regards the common plant nutrients, K, P and NO_3, no apparent differences between lakes with aberrant vegetation seem to be present from the values here given. It is impossible to discover the origin of the variant lake vegetation from an investigation of this type as the salt concentration is only one factor of the large complex forming the environments and it gives no contribution to the knowledge of the true requirements of the individual species.

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II.

ION DETERMINATIONS IN LAKE WATERS.

By Artur Almestrand.