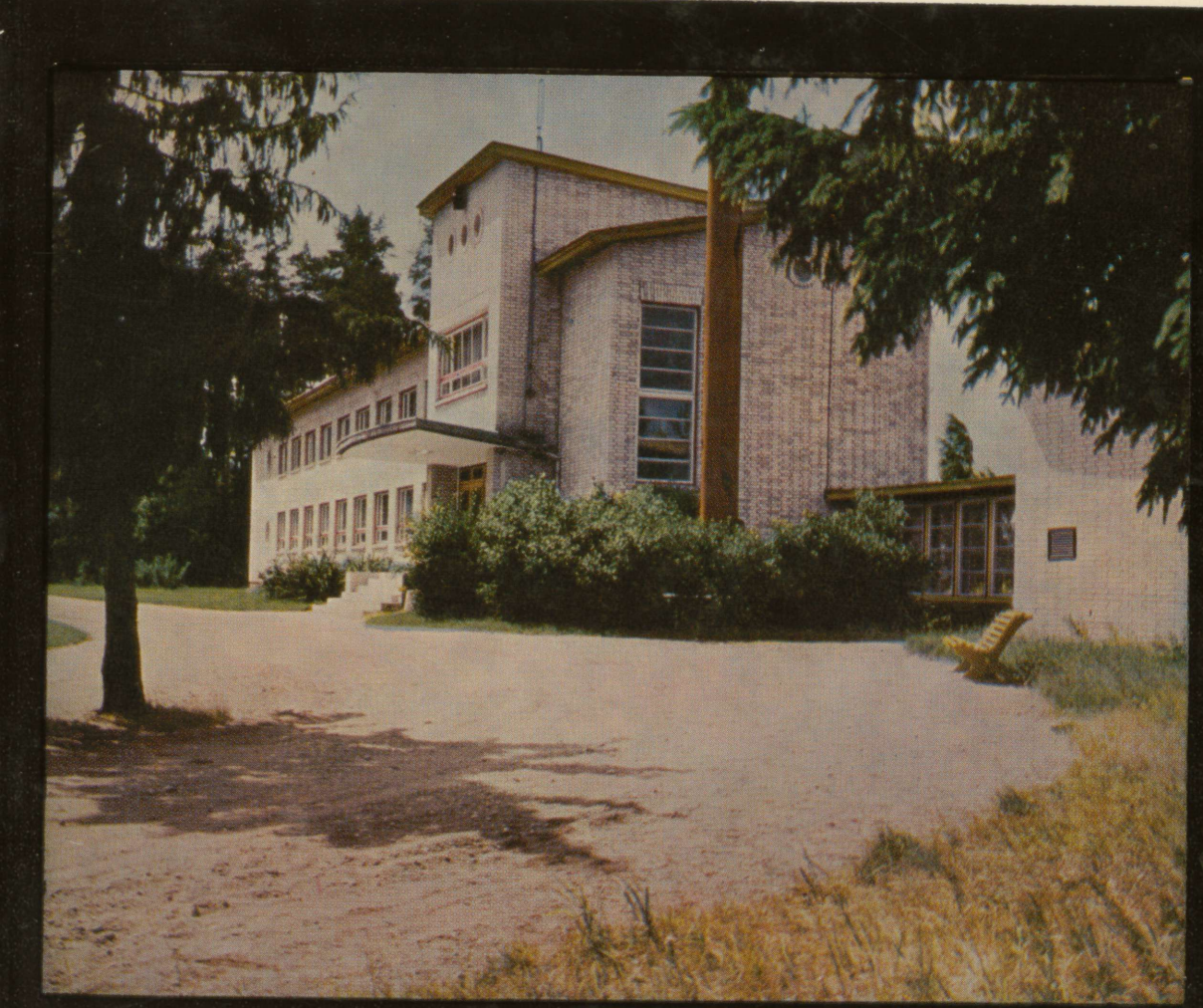
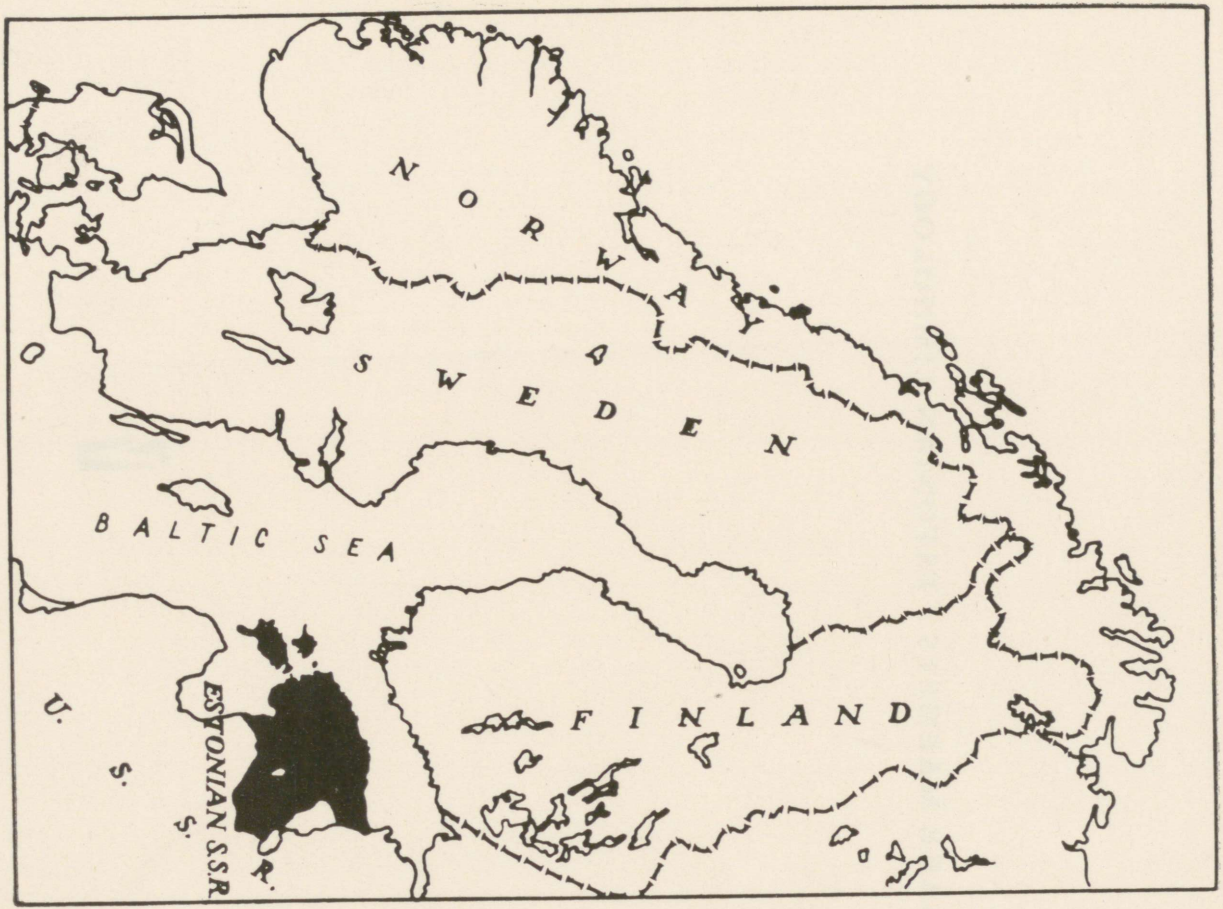
ESTONIAN LIMNOLOGY

by Aare Mäemets



AARE MÄEMETS · ESTONIAN LIMNOLOGY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AARE MÄEMETS

ESTONIAN LIMNOLOGY

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for Presentation to the 18th International Limnological Congress
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THE WATER RESOURCES OF ESTONIA

Estonia, the northernmost of the Soviet Baltic republics has an area of only 45, 215.5 sq. kms and is rich in inland waters which came into existence as a result of the last Glacial Period and the retreat of the Baltic Sea from the Estonian coastal areas. Estonia has more than a thousand lakes (1148 according to the 1964 census), with a total surface area of 2130 sq. kms or 4.78% of the national territory. The two largest lakes are the lakes Peipsi-Pskov (3566 sq. kms, of which 1584 sq. kms fall within the boundaries of the Estonian S.S.R.) and Võrtsjärv (270 sq. kms). The distribution of the lakes is especially dense in the hilly moraine landscapes of South Estonia and other areas of terminal deposits left by the Continental ice-sheet. The drumlin lakes of the Vooremaa area, which are lined by ridges and occupy the furrows gouged out by the moving ice, are regular in shape and elongate in a direction stretching from north-west to south-east. In West Estonia and along the north coast there are numerous coastal lakes, which have been separated from the sea by the tectonic uplift. In many cases when the sea runs high they are occasionally flooded with salt water.

Lake Kaali in Saaremaa is, on account of its meteoritic origin, unique in Europe (Reinwald 1939).

In the raised bogs of Estonia there are about 20 thousand hollow-pools.

The river network is fairly dense, with a total length of 31,153 kms (0,7 kms per sq. km). However, most of the streams are small and only nine rivers attain or exceed 100 kms. The most powerful of these is the River Narva, with an average annual outflow of 12.7 cubic kms, of which 3.87 cubic kms are discharged from Estonian territory. The remaining rivers discharge a yearly average of 7.91 cubic kms, and the total outflow from Estonian territory averages 11.78 cubic kms per annum.

A storage reservoir with an area of 200 sq. kms, of which about 54 sq. kms fall within the territory of the Estonian S.S.R., has been

constructed on the River Narva. Another large (4.5 sq. kms) storage reservoir is that of Paunküla on the River Pirita.

The underground waters have an average annual discharge of ca 113,000 cubic meters, both quantity and quality varying greatly in different parts of Estonia.

THE HYDROBIOLOGY OF THE ESTONIAN INLAND WATERS

1. HYDROBIOLOGICAL RESEARCH IN THE PAST (BEFORE 1944)

The first investigations into the fish reserves of Estonia were undertaken already in 1851—1852 on Lake Peipsi-Pskov under the guidance of the famous scientist K. E. Baer (Kullus 1964).

But the years 1904—1905, when Lake Ülemiste (near Tallinn), with its flora and fauna, was subjected to complex investigations may be regarded as the real beginning of the hydrobiology of the Estonian inland waters. A voluminous monograph dealing with the composition of the lake, its bottom deposits, temperature conditions, transparency, water chemistry, plankton, fishes and other problems was published (Schneider 1908).

A great impetus to the development of hydrobiology in Estonia was the establishment of the Lake Commission of the Naturalists' Society (LUS) of Tartu University in 1905. This Commission became the centre of hydrobiological research work up to World War I, during which period studies were made of lakes Saadjärv, Soitsjärv, Pangodi, Rõuge, Keeri, Tilsi, Väimela, Võrtsjärv, Peipsi-Pskov, etc., and work was already in progress on the rivers Emajõgi, Paala and Pedja.

Much material on the flora, fauna and geology of the lakes was gathered, depth and vegetation maps were charted.

But the investigations of that period were not of a complex character and mostly dealt with single problems. Among the works sponsored by the Lake Commission at that time M. zur Mühlen's investigations on the morphometry, deposits, flora and fishes of lakes are of greatest importance (see Pages 9, 27, etc.).

In addition to the activities of the Lake Commission, the fish reserves of Lake Peipsi-Pskov were investigated under the guidance of N. Samsonov in 1912—1913. Because of World War I all but a small part of the biological data on that lake was published. During the years 1911—1912 work proceeded at Võrtsjärv where, in addition to the flora and fauna the

Prof. H. Riikoja, founder of the Estonian limnology.

prospects of fishery were also treated. The results in the form of a monograph were published not until 1920 (zur Mühlen and Schneider 1920).

In bourgeois Estonia the Committee for the Investigation of Estonian Waters (EVUK) at Tartu University became the centre of research work in this field, Prof. H. Riikoja being the leading hydrobiologist. During this period great importance was attached to the cadastre of lakes and introduction of quantitative methods.

Thanks to Prof. H. Riikoja and his disciples an active programme of scientific research was now launched. A List of Estonian Lakes (Riikoja 1934) was published, together with works on the morphometry of 75 lakes (Riikoja 1930, 1937). The distribution of the Estonian lakes (Riikoja and Kärstna 1936), the colour and transparency of the lake water (Riikoja 1940) and the hydrochemistry of lakes (Riikoja 1940a) were investigated. Studies were also made of the plankton, benthos, etc., but the results were only partially published due to World War II. It is worth mentioning that several lake groups (Vooremaa, Võru, Rõuge, Kurtna, Aegviidu, Orava) were subjected to complex investigation. Of the hydrobiological works of the bourgeois period mention should be made of

A. Audova's and H. Bekker's study of Pühajärv (1923), which was the first hydrobiological work printed in Estonian, J. Käis' «Võru Lakes» (1923) and Harald Haberman's papers on the lakes Pühajärv (1935), Külajärv (1937), Klooga (1938) etc. Lake Külajärv at Vellavere is described by H. Haberman as an example of eudys succession.

During the same period comprehensive surveys of such hydrobiontic groups as the *Algae* (Mölder 1932, 1938 etc.), *Protozoa* (Jacobson 1928), *Rotatoria* (Riikoja 1925, 1932), *Cladocera* (Lepiksaar 1932), *Copepoda* (Vinkel-Voore 1934, 1934a, 1936, 1937), *Mollusca* (Krausp 1936, 1940), etc. were also published.

During World War II hydrobiological investigations in Estonia were neglected. Some works on the algae and typology of the Estonian lakes (Mölder 1943, 1943a, 1944, 1944a, 1946) were published abroad. As a result of the war we lost several talented hydrobiologists belonging to the younger generation.

2. HYDROBIOLOGICAL RESEARCH IN THE ESTONIAN S.S.R. BEFORE THE ESTABLISHMENT OF THE VÕRTSJÄRV LIMNOLOGICAL STATION

Only after World War II were extensive complex hydrobiological investigations of inland water bodies initiated in Soviet Estonia. They were called forth by the need to evaluate the Estonian inland water bodies, especially the lakes, with regard to fish reserves and devise means for the rational management of the water bodies. As knowledge of the flora and fauna is a necessary prerequisite in elucidating the biological processes involved and evaluating the fish reserves, floristic, faunistic and ecological investigations were carried out alongside with ichthyological investigations and those concerning fishery.

The Chair of Invertebrates and Hydrobiology (at present the Chair of Zoology) at Tartu State University and the Institute of Biology of the Academy of Sciences of the Estonian S.S.R. (now the Institute of Zoology and Botany) at Tartu became the centres of researches.

One of the most important Estonian rivers — the Suur-Emajõgi was chosen as the first object of the complex investigations launched by Prof. H. Riikoja, as the leader of the research group, in 1947. The work was completed by 1953 and it provided much new material on the morphometry, hydrology, flora, plankton, benthos and fish fauna (Lumberg 1956, 1962, Tõlp 1956, Lissenko 1956, Ristkok 1956 et al.). Prof. H. Riikoja (1956) also carried out the biological regionalization of the Emajõgi. Since then the Chair of Zoology of Tartu State University has, under the guidance of Assistant Professor Ristkok, carried out investigations of the tributaries and flood-plain lakes of the Emajõgi. This work is still in progress.

Investigations of the River Suur-Emajõgi. Gathering zoobenthos.

The second stage of the research work began in 1951 when, on the initiative of N. Mikelsaar, the complex investigation of the Estonian lakes was undertaken by the Institute of Zoology and Botany (ZBI).

These investigations were of a comprehensive character. Materials on the geography, hydrochemistry, flora, phytoplankton and zooplankton, benthos, fish fauna, crayfish and bird fauna of the lakes were gathered. Complex expeditions were continued till 1957 and over 70 people took part in them. More than 170 lakes were studied. After that date only

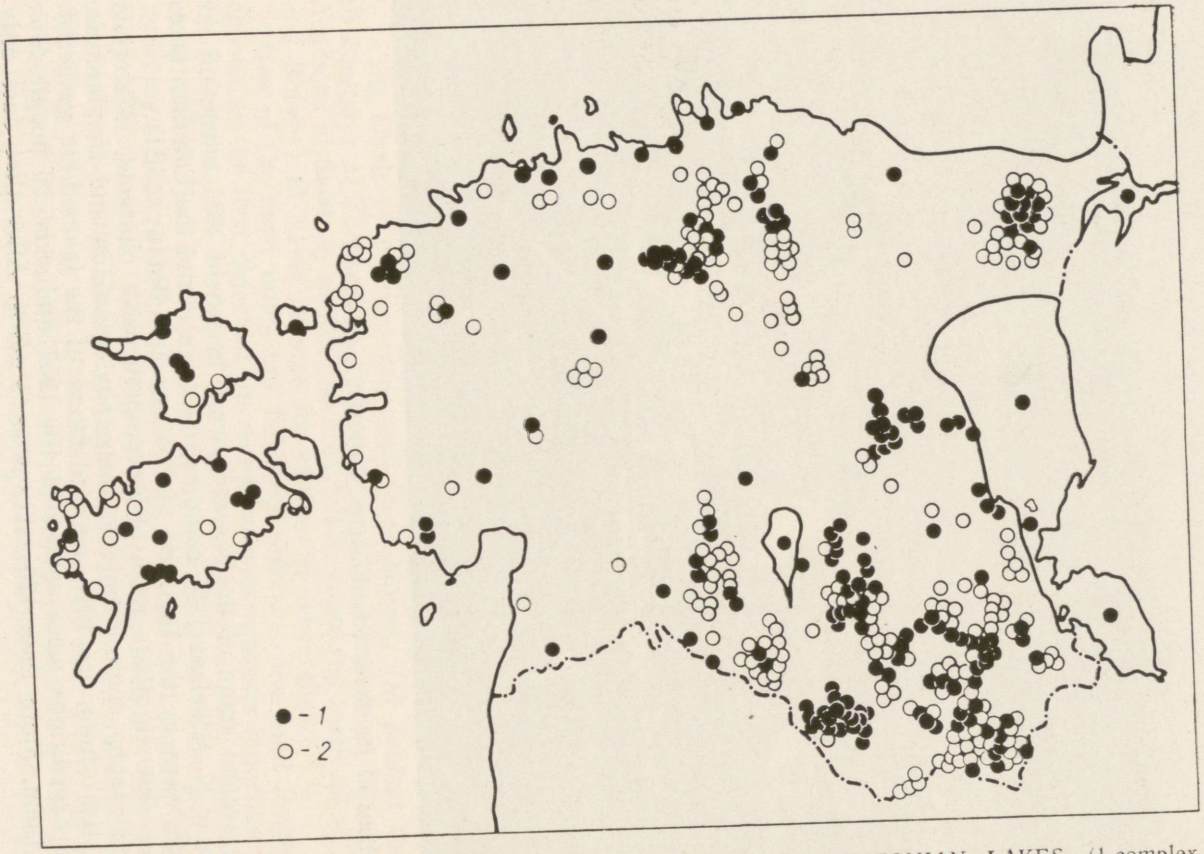


FIG. 1. THE HYDROBIOLOGICAL INVESTIGATION SITES ON THE ESTONIAN LAKES (1-complex investigation, 2-partial investigation).

separate groups have been busy with gathering some additional data on lakes and only a few lake groups have been subjected to complex investigation. Thus a scientific expedition to the South-East Estonian lakes was organized in the August of 1961, 37 lakes being investigated. In August, 1959 planktological expeditions to all the 62 Estonian oligotrophic (s. lat.) lakes took place. Analogical expeditions to oligotrophic and dystrophic lakes in North Estonia and South-East Estonia were undertaken in the summer of 1960, when 50 lakes were investigated while 18 dystrophic and dyseutrophic lakes were studied in the summer of 1964. The Paunküla lakes (9) were subjected to complex investigation in the summer of 1966.

Since 1953 the Institute of Zoology and Botany has, in collaboration with Tartu State University, been investigating Võrtsjärv in a complex way, and from 1962 the Institute has also been engaged in investigating the flora, plankton, benthos and fish fauna of Lake Peipsi-Pskov. In 1958—1962 hydrochemists and benthists of the Institute were working on the River Pärnu and its tributaries; in 1963 they were busy on the River Kasari. Benthists worked on the Paunküla storage reservoir in 1961—1963. In addition to the summer expeditions, hydrochemical samples and samples of zooplankton have been extracted seasonally from different types of lakes (1955—1956, 1961—1962). In 1962—1965 the hydrochemical conditions at the fish ponds at Põlula were investigated (Parts, Simm 1965).

So far 425 Estonian lakes (i. e. almost 37% of the total) have been hydrobiologically investigated by ZBI while 185 of them have undergone a complex investigation (Fig. 1). Nearly all the lakes with an area of more than 20 ha have been investigated.

The Chair of Zoology of Tartu State University has also to some extent dealt with the Vooremaa lakes. The personnel of the piscicultural department of the Estonian Research Institute for Cattle-Breeding and Veterinary Science (M. Puhk, M. Ennever, etc.) has gathered some hydrobiological materials on lakes at Väimela and some other Estonian lakes. The above mentioned department also deals with the problems of pond fishery. Fresh water organisms have also been studied by the staff of the Estonian Laboratory of Marine Ichthyology in Tallinn.

In addition to the lakes and rivers, the Institute of Zoology and Botany has, with the aim of settling various floristic and faunistic problems, investigated hundreds of pools, ponds, hollow-pools, hollows and small streams all over the republic. The investigations in the field of the pollution and protection of the inland waters carried out at the Tallinn Polytechnical Institute, the Estonian Agricultural Academy, Tartu University and some other centres cover hydrobiological problems to a certain extent, but they are mainly of technical character. The Lake

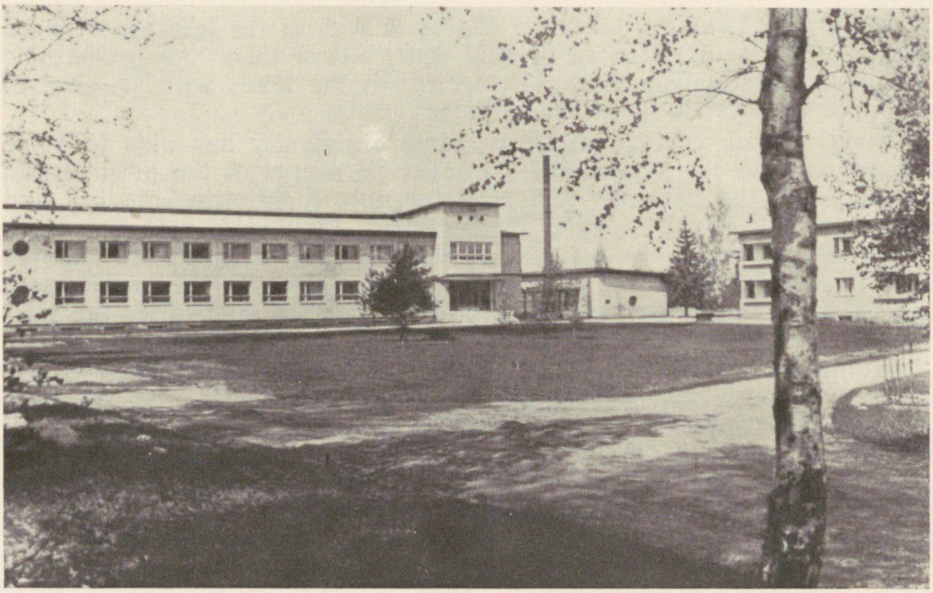
Commission of the Naturalists' Society has been relatively passive during recent years, dealing mostly with the organization of ichthyophenological observations (since 1951) and the publication of catalogues of aquatic plants and animals. It also organizes meetings and lectures.

We are not mistaken in declaring that at present Estonia is one of the leading countries in the world as regards the extent of the researches conducted on the inland water bodies.

3. VÕRTSJÄRV LIMNOLOGICAL STATION

The foundation of the Sector of Hydrobiology at the Institute of Zoology and Botany in 1957 and the construction of the Võrtsjärv Limnological Station (opened in 1959) acted as a great impetus to the development of hydrobiology in Estonia. Especially important was the year 1961, when the first scientific workers settled down to work there and the Station

The Võrtsjärv Limnological Station. The view of the main building.



partially began to fulfil its functions. In 1963 the construction of the main building of the Station was completed and since that time the Sector of Hydrobiology has resided here.

The Võrtsjärv Limnological Station (head N. Mikelsaar) of the Institute of Zoology and Botany of the Academy of Sciences of the Estonian S.S.R. — to give its full title — is the main research centre for investigations of all the Estonian inland waters. It is situated on the eastern coast of Lake Võrtsjärv (see Fig. 2), not far from the deepest point (6 m) of the lake. Besides the eutrophic Võrtsjärv, a small (23 ha) dyseutrophic forest lake Mustjärv (Black Lake) is situated in the vicinity of the Station. The Station is equipped with a main building, containing modern laboratories (microbiology, hydrochemistry, biochemistry, biology, physiology), studies and a library, an aquarium house, a quay and four dwelling-houses. To carry out investigations on Võrtsjärv and Lake Peipsi-Pskov the Station has a 150 hp research ship (*Bioloog II*) at its disposal. The number of people on the staff is 41, of whom 19 are scientific workers. As a result of the completion of the laboratories and

The Võrtsjärv Limnological Station. A study.

L. Võrtsjärv in the spring of 1967. Ice masses attacking the shore.

the aquarium house the range of problems covered by the Sector of Hydrobiology of the Institute of Zoology and Botany has considerably broadened. From 1965 to 1970 the Station was engaged in problems of the artificial breeding of food for fish. For that purpose special attention was devoted to the biotechnics of mass breeding of the *Cladocera*, *Oligochaeta* and *Chironomidae larvae* (supervisor Aare Mäemets). Ichthyological work was concentrated on the problems of intraspecific biological qualities of productivity (supervisor Henn Haberman) and on the elaboration of theoretical basis for the evaluation of the fish reserves in lakes Peipsi-Pskov and Võrtsjärv (supervisor Ervin Pihu). In addition, contractual investigations have been carried out on lakes Maardu, Hino and Aheru, on the storage reservoir at Narva and in peat pits at Ulila, Lavassaare and Ellamaa. Similar work has been done on several other water bodies to settle problems of fishery and the water reserves. Thus the general tendency of hydrobiological research has effected a marked shift in the direction of applied biology.

In 1969 the Võrtsjärv Limnological Station was included in the list of participants of the International Biological Programme (IBP). Its

object of study is the biological productivity of Võrtsjärv and its task to create a model reflecting the production processes of the ecosystem of the lake.

In 1971 the Võrtsjärv Limnological Station is to take up the comparative qualitative and quantitative investigation of the biocoenoses of the Estonian lakes in order to elucidate the mechanism of bioproductivity in lakes of different types, to simulate models expressing the cycles of matter and energy circulation and to elucidate intraspecific biocoenotic relations. Ignorance of the last mentioned problems has often exercised an adverse effect on acclimatization work in the Estonian S.S.R.

MAIN WORKS AND PUBLICATIONS ON HYDROBIOLOGY

Of the hundreds of hydrobiological works and articles published in Soviet Estonia one should mention first and foremost the five volumes of "Hydrobiological Investigations" ("Hüdrobioloogilised uurimused") issued by the Institute of Zoology and Botany. Volume I (1958) contains 22 investigations on problems of physical geography, hydrochemistry, the phytoplankton and zooplankton, the fauna and ecology of the invertebrates, diseases of the crayfish, and the feeding habits, growth rates, reproduction, artificial breeding and exploitation of the fish populations of the Estonian lakes (Võrtsjärv included). Volume II (1961) contains 11 articles dealing mainly with the biology, morphology and embryology of the Estonian inland fishes, the ecology of the *Cladocera*, the biology of the *Copepoda* and *Ostracoda*, the diatom flora and the hydrochemistry of the lake water. Volume III (1962) consists of 54 reports delivered at the eighth Baltic Inland Waters Conference in 1960, 13 of them being devoted to the Estonian inland waters and dealing with the hydrochemistry, phytoplankton and zooplankton, benthos, fish fauna and fish industries of the lakes. Volume IV (1966) entitled "The Hydrobiology and Fisheries of Lake Peipsi-Pskov" contains 27 articles dedicated to the hydrobiology and fishery of Lake Peipsi-Pskov. Volume V (1969), "The Hydrobiology and Fisheries of the Inland Waters of the East Baltic Area", contains the principal reports (43) delivered at the thirteenth Baltic Inland Waters Conference in 1966, 13 of which concern the Estonian inland waters.

Materials on the hydrobiology of the Estonian inland waters have also been published by other countries participating in the annual conferences devoted to Baltic inland waters. These conferences were

initiated by the Institute of Zoology and Botany at Tartu in 1953 and have been regularly held in Estonia (1956 — Tartu, 1960 — Tartu and 1966 — Tallinn).

A symposium on the Oligochaeta organized by the Institute of Zoology and Botany together with the Soviet Hydrobiological Society was held at Tartu and the Võrtsjärv Limnological Station in 1967. Theses of the principal contributions have been published.

The most outstanding and voluminous work on Estonian hydrobiology is the monograph "Eesti järved" ("Estonian Lakes"), which was compiled by A. Mäemets, and published in 1968 (523 pp.). Fifteen authors contributed to this collection which gives an exhaustive survey of the physical geography (E. Varep), hydrochemistry (H. Simm), macroflora (H. Tuvikene), phytoplankton (M. Pork, V. Kõvask), zooplankton (A. Mäemets), bottom fauna (Õ. Tõlp), ichthyofauna and fisheries (Henn Haberman, N. Mikelsaar, Ervin Pihu), crayfish (A. Järvekülg), bird fauna (S. Onno), archeology (sector of Archeology of the Institute of History) and folklore (E. Liiv) of 150 of the more important minor lakes. At present a still bigger team of specialists is busy with the compilation of the second part of the "Estonian Lakes". Part II is to generalize the whole of the extant hydrobiological materials on the Estonian lakes and to complete their typology, defining each basic type from the point of view of its ecology and production. The results should enable us to determine the most suitable and rational methods of exploitation and nature conservation.

A voluminous (400 pp.) monograph on Lake Võrtsjärv, compiled by T. Timm is also available. It surveys the physical geography (A. Kongo), geological evolution (K. Orviku), bottom deposits (K. Veber), hydrology (A. Jaani), hydrochemistry (H. Starast, A. Simm), macrophytes (Aime Mäemets), bacteria (S. Lokk), algae (M. Pork, V. Kõvask), zooplankton (J. Haberman, Aare Mäemets), bottom fauna (H. Riikoja, J. Ristkok, K. Ruse, T. Timm, V. Timm, Õ. Tõlp), ichthyofauna and fisheries (H. Haberman, M. Kangur, A. Kirsipuu, A. Luts, N. Mikelsaar, Evi Pihu, Ervin Pihu, H. Tell), fish parasites (H. Tell), ornithofauna (O. Renno) and the composition of floora and fauna (T. Timm), etc. of the second biggest Estonian lake.

Many hydrobiological and ichthyological articles have been published in the Biological Series of the Transactions (of the Academy of Sciences of the Estonian S.S.R.) (Eesti NSV Teaduste Akadeemia Toimetised), in the journal "Eesti Loodus" ("Estonian Nature"), in the Annals of the Naturalists' Society (Loodusuurijate Seltsi Aastaraamat) and in the Transactions of Tartu State University (Tartu Riikliku Ülikooli Toimetised).

During the post-war period 20 candidate's dissertations dedicated to

the inland waters and their biota have been defended in the Estonian S.S.R., 13 of them at the Institute of Zoology and Botany. To these should be added H. Simm's doctoral thesis on the chemical composition and formation of the Estonian surface waters.

PHYSIOGRAPHICAL RESEARCHES

Extensive physiographical researches have been carried out on the Estonian lakes ever since the early days of limnology. Mention might be made of works on the geology, deposits, morphometry, hydrology, etc., of L. Ülemiste (Schneider 1908), L. Rõuge (M. zur Mühlen 1908), L. Saadjärv (M. zur Mühlen 1911), L. Soitsjärv (L. zur Mühlen 1910), L. Võrtsjärv (L. zur Mühlen 1919a) and others. L. zur Mühlen's study of Lake Pakasjärv in North Estonia ("Zur Entstehungsgeschichte der Hochmoorseen", 1919) may be considered one of the first descriptions of a raised-bog lake in the Baltic countries.

Since the early days of bourgeois Estonia the Bureau for the Investigations of the Estonian Inland Waters under the guidance of A. Vellner was studying the hydrology, to some extent also hydrochemistry, of inland waters. During the period of 1922—1941 it published ten volumes of annals. In addition to the annals A. Vellner compiled a collection of data on the studies of inland waters (four volumes) (Vellner 1922, 1923, 1923a, 1924) and a summary (Vellner 1925) which reviews the Estonian hydrography. It also contains descriptions of about 30 rivers and materials on several bigger Estonian lakes (Peipsi, Võrtsjärv, Pühajärv, Ülemiste, etc.). A. Vellner and his assistants actively participated in the conferences of the hydrologists of Baltic countries held at that time.

In bourgeois Estonia a fairly comprehensive geophysical and botanical investigation of L. Pühajärv was published by A. Bekker (1923) to be soon followed by J. Käis' work on the lakes of the Võru region (Käis 1923). In 1930 H. Riikoja published the first part of his treatise "Zur Morphometrie einiger Seen Eestis", which presents a survey of the morphometry of 47 Estonian lakes together with depth charts and batygraphic curves. In 1937 the second part was published, containing a morphometric description of 28 lakes. All in all 75 lakes with a total surface area of 350 sq. kms were discussed in these two volumes. In 1934 H. Riikoja published his "List of Estonian Lakes" which enumerates all Estonian lakes with an area over 0.3 hectares. The total number of these lakes is 1617 and their total area is 511.9 sq. kms (excluding Lake

Peipsi-Pskov). The handbook gives the name, location, length, breath, surface area, height from sea-level and connections with other water bodies; and, in many cases, the average and maximum depths and the volume of water.

H. Riikoja and A. Kärstna (1936) have analyzed mathematically the distribution of the Estonian lakes, mapping the isolimnarisms (the relative number of lakes), isolimnareals (average surface areas) and isolimns (the proportion of the total territory occupied by lakes). The average frequency for the whole of Estonia is four lakes per 100 sq. kms. The greatest frequency (over 16 lakes per 100 sq. kms) was recorded in the Haanja Uplands (the central part of which contains more than 30 lakes per 100 sq. kms (Kask 1963)). The Otepää Highlands and the Tagamõisa peninsula are also rich in lakes (12—16 lakes per 100 sq. kms). Other areas rich in lakes are to be found in North Estonia. In Kurtna there are 40 lakes in the territory of 30 sq. kms, while North Kõrvemaa contains about 30 lakes per 100 sq. kms (Kask 1963).

Professor H. Riikoja has also published a survey (Riikoja 1940) of the transparency and colour of the water in 51 Estonian lakes.

A rather extensive survey of the stratigraphy of Estonian marsh and lake sediments was drawn up during the bourgeois period by P. Thomson (1926, 1929, 1933, etc.), who plotted more than a score of profiles from various parts of Estonia. These paleolimnological studies contained valuable materials both for pollen analysis and for the flora of the ancient algae and macrophytes.

H. Riikoja (1936) has published some data on the occurrence of lacustrine ore in Lake Vagula.

On the eve of the Great Patriotic War a voluminous monograph "Lake Peipsi-Pskov" (Sokolov 1941) was published in the U.S.S.R. This investigation was based on physiographical and biological materials gathered from the Russian part of the lake, and it remains one of the most comprehensive studies of Lake Peipsi-Pskov.

One of the most outstanding works published in Soviet Estonia is the "List of Lakes in the Estonian S.S.R." (Kask 1964). It revises the data of the earlier "List of Estonian Lakes" and lists 1148 lakes on the territory of the Estonian S.S.R. (lakes with the area over 1 ha have mainly been taken into account). The new catalogue gives the name, location, height from sea-level, length, breath, surface area, length of coast line, circumference ratio, and, in many cases also the maximum depth and the volume of water. Moreover it contains abundant hydrological and hydrobiological data.

Extensive physiographical surveys of Võrtsjärv have been published (Varep 1958, Mikelsaar 1962) as well as L. Pühajärv (Loopmann 1960), and L. Peipsi-Pskov (Eipre 1964; Kullus and Merila 1966) and in the

monograph "Estonian Lakes" similar information can be found for 150 of the more important minor lakes (Varep), including such essential morphometric data as height from sea-level, length, maximum breadth, surface area, etc., while the geographical location is indicated with reference to both the chief natural regions of Estonia and the type of landscape in which the lake is situated. After a brief account of the surroundings (relief, geology, soil and plant cover), the basic data on the lake itself are presented (origin and evolution, shape, nature of the inflow and outflow, the hydrological regime and the colour, transparency and pollution of the water) are discussed.

The Tiirikoja Hydrometeorological Lake Station of the Hydrometeorological Service Board of Estonian S.S.R. at the Lake Peipsi (near Mustvee) carries out year-round hydrological (the temperature and evaporation of water, colour and transparency of water, current flows, undulation etc.) and hydrochemical observations. In addition there are 88 permanent water-level measuring posts in the republic, 10 of them on lakes. This network carries out detailed observations of the hydrological regime on the basis of a programme applicable throughout the whole of the Soviet Union. The results obtained are regularly published in the "Hydrological Annals" of the Board and other special publications (Surface Water Resources 1966, etc.).

During the post-war years workers of the Hydrometeorological Service Board have carried out examinations of 6 lakes with a total area of 297 sq.kms in the vicinity of L. Peipsi. These reports cover the geology, geomorphology, vegetation and network of waters, as well as the morphometry, water-regime and ice-regime of the lakes in question. A. Loopman has produced a general hydrographical survey on the basis of the results obtained.

Many physiographic and hydrobiological discussions of lake groups have been published during the last decade, including regions of Alutaguse (Mäemets 1966a), Sakala (Mäemets 1967, 1968b), Haanja (Mäemets 1968), Paunküla (Mäemets 1968a), Southeast-Estonia (Kask 1968) and others. Descriptions of the flood-plain lakes of the Emajõgi (Ristkok 1969) and Estonian temporary karst lakes have also appeared (Mäemets 1969c). As a part of his treatment of several other problems A. Järvekülg (1958b) has written an interesting survey on the depth of the Estonian lakes. It appears that over three-quarters of the investigated are less than 10 m deep, while less than 5% are deeper than 20 m. The deepest lake in Estonia is Rõuge-Suurjärv — 38 m. All the deep lakes are situated in Upper Estonia ("Kõrg-Eesti"), which became dry land immediately after the retreat of the Continental ice-sheet.

J. Kask (1963) has investigated the size of the Estonian lakes. It appears that about 50% are less than 3 hectares in extent, approximately

L. Rõuge Suurjärv, the deepest (38 m) among the Estonian lakes.

30% from 3 to 10 hectares, and less than 20% from 10 to 100 hectares. Only 45 lakes (i. e. 3.9%) can be called large or very large. Aare Mäemets (1965) has complemented H. Riikoja's survey (Riikoja 1940) on the transparency and colour with materials drawn from 289 lakes. It appears that the transparency of the water in summer is below average in about 50 per cent of the Estonian lakes (less than 1.55 m*). It is average in about 37 per cent of the lakes (1.55—3.0 m), while very transparent lakes (over 4.5 m) account for only 3 per cent of the total. L. Valgjärv

* The transparency was measured with a Secchi disc 30 cm in diameter while the colour was defined subjectively without using a colour scalet or colorimeter.

at Nohipalu has the most transparent water (8.8 m) of all the Estonian lakes. In the coloration scale yellowish-green or greenish-yellow dominate (about 40%), whereas in about 20% the water is brownish-red, reddish-brown or brown. Lakes with yellow, brownish-yellow, yellowish or greenish-brown water are less frequent. Clear regional divisions are noticeable in the distribution of both transparency and colour.

During the last decade the chemical composition and stores of sapropel and limnetic marl in the Estonian lakes have been investigated rather extensively (Veber 1964, 1970a). These stores obtain 3 milliard cubic meters (Veber 1970), while the biggest thickness of the mud layer has been estimated at 18 m (L. Alajärv at Väimela). Many deposits occur in marshes because the total surface area of the Estonian lakes has decreased approximately 3 times since the beginning of the Holocene (Veber 1964).

K. Orviku, L. Orviku, H. Kessel, R. Männil, R. Pirrus, A. Sarv and other Estonian geologists have studied the stratigraphy and distribution of the Estonian lake deposits in greater details. Of biologists M. Pork has analyzed the algae of the lake and swamp sediments, while A. Mäemets has studied the Cladocera to some extent. E. Ilves' (the Laboratory of geochemistry of ZBI) dissertation (1970) on ascertaining the absolute age of marsh and lake sediments of the Holocene (by C^{14}-method) is an outstanding work and contains 77 dates on the sediments of 7 swamps. The work provides a survey of the main stages of the formation of the Estonian lakes and swamps in the Holocene (Ilves, Sarv, 1969; Ilves, Sarv 1970, etc.).

Hydrological, limnological, etc. regionalizations have been carried out on the Estonian territory.

As a result of the hydrological investigation of the Estonian surface waters including the lakes T. Eipre (1967) has distinguished 7 hydrological regions in Estonia. A preliminary scheme for the limnological regionalization of the territory of the Estonian S.S.R. has been drawn on the basis of the distribution of the dominant lake types (Mäemets 1965, 1969, ESE 1970). According to this scheme the territory is divided into seven regions and six subregions (see Fig. 2), each of which calls for different methods of economic exploitation and nature conservation.

As a result of the physiogeographical studies carried out so far there is a survey of the distribution and morphometry of the Estonian lakes, the transparency and colour of the water at our disposal. Relatively less studied are the regularities of the dynamics of the water and the formation of thermal conditions, also their dependence on the form and size of the bed of the lake, the influence of the thermal stratification on other hydrological, hydrochemical and hydrobiological factors. Thanks to the contribution of the workers of the Hydrometeorological Service

Board of the Estonian S.S.R. (A. Jaani, T. Eipre, etc.) and the Chair of Geography of Tartu University (E. Varep, T. Kullus) there is some new material on the mentioned questions, especially on those concerning the water conditions, thermal and water balance of L. Peipsi, L. Võrtsjärv, Narva storage reservoir and some other big water bodies. These data will be summarized in Part II of the "Estonian Lakes".

In order to understand the regularities of the past and future evolution of the lakes it is necessary to undertake an extensive complex of paleolimnological investigations. These investigations should in addition to the fixation of the age of lacustrine sediments and their physical and chemical analysis provide us also both with the qualitative and quantitative analysis of their flora (algae, macrophytes) and fauna (*Cladocera*, *Ostracoda*, *Copepoda*, *Chironomidae*, *Mollusca*). The work on these problems is already in progress at the Institute of Zoology and Botany (E. Ilves, V. Kõvask, A. Mäemets), at the chair of Systematic Botany and Geobotany of Tartu State University (M. Pork) and at the Institute of Geology of the Academy of Sciences of the Estonian S.S.R. (A. Sarv, R. Pirrus, H. Kessel). The results will be published in Part II of the work "Estonian Lakes".

HYDROCHEMICAL STUDIES

The first important investigations into the hydrochemistry of the Estonian lakes were undertaken already in 1904—1905 on Lake Ülemiste and other lakes (Schneider 1908, Mühlen 1906). But it was H. Riikoja, who initiated the systematic hydrochemical investigation of the Estonian lakes. Already in 1929 he published a work on oxygen stratification in the eutrophic lakes in summer (Riikoja 1929) where he discussed the formation of the oxygen stratification on the basis of six Estonian lakes. In 1940 was published H. Riikoja's voluminous investigation "Zur Kenntnis einiger Seen Ost-Eestis insbesondere ihrer Wasserchemie", which summarizes the data obtained from samples taken in 76 Estonian lakes in 1925—1937. Although this work is mainly concerned with the lake groups situated in East Estonia, we can also find some materials on the West-Estonian lakes for purposes of comparison. The aspects considered include the pH, specific conductivity, content of total solids and non-volatile solids, CO_2, hardness, lime-content, ion content (Ca, Mg, K, Na, Fe, Al, SiO_2, PO_4, P_2O_5, NO_2, NO_3, HCO_3, Cl, SO_3); the potassium permanganate consumption of the water, etc. The fact that the water

Taking hydrochemical samples on L. Võrtsjärv.

in seepage lakes is, as a rule, softer than that in drainage lakes is once more confirmed.

During the Soviet period the Laboratory of Geobiochemistry of the Institute of Zoology and Botany (presided over by H. Simm) has become the centre of the hydrochemical investigation of the Estonian lakes. Complete hydrochemical analyses have been made of about 200 lakes. Data on 150 of them have been published in the monograph "Estonian Lakes" (1968) were the O_2 content, CO_2 content, pH, potassium permanganate and potassium dichromate consumptions, and ion contents (HCO_3, SO_4, Cl, Ca, Mg, Na, K, Fe, SiO_2, NO_3, PO_4) are dealt with. Samples for partial analyses have been taken from hundreds of Estonian lakes and bog-pools. Seasonal hydrochemical investigations have been carried out on lakes Võrtsjärv (Simm, 1958; Simm and Starast 1965),

Aheru, Saadjärv, Veisjärv, the lakes at Tooma and Nohipalu and elsewhere.

Comparative investigations of specific humic substances in the Estonian lakes have been regularly carried out, and their results have been published by H. Simm (1955, 1956, 1958a, 1959, 1959a, 1961, 1962, 1968, 1969). The investigations show that the Estonian lakes are characterized by a high concentration of humic substances in the water. Over 40% of the 155 lakes studied reveal potassium dichromate consumption to be over 35 mg of oxygen per litre. The study of the organic substances in the water of the lakes (different in humosity), showed that parallel to the general increase in the total amount of suspended substances indicating a steady transition from an oligohumous to a polyhumous — the proportion of colloidal fractions in the composition of the organic substances, as well as the degree of oxidation and the intensity of colour of the water, are gradually increasing. The non-colloidal fraction dominates in the composition of organic substances of autochthonic origin in oligohumous lakes. The fraction of fulvic acids dominates in the water of mesohumous and polyhumous lakes, where organic substances are of allochthone origin, and formed in marshy areas. The organic substances of the polyhumous lakes, formed in raised bogs, differ from those of the mesohumous lakes, which are formed in other types of swamps, by reason of their higher content of the humic acid fraction.

Problems of the balance of the carbonate system in the water of L. Võrtsjärv have been studied by H. Starast (1966, 1970).

H. Simm (1963, 1967) provides a hydrochemical classification of the Estonian lakes, dividing them into five groups according to the concentration of electrolytes and organic matter and regionalizing Estonian territory on the basis of the results obtained. The same author (Simm 1967) has also discussed the formation of the surface waters and regionalized Estonia on the basis of the chemical composition of the surface water (Simm 1965, 1966, 1969a, 1970).

In addition to the above mentioned hydrochemical works the Chair of Hygiene of Tartu State University (M. Kask, M. Uibo, etc.) has studied the content of microelements (Ag, Al, B, Bi, Co, Cu, Fe, Mn, Mo, Ni, Pb, Sn, Ti, V) in the Estonian inland waters, including about 20 lakes and water reservoirs.

Thus the stage of the description and typification of the hydrochemical conditions in the Estonian lakes is now superseded. The future plans of the Geobiochemical Laboratory of the Institute of Zoology and Botany include the formation of the chemical composition in lakes of different types. This work is to be carried out in a complex way, hand in hand with planktological research and studies of macrophytes.

THE MACROPHYTES

Early floristic notes on the vegetation of the Estonian lakes date as far back as the middle of the 19th century. They can be found in the works of P. Glehn, E. Russow, J. Klinge and other authors. On the basis of materials on Estonian and other Baltic lakes J. Klinge proposed the law bearing his name for the filling up of lakes by vegetation.

Somewhat more detailed vegetation descriptions appeared in the early years of the 20th century in works by G. Schneider (1908), G. Schneider and M. zur Mühlen (1920) M. zur Mühlen (1906, 1908,

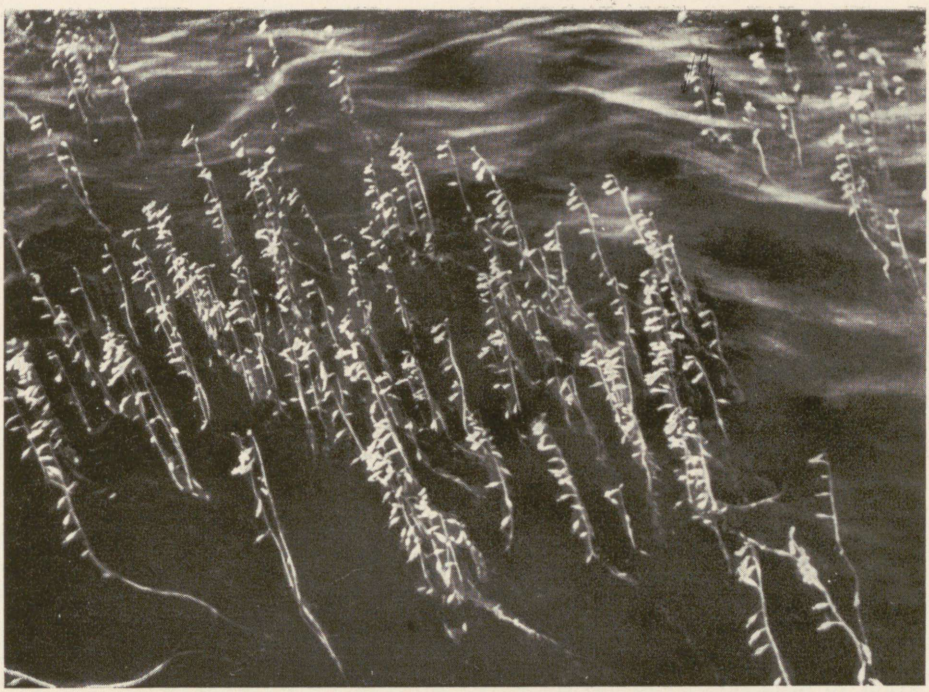
Charting the vegetation of L. Võrtsjärv.

1908a, 1911), L. zur Mühlen (1910), Oettingen (1906) and others, most of which were concerned with the lakes in the surroundings of Tartu. H. Bekker's (1923) vegetation description of L. Pühajärv, that of J. Käis (1923) on Võru lakes and H. Haberman's (1937) vegetation descriptions of L. Külajärv at Vellavere and several other lakes were added in bourgeois times. Abundant data on the vegetation of water bodies can be found in the vegetation surveys of certain Estonian districts compiled by E. Sphor (later on by K. Eichwald) and in H. Riikoja's study of the hydrochemistry of the Estonian lakes (Riikoja 1940a).

Some interesting finds of subfossile macrophytes are mentioned in P. Thomson's works (1929, et al.) who presents some materials on the occurrence of *Cladium mariscus, Myriophyllum alterniflorum* and other (now) rare plants in Estonian lakes in the past.

The vegetation associations of Estonian lakes were first analyzed by A. Miljan. In the eutrophic lakes and rivers situated in the surroundings of Otepää he described four associations and six subassociations (Miljan 1933). To these he later added five associations of North-Estonian oligotrophic and dystrophic lakes (Miljan 1958). V. Sirgo (1935) studied plant associations at the mouth of the River Emajõgi. In the 1960's L. Laasimer (1965) investigated plant associations in the Estonian lakes describing five associations in oligotrophic lakes and six associations in eutrophic lakes. She considers the absence of typical associations a characteristic feature of dystrophic lakes.

Owing to the material gathered mainly by H. Tuvikene and Aime Mäemets during some last decades we have a survey of the composition and amount of the vegetation in 250 Estonian lakes. Vegetation descriptions of 150 Estonian lakes compiled by H. Tuvikene ("Eesti järved", 1968) is the main work dedicated to the macroflora of the Estonian lakes. H. Tuvikene (1956, 1958, 1961, etc.) has published various data on the vegetation of about 170 Estonian lakes distinguishing between three main vegetation zones in the Estonian lakes (emergent vegetation, floating-leaved vegetation, submerged vegetation) and providing depth limits and descriptions for all zones. The average depth limit of the first zone in the Estonian lakes is 1.5 m (maximum 2.3 m), that of the second zone being 2.0 m (maximum 2.5 m) while the depth limit of the third zone reaches the depth of 2—4 m (in exceptional cases 7 m). The data prove that there is a reliable correlation between the floristic composition, number of species, vegetation density and content of inorganic matter in water. H. Tuvikene is also the author of the vegetation scheme and description of the biggest Estonian lake — L. Peipsi-Pskov (Tuvikene 1966). Aime Mäemets (1965a) has published a survey of the macroflora of 32 South-East Estonian small lakes analyzing the relations of the vegetation with the transparency, colour, content of inorganic and organic



Lobelia Dortmanna in L. Valgejärv at Kurtna. Nowadays the species occurs only in 13 Estonian lakes.

matter and nutrient content of the water and other factors. She has reached a conclusion that the vegetation covered area in these lakes largely depends on the depth and transparency of the water body while the species composition is mainly determined by chemical properties of the water, especially the content of inorganic matter. The same author has also drawn up a detailed vegetation map of L. Võrtsjärv and is studying the production of higher vegetation of the above lake at present.

Survey of the Estonian charophytes (Pork 1954), of the occurrence and ecology of the *Lobelia* and *Isoëtes* in the Estonian lakes (Mäemets, Mäemets 1967), data on the occurrence of the *Najas marina* and *Myriophyllum alterniflorum* (Mäemets 1969e, 1970) have been published, a critical survey of the Estonian potamogetons compiled (Mäemets), etc.

The total number of species found in the macroflora of the Estonian lakes is 120, which is obviously rather close to the maximum number.

The floristic stage in the investigation of the macroflora of Estonian lakes is now superseded. The further studies should make use of the abundant chemical and floristic data on Estonian lakes, compile the ecological descriptions of the macrophytes of the Estonian lakes, analyze the structure of plant associations, productivity, distribution and genesis. Investigations of such kind have been initiated at the Võrtsjärv Limnological Station (Aime Mäemets). Results of the studies will be published in Part II of the monograph "Estonian Lakes".

MICROBIOLOGICAL STUDIES

The first microbiological works in Estonia were carried out on L. Ülemiste (Schneider 1908). Except for some single sanitary analyses, general microbiological studies of Estonian water bodies were absent till 1960's.

In 1962 Aime Mäemets extracted the first samples to ascertain the general amount of bacteria and the number of saprophytic bacteria in a score of lakes representing almost all Estonian lake types. L. Peipsi-Pskov was one of them and the corresponding survey of it was published (Mäemets 1966b). The investigation proved that in 1962 the number of bacteria in the northern part of the lake, so called Peipsi was on the average 1.4 million cells and 2.4 million cells in the southern parts (Lämmijärv and Pihkva). Thus L. Peipsi may be considered as a mesotrophic water body while the southern parts of the lake are eutrophic. The northern part of L. Peipsi-Pskov was especially poor in saprophytic bacteria (not over 15 cells in 1 ml of water). Even the corresponding indices of the most oligotrophic Estonian lake — L. Valgjärv at Nohipalu — are higher than the above mentioned numbers.

Since 1963 S. Lokk has been carrying out seasonal studies of the microbiology of the water and mud in Võrtsjärv and published several articles on the subject (Lokk 1966, 1970). S. Lokk's articles provide us a survey of the seasonal dynamics of the general amount of the bacterioplankton and some physiological groups in different biotopes and parts of the lake. The regularities of the distribution of bacteria in bottom deposits are also observed.

In L. Võrtsjärv the number of bacteria was 0.9—9.9 million per 1 ml

in the open water in 1963—1965, 2.2—8.5 million per 1 ml in the littoral — which is rather high.

In the bottom deposits of the open part of the lake 0.6—35 milliard, in the littoral 2.0—39.1 milliard bacteria per 1 g of raw mud were found in 1965. In the mud at the depth of 110—115 cm the amount of bacteria was 55% of that in the 0.1—10 cm layer.

At present microbiological work on L. Võrtsjärv is carried on as a part of the International Biological Programme (IBP).

In course of the further microbiological investigations it is necessary to study the other Estonian lake types as comprehensively as it has been done on the eutrophic lake Võrtsjärv. Further studies in the field of the production of bacteria are also necessary.

ALGOLOGICAL STUDIES

Although some floristic notes on the Estonian algoflora can be found in J. Fischer's works published at the end of the 18th century (1778, 1791), the first reliable algological investigations were still carried out only at the beginning of the 20th century.

Only N. Samsonov's (1906) survey of the algoflora in L. Saadjärv (57 species found), K. M. Levander's works on the phytoplankton of lakes Ülemiste and Võrtsjärv (Schneider 1908; M. zur Mühlen, Schneider 1920) (the occurrence of 87 species is observed and as a new species *Anabaena Levanderi* is described in the former while the latter determines 37 taxons) and A. Audova's (1923) investigation which is dedicated to the plankton of L. Pühajärv deserve special attention.

Various algological material can also be found in smaller works by A. Vaga, J. Käis, E. Lepik, H. Riikoja and other authors. Later on the compilation of regional surveys of certain districts or groups of the algae was initiated. So A. Skuja (1930) published a rather profound survey of the algoflora of the big West Estonian islands — Saaremaa and Hiiumaa — where 580 taxons were found, 14 of them being new for science. In 1928 an extensive treatise on Estonian protozoans was published by I. Jacobson. Several flagellates are also treated.

Since 1931 K. Mölder's name exists among the authors studying the Estonian algoflora. He is the author of the surveys of the phytoplankton in the River Emajõgi (1931) and L. Veisjärv (1932). He states the occurrence of 97 taxons in the Emajõgi and 191 taxons in L. Veisjärv. Since 1938 K. Mölder began to publish comprehensive reviews of the groups of the algae. These reviews were the first generalizations on

the treated groups of algae in Estonia. Here we could mention a survey of the Estonian diatoms (Mölder 1938) where data on 481 taxons can be found. It was followed by a treatise on the flora of the Estonian flagellates and dinoflagellates (Mölder 1943) which contains 213 taxons and includes a new species *Euglena estonica* found in L. Viljandi and described in the treatise. In 1944 a paper on the Estonian green algae (Mölder 1944) providing data on the place of occurrence of 400 taxons was published. It was followed by a review of the Estonian blue-green algae (Mölder 1944a). As one of the last papers of the series K. Mölder's treatise "Geographische Verbreitung der Algen in Estland nebst einem Verzeichnis der Konjugaten" appeared (1946). The paper gives a survey of the Estonian algological investigations and the distribution of the algae in Estonia. An attempt is made to associate the occurrence of the algae with the water pH. It also contains a list of the Estonian desmids where 375 taxons are enumerated.

Of the other authors R. Vinkel's name should be mentioned. His work "On the Plankton and Littoral Fauna of Lake Külajärv at Vellavere" (1934) gives a survey of the phytoplankton of the lake and states the occurrence of 93 taxons.

During the Soviet period phytoplanktological investigations have been carried out on more than 300 Estonian lakes and several hundreds of small and stream water bodies. The work carried out has mainly been of floristic-ecological character. N. Voronikhin's article (Voronikhin 1950) on the phytoplankton of L. Peipsi-Pskov (114 taxons found) and H. Riikoja's article (1953) on L. Jussi Suurjärv (110 taxons in the list of the algae) were the first to appear. Afterwards K. Pork compiled the key of the Estonian fresh water Chroococceae (Pork 1955) which also contained some data on the ecology and distribution of the species. K. Pork's next work (1958) gives a survey of the summer phytoplankton in 36 South-East Estonian lakes and offers an original system for the division of lakes according to the dominant species of the algae. M. and K. Pork's (1958) work analyzes the seasonal dynamics of the phytoplankton and epiphyton of four eutrophic South-East Estonian lakes. They were followed by the works on the diatoms of L. Endla (Pork 1958a), on some green algae of Estonia (Kukk 1958c), on the distribution of the *Tabellaria binalis* in Estonia (Pork 1958b) and the distribution *Anabaena Sedovii* (Kukk 1961), a list of the diatoms in the Estonian lakes (Pork 1961), regional division of Estonia on the basis of the diatoms (Pork 1962), etc.

During the last decade several voluminous candidate's dissertations dedicated to the phytoplankton of inland waters have been defended and many articles based on the same material published. E. Kukk defended his dissertation dedicated to the Estonian blue-green algae in 1961. He found 376 taxons in the 373 investigated water bodies. Of these taxons

four were so far unknown for science (the *Calothrix estonica* and 3 forms), 12 for the Soviet Union and 100 for Estonia. The author elucidated several interesting problems concerning systematics (Kukk 1958, 1958a, 1958b), and proved (Kukk 1958), for instance, that the *Oscillatoria lacustris* (Kleb.) Geis. so far described as an independent species, is but a sporohormogones of some species of the *Gloeotrichia* genus, etc. E. Kukk has taken special interest in the blue-green algae which cause the water-bloom (Kukk 1965, 1965a). He has analyzed the geographical distribution of the blue-green algae (Kukk 1969), phylogenesis (Kukk, Hollerbach 1964), etc. At present, the author is completing his doctoral dissertation on the distribution of the arctic and alpine blue-green algae in the European part of the Soviet Union and Central Asia.

In 1965. V. Kõvask defended her dissertation on the flora of the Estonian desmids. The work was based on the material of 450 water bodies, 270 of them being lakes. 605 taxons were identified, of which 231 were new for Estonia (Kõvask 1961, 1965a, etc.). The same author has published several reviews of the associations between desmids and the water pH, content of inorganic matter and humic matter content (Kõvask 1962, 1963). V. Kõvask proved close relations between the desmids and hydrobiological lake types (Kõvask 1969). Often several lake groups distinguished according to the occurrence of the desmids correspond to one lake type (see Table 1).

Table 1

1. Oligotrophic Lakes

1. 1. *Staurodesmus — Staurastrum* lakes (3%) *
1. 2. Lakes with filamentous desmids (5%)
1. 3. Lakes with raised bog desmids (9%)

2. Semidystrophic Lakes

2. 1. *Micrasterias* lakes (8%)

3. Dystrophic Lakes

3. 1. *Staurastrum aciculiferum* lakes (5%)
3. 2. *Closterium* lakes (6%)

4. Eutrophic Lakes

4. 1. *Staurastrum furcigerum* lakes (9%)
4. 2. *Staurastrum smithii* var. *verrucosum — Cosmarium depressum* var. *planctonicum* lakes (22%)
4. 3. Lakes whose pelagic zone is poor in desmids (9%)

* Percentage of the investigated lakes.

5. Dyseutrophic Lakes

5. 1. Lakes with the mixed type of desmids flora (17%)

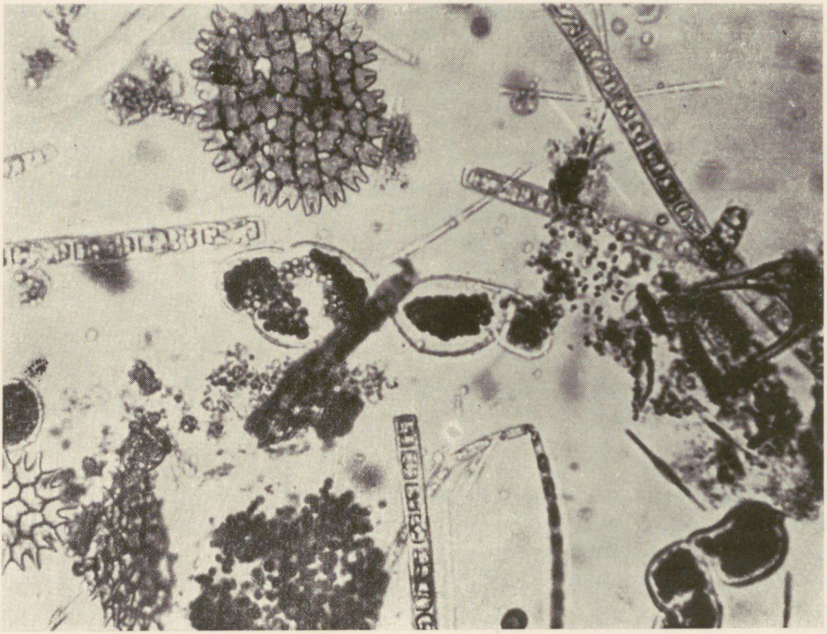
6. Halotrophic Lakes

6. 1. *Euastrum insulare* — *Staurastrum alternans* lakes (7%)

V. Kõvask has also treated the water-bloom in the Estonian lakes.

In 1967 M. Pork's candidate's dissertation on the diatoms of the Estonian lakes was defended. The work was based on the material of 159 lakes. 706 taxons of diatoms of which 214 were new for Estonia and at least 31 new for the Soviet Union were found. In addition 11 diatoms forms which are probably new for science, were also found. In her dissertation and other works M. Pork has demonstrated close relations between the diatoms and hydrochemical factors, especially the water pH.

Phytoplankton of the eutrophic lake of Aheru.



According to the composition of the coenoses of the diatoms and the indices of phytoplankton M. Pork divided the Estonian lakes into six groups and 15 subgroups which are in rather good correspondence with the hydrobiological lake types (see Table 2).

Table 2

1. Oligotrophic and Dystrophic Lakes

1. 1. *Tabellaria binalis* lakes (11%)
1. 2. *Eunotia exigua* lakes (5.5%)
1. 3. *Tabellaria flocculosa—Eunotia pectinalis* lakes (3.7%)

2. South-East Estonian Mesotrophic Lakes

2. 1. *Cymbella angustata — Anamoeoneis exilis* lakes (4.5%)

3. North-Estonian Mesotrophic and Eutrophic Lakes

3. 1. *Melosira ambigua* lakes (9.2%)

4. Central and South Estonian Mesotrophic and Eutrophic Lakes

4. 1. *Fragilaria-Tabellaria-Asterionella* lakes (14.5%)
4. 2. *Melosira islandica* subsp. *helvetica* lakes (only the Lake Peipsi-Pskov)
4. 3. *Melosira granulata* lakes (12.8%)
4. 4. *Melosira granulata* lakes poor in phytoplankton (8.3%)

5. Dyseutrophic and Eutrophic Lakes in Western Estonia and on Islands

5. 1. *Anomoeonis exilis* lakes (16.5%)

6. Halotrophic Lakes

6. 1. *Mastogloia smithii* var. *lacustris* lakes (6.4%)
6. 2. *Cymbella pusilla — Campylodiscus clypeus* lakes (5.5%)

As M. Pork demonstrates we can divide the Estonian territory on the basis of the diatoms into 7 regions which correspond to the Estonian lake types and partly to the earlier phytogeographical, geobotanical and zooplanktological divisions.

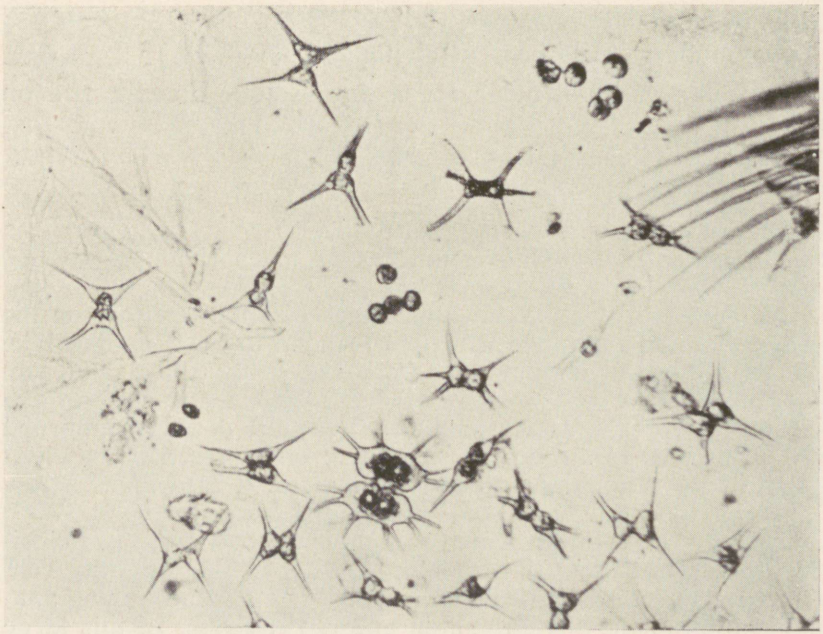
M. Pork and V. Kõvask are the authors of a part of the monograph "Eesti Järved". The part treats the phytoplankton and presents a qualitative description of the phytoplankton and its indices. It also gives a survey of the microphytobenthos and epiphyton of the lakes.

R. Laugaste's dissertation dedicated to the phytoplankton in L. Peipsi-Pskov (1968) is a voluminous phytoplanktological work. In this work and several articles (Laugaste 1966, 1966a, 1969a, etc.) the author analyzes the composition of the phytoplankton and phytobenthos of this large

lake (757 taxons were found, of which 145 were new or rare for the Estonian algoflora), the vertical and horizontal distribution and the seasonal dynamics of the phytoplankton. The author has applied a new (in Estonia) membrane filter method in the determination of the standing crop of the phytoplankton (Laugaste 1969). The intensity of the photosynthesis was also studied by means of the so-called bottle method. I. Tenson (1967) has studied the flagellates in the Estonian lakes and found 103 taxons of them in the lakes in the surroundings of Räpina (South-East Estonia).

In addition to the works dealing with the algae flora of the lakes problems of the breeding of the algae cultures, their nutrition conditions and biochemical properties have been studied (V. Jaaska, J. Toom, M. Männik, V. Kõvask). So V. Jaaska (1964, 1964a, 1965, 1965a) has studied the dependence of the productivity and chemical composition of

Phytoplankton of the oligotrophic lake of Pikkjärv at Viitna.



The desmid flora, rich in species (113 taxons), is characteristic of the oligotrophic lake Vaskna in the Haanja Uplands (South Estonia).

the species *Chlorococcum botryoides*, *Scenedesmus quadricauda*, *S. acuminatus*, etc. on the nutrition with nitrogen. He has defended his dissertation (Jaaska 1965b) on the same subject. V. Kõvask has created several cultures of the *Scenedesmus* and *Chlorella* for the purpose of the experimental work at the Võrtsjärv Limnological Station.

Cultures of the *Chlorella* and other algae are extensively being studied at the Chair of Systematic Botany and Geobotany of Tartu State

University where J. Toom (1967) and M. Männik (Toom) (1968) have defended their dissertations on the subject.

Investigations carried out so far provide us an exhaustive survey of the composition and coenoses of the phytoplankton of the Estonian lakes, also of the ecology and the distribution of main taxons. Only some less studied groups of the algae need floristic-ecological investigations, especially the filamentous algae and flagellates. The seasonal dynamics and productivity of the phytoplankton in different types of lakes are being studied at the Võrtsjärv Limnological Station (e. g. Kõvask, Laugaste, Pork 1970). At present the Chair of Systematic Botany and Geobotany of Tartu State University (M. Pork) is studying the algae of swamp and lake deposits, especially the diatoms, in order to elucidate the genesis of the flora and lakes. The results of these studies will be summarized in Part II of the "Eesti järved". Possibilities of the active influence on the production of the phytoplankton need further studies.

ZOOPLANKTOLOGICAL STUDIES

K. M. Levander's work on the plankton of the eutrophic lake Ülemiste is the first scientifically important zooplanktological study in Estonia (Schneider 1908). It gives a survey of the composition of the zooplankton in the lake (52 taxons), its seasonal changes and distribution.

N. Samsonov's thorough investigation on the zooplankton of L. Pangodi appeared in the same year (Samsonov 1908) and it treats the composition of the zooplankton (87 taxons) and its seasonal changes. An attempt is made to describe the zooplankton of the lake quantitatively (by the volume method).

K. M. Levander is also the author of the survey of the plankton in L. Võrtsjärv (M. zur Mühlen, Schneider 1920). The survey not only presents a qualitative composition of the plankton (53 taxons) but notes on the seasonal dynamics of the species are also added and a great similarity of the plankton to that of eutrophic lakes, L. Ülemiste included, is proved.

The fourth zooplanktological work, A. Audova's investigation (1923) on the plankton of L. Pühajärv is thus treating a eutrophic lake. A. Audova identified 83 taxons of zooplankters in L. Pühajärv and studied their dynamics. The summer dynamics of the zooplankton is also the subject of H. Riikoja's work (1924) on the zooplankton in lakes Tamula and Vagula. 66 taxons are observed here. H. Riikoja also studied some lakes

and bays on the West-Estonian coast and described there two new species of the *Rotatoria*: *Macrochaetus estonicus* (Riikoja 1925) and *Lecane matsaluensis* (Riikoja 1933). R. Vinkel's (1934) survey of the zooplankton in L. Külajärv at Vellavere and J. Lepiksaar's (1932) survey of the Estonian *Cladocera* based on a rather voluminous material extracted from the lakes are to be mentioned of the studies carried out in bourgeois Estonia.

The early investigations of the zooplankton in the Estonian lakes were rather one-sided (eutrophic lakes were mostly studied). Large-scale zooplanktological research was initiated after World War II. Its aim was to determine the qualitative and quantitative composition of the zooplankton and the regularities of the seasonal dynamics in all Estonian lake-types. Since 1951 415 lakes have been subjected to zooplanktological investigations (more than $^1/_3$ of all Estonian lakes).

The composition and seasonal dynamics of the zooplankton in L. Võrtsjärv were studied by N. Schönberg in 1952—1954. N. Schönberg stated the occurrence of 63 species and was the first to give a survey

The dystrophic lake Mustjärv at Nohipalu (South-Estonia). Rare zooplankters, e.g. *Alona karelica*, *A. rustica*, *Scapholeberis microcephala*, etc. occur here.

of the seasonal dynamics of the population density and the biomass of the zooplankton in L. Võrtsjärv (Schönberg 1958). N. Schönberg (1961) has published a work on the biology of some pelagic *Copepoda* (*Eudiaptomus gracilis*, *Cyclops kolensis*, *Mesocyclops leuckarti*, *M. oithonoides*), especially on the period of occurrence, sex relations, number of generations, etc. Rich material on the zooplankton of lakes is to be found in Aare Mäemets' candidate's dissertation "Water-fleas (*Cladocera*) of the Estonian S.S.R." (Mäemets 1961b) and several articles on the zooplankton. The above mentioned faunistic-ecological study was based on the results of investigations on 521 water bodies including 292 lakes and it gives a survey of the species composition, species systematics, ecology and distribution. A. Mäemets (1958) has published a survey of the composition of the crustacean fauna in the summer zooplankton of 134 Estonian lakes. He distinguishes between 6 characteristic pelagic complexes and demonstrates the regularities of their distribution and relations with ecological conditions. The system of the complexes was further developed in the next work (Mäemets 1958c) where 13 complexes of the zooplankton were distinguished. In the same year (Mäemets 1958a) a survey of the Estonian water-fleas fauna and the ecology of the species was given. A new water-flea species *Alona estonica* was described (Mäemets 1958b) on the basis of the female specimens extracted from dystrophic lakes and hollow-pools. Afterwards male specimens of the same species were found and described by L. Meelva. A possibility of their being identical to the *A. rustica* so far found on the Britisch Isles only was hinted at (Mäemets 1960). D. G. Frey (1965) and D. Flössner (1967) have proved that they are identical. A. Mäemets (1961) is also the author of the work on the ecology and phenology of the Estonian *Cladocera*. He has stressed the close relations between several lake and bog forms of this group and the biotopes, pH, concentration of electrolytes, organic matter and nutrients content, lake type and temperature. A review (Mäemets 1962) of the regularities of the geographical distribution of the Estonian *Cladocera* (136 taxons have been found so far, of them 83 species), proves that northern elements, i. e. elements of the taiga zone are characteristic of oligotrophic and dystrophic lakes while southern elements, i. e. those of the mixed forest zone are characteristic of eutrophic lakes. It obviously corresponds to the regularities of the geographical distribution of the lakes of the corresponding types. In the same work a division of the Estonian territory into 4 regions on the basis of the fauna elements of water-fleas and pelagic complexes is given.

A. Mäemets (1965, 1969 etc.) has made an attempt to find connections between the zooplankton complexes of the lakes and the Estonian lake types (see Table 3).

Table 3

1. Oligotrophic Type

1. 1. *Holopedium-Daphnia-Ophryoxus*-complex
1. 2. *Holopedium-Daphnia cucullata-Bosmina coregoni*-complex
1. 3. *Limnosida-Daphnia longispina*-complex
1. 4. *Daphnia cristata-Bosmina longispina*-complex

2. Semidystrophic Type

2. 1. *Holopedium-Daphnia-Ophyoxus*-complex

3. Dystrophic Type

3. 1. *Holopedium*-complex
3. 2. *Holopedium-Daphnia longispina*-complex

4. Eutrophic Type

4. 1. *Cyclops scutifer-Daphnia cucullata-Bosmina coregoni*-complex
4. 2. *Heterocope appendiculata-Daphnia cucullata*-complex
4. 3. *Daphnia cucullata-Bosmina coregoni-Chydorus sphaericus*-complex

5. Alkalitrophic Type

5. 1. *Heterocope-Bosmina obtusirostris*-complex
5. 2. *Hemidiaptomus-Mixodiaptomus*-complex

6. Dyseutrophic Type

6. 1. *Heterocope appendiculata-Daphnia galeata*-complex
6. 2. *Daphnia longispina*-complex
6. 3. *Daphnia cucullata*-complex
6. 4. Littoral species complex

7. Halotrophic Type

7. 1. *Eurytemora velox*-complex

Data on the ecology and distribution of the *Copepoda* in the Estonian lakes can be found in Aare Mäemets' and I. Veldre's (Mäemets, Veldre 1956, Veldre, Mäemets 1956) key of the Estonian *Copepoda* (in two parts), in one article by I. Veldre (1957) and A. Mäemets' work treating the Estonian fresh-water *Calanoida* (Mäemets 1959). The latter states also the distribution of two vicarious species, *Eudiaptomus gracilis* and *E. graciloides*, in the Estonian lakes. I. Veldre has treated the Estonian *Harpacticoida* (1961).

In 1966 A. Mäemets' work on the qualitative and quantitative com-

L. Lemküla. An alkalitrophic temporary lake, extraordinarily rich in the species of the fauna of calanoids (*Hemidiaptomus amblyodon, Mixodiaptomus theeli, Eudiaptomus vulgaris, E. graciloides, Heterocope saliens*).

position and horizontal distribution of the summer zooplankton of L. Peipsi-Pskov was published (Mäemets 1966). 84 taxons of zooplankton, of them 9 subspecies of the *Bosmina coregoni*, and other forms were recorded. It was proved that Peipsi-Pskov is a water body rich in zooplankton while, contrary to some earlier data, the richest part both as regards the number and biomass is the southern part, the so-called Lake Pskov.

A collection of writings "Eesti järved" compiled by Aare Mäemets presents the zooplanktological characterization of 150 Estonian lakes. It contains an estimation of the general quantity of zooplankton (on the basis of data on 61 lakes) and distinguishes dominating groups and species, ecologically characteristic indicators and faunistically rare species.

Two interesting works have been published by A. Lumberg (1960) and K. Ruse (1969). They treat of the qualitative and quantitative composition of the zooplankton in the Emajõgi flood-plain lakes. The same authors have also published a survey of the Rotatoria in the Emajõgi and its flood-plain lakes (Lumberg, Ruse 1962).

Since 1965 J. Haberman has been studying zooplankton in lakes Võrtsjärv and Peipsi-Pskov. She and A. Mäemets have published a work (J. Haberman, Mäemets 1968) on the seasonal dynamics of the zooplankton in Võrtsjärv. J. Haberman and R. Laugaste (1970) are the authors of an article on the mutual relations of the phytoplankton and zooplankton in Peipsi-Pskov. J. Haberman has written an article (Haberman 1971) on the seasonal changes of the zooplankton in L. Peipsi-Pskov.

In course of these investigations a new species of the *Ploesoma* was discovered in the lake. She has also elucidated some possibilities of the application of electronic computers in the computation of the results of the quantative analysis of zooplankton.

To clear up some problems of the genesis of the zooplankton of lakes Aare Mäemets has in 1960—1970 made several attempts to introduce zooplankton into seven Estonian lakes with relatively young unsaturated fauna. The introduction of the *Daphnia cucullata* into the dyseutrophic lake Veskijärv was a success (Mäemets 1969a). This lake isolated itself from the sea during the second half of the Litorina stage. The success of the experiment proved that the absence of the above-mentioned species in L. Veskijärv was due to the historical, not ecological reasons, and that the zooplankton of young lakes may be unsaturated even as regards the *Cladocera*, a fauna group having a great ability of passive spread.

Possibilities of the artificial cultivation of zooplankters have under the guidance of Aare Mäemets also been studied at the Võrtsjärv Limnological Station. The best results in outer conditions were achieved with the *Daphnia magna* population taken from L. Porkuni (Mäemets 1969b). The population proved to be the most resistant (it survived under the temperature rise from 0.5° to 31°) and fertile (the highest fecundity being 41 ova in November under the ice-cover). The experiments with the *D. magna* demonstrated that the scanty occurrence of the species in Estonia and elsewhere on the northern regions is caused first of all by the conditions of obtaining food and not temperature conditions. The great variability of the nutritive value of the *D. magna* and its dependence on conditions of obtaining food also appeared.

As a result of the investigations carried out so far there is a sufficient survey of the composition and ecology of the species, complexes of the zooplankton (*Cladocera*, *Copepoda*, *Rotatoria*) of the Estonian lakes and their distribution. We also have a survey of the seasonal dynamics of

zooplankton in eutrophic lakes. Further investigations are necessary on the dynamics of zooplankton in other lake types, also on the regularities of the productivity of zooplankton and its dependence on the lake type. Work in this direction is in progress in the Võrtsjärv Limnological Station (Aare Mäemets, J. Haberman). Only the *Protozoa* fauna of the Estonian lakes has been studied to a small extent.

The coenoses of the *Cladocera* in swamp and lake deposits are also studied.

Due to the mosaic character of the Estonian territory (which is the result of the glacial epoch and changes in the sea-level) and typological diversity of the lakes there are favourable conditons in Estonia to study the systematics and evolution of the genera of zooplankters which are obviously in the process of the formation of species at present (*Bosmina*, *Cyclops*, *Bythotrephes*, etc.).

The results of these studies will be presented in the collection of writings "Estonian Lakes" II.

INVESTIGATIONS OF THE ZOOBENTHOS

Various faunistic materials of the zoobenthos of the Estonian lakes can be found in M. Grube's, M. Brauns's, G. Flor's and other authors' works as early as the middle of the 19th century.

Data on the composition of the bottom fauna of lakes are to be found in G. Schneider's (1908) monograph on L. Ülemiste, also in G. Schneider's and M. zur Mühlen's (1920) monograph on L. Võrtsjärv. 113 taxons of the bottom fauna are said to be in the former and 236 in the latter one.

Harald Haberman in his investigation (1935) treating the bottom and coastal fauna of L. Pühajärv analyzes the bottom fauna (86 taxons were found) in biotopes. This work and also that on L. Külajärv in Vellavere (Haberman 1937) are of a new quality. The latter deals with the regularities of the vertical distribution of the animals while quantitative data on the zoobenthos are also given. H. Haberman has also studied the bottom fauna of lakes Tamula, Vagula, Klooga, Pikkjärv at Viitna, etc. Various, first of all faunistic data and data on the distribution, can be found in some faunistic articles by P. Lakschewitz, A. Jüris, H. Mühlberg-Kauri, L. Sepp, C. Krausp, A. Schlesch, L. Černosvitov, S. Hrabe, N. Mikelsaar and other authors. T. Joffe published a profound investigation on the zoobenthos of the eastern part of Peipsi-Pskov (Joffe 1939) and developed it in his next work (Joffe 1948).

The eutrophic lake Lahepera. A feeding region of the young fish of L. Peipsi.

Some data on the population density of the zoobenthos in 41 Estonian lakes can be found in H. Riikoja's work on the hydrochemistry of the Estonian lakes (Riikoja 1940a). H. Riikoja (1940b) has also treated the phenomenon of anabiosis with the *Corethra* (= *Chaobarus*) larvae in the Orava lakes. Anabiosis is caused by the absence of oxygen.

After World War II, in 1951 systematic investigations of the zoo-

benthos of the Estonian lakes was initiated. It was mainly done as a part of the lake investigation expeditions carried out by the Institute of Zoology and Botany. In 1951 the Chair of Zoology of Tartu State University, under the guidance of Prof. H. Riikoja, initiated investigations of the benthos of L. Võrtsjärv. The major part of the results of the studies on the zoobenthos of Võrtsjärv and other Estonian lakes has been summarized and published by Õ. Tõlp who has specialized in the studies of the *Chironomidae* larvae and defended her candidate's dissertation on the *Chironomidae* of the River Emajõgi in 1958. In the same year Õ. Tõlp published a survey of the *Chironomidae* fauna of Võrtsjärv (Tõlp 1958) where she demonstrated that the *Chironomidae* form 50—55% of the bottom fauna of the lake and identified 51 larvae forms. The evaluation of the population density and biomasses for different kinds of deposits and different parts of the lake are given. During the following years. Õ. Tõlp (1959) has analyzed the distribution of the *Chironomidae* larvae (62 larvae forms) in different parts of the lake, different biotopes and depths both qualitatively and quantitatively (at the same time K. Elberg (1959) gave a survey of the fauna of the adults of the *Chironomidae* in the surroudings of Võrtsjärv). Õ. Tõlp (1969) has added a survey of the seasonal dynamics of the *Chironomidae* larvae of Võrtsjärv to the above mentioned works. All existing data on the *Chironomidae* fauna of Estonia and its neighbouring countries have been summarized in Õ. Tõlp's another work published in 1959 (Tõlp 1959a) where the occurrence of 95 larvae forms in the Estonian waters is stated on the basis of the materials about 140 lakes. Õ. Tõlp (1965) has compiled a short summary of the complexes of the *Chironomidae* larvae of the Estonian lakes and their occurrence in the food of bream in 20 investigated lakes. Õ. Tõlp has summarized the materials on zoobenthos gathered by the lake investigation expeditions which were organized by the Institute of Zoology and Botany. So a work based on the materials about 100 lakes was published (Tõlp 1962). It provides a picture of the population density and biomass of zoobenthos in the Estonian lakes and is based on quantitative analysis. It appears that in about 25% of the investigated lakes biomass is high (on the average over 10 g/m^2). Taking the population density as a criterion the Estonian lakes belong to the *Chironomidae*-lakes while on the basis of biomasses they belong to a mixed type (*Mollusca-Chironomidae* or *Varia-Chironomidae*).

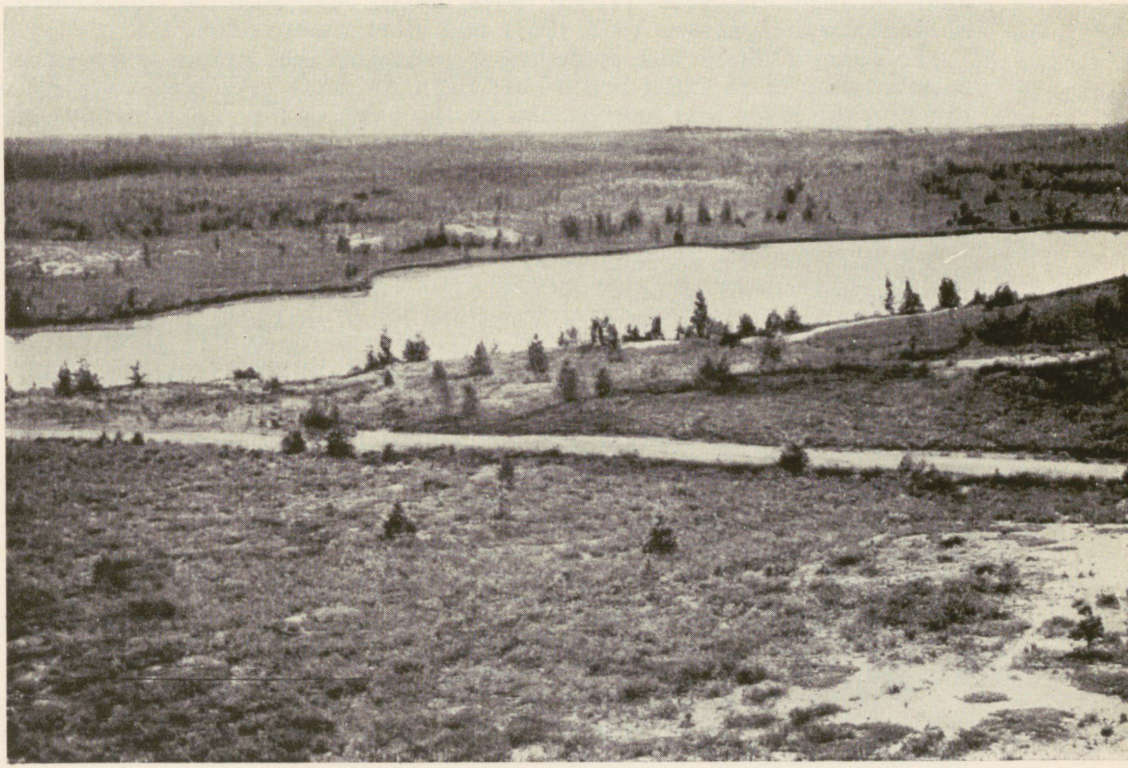
A voluminous work, compilation of the parts dedicated to the bottom fauna for the collection of writings "Estonian Lakes", was done by Õ. Tõlp. In the case of each observed lake the population density and biomass, dominating groups and more important *Chironomidae* forms are given.

Õ. Tõlp (1966a) has also compiled a survey of the composition of

the summer bottom fauna in L. Peipsi-Pskov, its number and standing crop in different parts of the lake. She is the author of a survey (Tõlp 1969a) of the formation and composition of the bottom fauna in the Narva storage reservoir.

Another outstanding benthos investigator in Estonia is T. Timm who in 1964 defended his candidate's dissertation on the Estonian *Oligochaeta*. The dissertation was a faunistic-ecological work based on materials about more than 400 Estonian water bodies, 54% of them being lakes. In addition to the systematic treatment and investory of the fauna (76 species

The oligotrophic lake Martiska at Kurtna (North-East Estonia). *Lobelia Dortmanna* and *Tabellaria binalis* occur here.



were found) a profound survey of the ecology of the species (with many ecological spectra) was given, life cycles of species, first of all those of the lake forms, elucidated and the genesis of the Estonian *Oligochaeta* fauna analyzed. T. Timm has published several articles on the Estonian *Oligochaeta* fauna. So there is a faunistic-ecological summary of the Estonian *Oligochaeta* collected in 1954—1960 (Timm 1962) and a summary of the *Oligochaeta* of the Estonian lakes (Timm 1962a). In the latter problems of the distribution of the *Oligochaeta* in connection with the depth, bottom deposits and flora are under observation, and lakes are divided into four groups on the basis of the *Oligochaeta* fauna: 1) eutrophic lakes (their characteristic species being *Ilyodrilus hammoniensis*), 2) young relict (halotrophic) lakes (the characteristic species being *Psammoryctes barbatus*), 3) dystrophic lakes (the characteristic species being *Lumbriculus variegatus*), 4) *Lobelia*-lakes (the characteristic species being *Stylodrilus heringianus*). T. Timm has published several works on the *Oligochaeta* faunistics (Timm 1959, 1960, 1962b, 1970), analyzed their life cycles (Timm 1964a, 1965), dealt with the *Oligochaeta* of stream waters (Timm 1963, 1967) and other water bodies.

T. Timm (1965a) has published a survey of the composition of the bottom fauna of 35 small South-East Estonian lakes (142 taxons stated), dividing the lakes into four groups on the basis of the concentrations of electrolytes and organic substances and demonstrating relations between zoobenthos and these groups.

T. Timm and V. Timm (1968, 1969) have together published some works of the bottom fauna of the Paunküla storage reservoir.

A work on the zoobenthos of Peipsi-Pskov have been published by B. Strugach (1966), a study on the composition and distribution of the bottom fauna of the littoral of Võrtsjärv by J. Ristkok and K. Ruse (1962). The latter states the occurrence of 250 taxons. As regards the frequency of occurrence the *Chironomidae* occupy the first place, the *Oligochaeta* and *Pisidium* follow.

Various data concerning the zoobenthos of the Estonian lakes can be found in several studies dedicated to separate groups of the bottom fauna. So I. Lissenko (1958, 1962) has published materials on the Estonian *Hydracarina*, V. Timm (1969) has treated the *Mollusca* of Võrtsjärv, I. Maasik (1966) the *Heleidae* of Võrtsjärv, H. Remm the Estonian *Chaborinae* (1955), *Odonata* (1957) and *Heleidae* (1958, 1959), E. Remm (1963) the larvae of *Odonata*, H. Haberman (1953) and E. Remm (1966, 1970) the *Ephemeroptera*, A. Järvekülg (1959, 1960) the *Ostracoda*, H. Krall (1959 etc.) the *Nematoda* etc.

Õ. Tõlp, T. and V. Timm have dealt with problems of the artificial cultivation of bottom animals. The former of them has elucidated some possibilities of the cultivation of the *Chironomidae*, T. Timm has elabo-

rated several cultivation methods for the *Oligochaeta*, especially for the *Tubificidae* (T. Timm 1966, 1967a) while V. Timm has cultivated artificially the *Asellus aquaticus* (V. Timm 1969).

In the course of further investigations of zoobenthos it is necessary to study the structure of coenoses, biocoenotic relations and productivity, also the relations between biocoenoses and lake types. In connection with the compilation of Part II of the "Eesti järved" such work is in progress at the Võrtsjärv Limnological Station (Õ. Tõlp, T. Timm). It is also necessary to continue work on the identification of the *Chironomidae* larvae and adults, carry on studies on the systematics and ecology of several groups of benthos (e. g. the *Mollusca*), ascertain the role of microbenthos in the coenoses of the benthos, etc. It would be desirable to continue (so far unsuccessful) attempts to introduce the *Mysidae* of the Ponto-Caspian basin into the Estonian lakes.

RESEARCHES OF THE CRAYFISH

The early research data on the Estonian crayfish (*Astacus fluviatilis*) can be found in smaller works and manuscripts by M. zur Mühlen, C. Happich, E. Reinwaldt, A. Määr and other investigators and date back as late as the end of the 19th century and the 1st half of the 20th century. As the data prove the Estonian inland waters were even at the beginning of the 20th century exceptionally rich in the crayfish. In L. Kuremaa (whose area at that time was about 405 ha) 430 000 crayfish with the total weight of 17 tons were caught for export in 1907 (M. zur Mühlen 1909, Järvekülg 1963). But the crayfish pestilence which began to spread in the River Emajõgi at Tartu and in Lake Tamula near Võru has devastated the Estonian crayfish reserves considerably. The pollution of waters, sinking of the water level of lakes, excessive catch and other factors have also had a devastating effect on the Estonian crayfish stock. They have steadily decreased to such a degree that in 1968 it was inevitable to impose a complete prohibition on the crayfish catch.

Since 1952 A. Järvekülg has thoroughly been studying the biology and possibilities of the restoration of the reserves of the Estonian crayfish. In addition to numerous articles (Järvekülg 1957, 1957a, 1958, etc.) he has published a monograph "Crayfish in Estonia" in 1958 and defended his candidate's dissertation on the same subject (1957b).

A. Järvekülg's works were based on the analysis of almost 8000 crayfish caught from more than 300 water bodies. The author clarified the

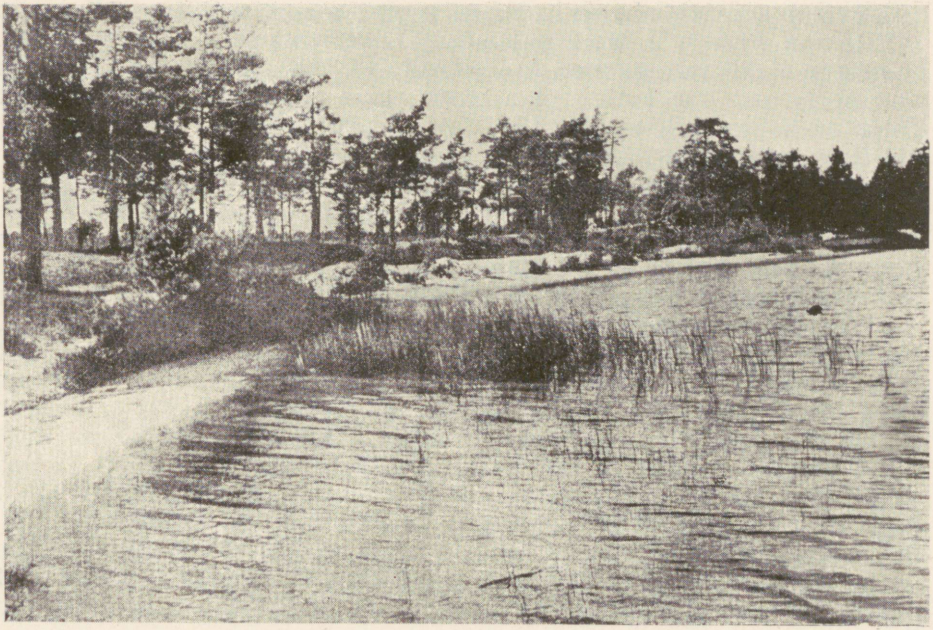
relations of the crayfish to the biotope, its growth rate, food, diseases, parasites and other questions. According to A. Järvekülg about 50% of the Estonian lakes and 90% of rivers are suitable for the crayfish to live in. Unsuitable are muddy meres, lakes rich in humic substances and coastal lakes. The richest area in crayfish is the Peipsi-Pskov-Võrtsjärv basin. It appears that the Estonian crayfish is very fertile (the average fecundity being 182 eggs) and has a high growth rate in South Estonia. Of diseases the crayfish pestilence is spread all over Estonia (except for Saaremaa) while "spot disease" can be observed in about $^3/_4$ of water bodies. The "spot disease" in Estonia is caused by the fungus *Septocylindrium eriocheir*. Of crayfish parasites there are the *Branchiobdella pentodonta*, *B. parasita* and *B. astaci*. The *B. pentodonta* and *B. parasita* are vicarious species. The author offers (Järvekülg 1958a, 1963, 1969, Estonian Lakes, 1968) measures for the restoration of the Estonian crayfish reserves.

INVESTIGATIONS OF THE FISH FAUNA AND FISHERY

Already at the end of the 18th century Hupel and Fischer have published some data on the distribution of the Estonian fish and fishery. In 1860 the first volume of K. E. Baer's and N. Danilevski's work "Investigations of the State of Fishery in Russia" (Baer, Danilevski 1860) summarizing the results of the investigations on fishery on lakes Peipsi-Pskov and the Baltic Sea in 1851—1852, which were organized by the famous scientist K. E. Baer and his companions, was published. These were the first fishery-biological studies concerning the Estonian territory while a considerable decrease of the fish catches in L. Peipsi-Pskov and other water bodies served as an impetus for initiating such investigations. K. E. Baer was the first to pay special attention to the factors upon which the fluctuation of the number of fish in water bodies depends. His idea of the main regularities of the formation of the biological productivity and the fish production of water bodies in high degree coincides with the modern treatment of this problem (Järvekülg 1962).

J. G. Spuhl-Rotalia's "Fishes of the Native Country" published in 1896 can be considered the first summarizing work on the Estonian fish fauna which contains rather many data on the biology of the lake fishes.

At the end of the 19th and at the beginning of the 20th century problems of the ichthyology and fishery of the Estonian lakes were dealt with by M. Braun, M. zur Mühlen, G. Schneider and other authors. Note-



The semidystrophic lake Tänavjärv (North-East Estonia). *Lobelia Dortmanna* and *Bythotrephes cederstroemi* occur here.

worthy for their thoroughness are G. Schneider's works treating the age, the questions of sexual maturity, problems of food and parasites of the fish in L. Ülemiste (Schneider 1908) and L. Võrtsjärv (M. zur Mühlen, Schneider 1920). G. Schneider has published several surveys of the Baltic fish fauna, that of Estonia included (Schneider 1926, 1928, etc.).

During the period between World War I and World War II H. Riikoja (1927) summarized the data concerning the Estonian fish and published a catalogue "Fishes of the Native Country" treating 73 species. The data were supplemented by E. Reinwaldt and H. Riikoja (1931). In general investigations of that period dealt with single questions while thorough studies treating the fish fauna of the lakes in all aspects were absent. At that time studies on the crucian carp (*Carassius carassius*) L. Kahala (Määr 1929), on the fish fauna and *Leucaspius delineatus* of L. Pangodi (R. Voore 1938, 1938a), on the vendace of Peipsi (R. Voore

1939) and several smaller articles in the magazine "Eesti Kalandus" ("Estonian Fishery") were published. E. Reinwaldt (1941) compiled a summary of all introduction experiments of fish into the Estonian lakes and he is also the author of a work about the main principles of the Estonian fishery (Reinwaldt 1943). Main ichthyological investigations of the time were undertaken by the Estonian Fishery Chamber.

During the Soviet period the Institute of Zoology and Botany of the Academy of Sciences of the Estonian S.S.R. became the main research centre in the field of the fish fauna of the lakes and fishing. The same problems are studied by the Chair of Zoology of Tartu State University and the Estonian Laboratory of Marine Ichthyology residing in Tallinn.

The first extensive work "Fishes of the Estonian S.S.R." was published by Prof. H. Riikoja (1950). It gives a survey of 75 species of the fish living in the Estonian waters, 40 of them in lakes. The work contains morphometrical, various biological and ecological data, and data on the distribution of the fishes. In 1955 J. Ristkok defended his dissertation on the growth of the young fishes in the lake group of Saadjärv. The work was published as a monograph (Ristkok 1960). On the basis of more than 20,000 specimens he characterized the growth rate of the young fish of 16 species and its connection with life conditions. At the present time the author is completing his doctoral thesis on the interspecies morphobiological heterogeneity of the Estonian fresh-water fish fauna.

In 1955 V. Erm got the candidate's degree for a voluminous monograph on the Estonian pike-perch. The material (1330 specimens) was gathered from 17 water bodies and problems of the biology, distribution, morphometry and systematics of the pike-perch were clarified. V. Erm even described a new subspecies of the pike-perch in the Bay of Pärnu. According to V. Erm (1961, 1962, 1962a, 1969) the growth-rate of the pike-perch in the Estonian waters depends on the transition time to the predatory way of life, food basis, but also on the temperature of the water and oxygen conditions.

An analogical voluminous candidate's dissertation on the Estonian bream was defended by Henn Haberman in 1964. The work was based on the material of more than 5,000 breams caught from 30 water bodies. The dissertation contains a survey of the reproduction, food, growth, growth rate, morphometry and systematics of the bream in the Estonian lakes and offers several measures for the management of the bream lakes. According to Henn Haberman (1962, 1963, 1963a, 1964) the bream in Estonia becomes sexually mature at the age 5—6 years when its length is 20—30 centimeters. The main food for the grown-up bream are the *Chironomidae* larvae and its main rivals for good are the ruff and the perch. Morphometrical investigations prove that the Estonian bream

differs from all other bream forms described so far and is most similar to the *Abramis brama orientalis* (Haberman 1970).

In general biological problems, especially reproduction biological problems dominate in ichthyological studies. Ervin Pihu's dissertation on the reproduction biology of the fish of Võrtsjärv defended in 1961 serves as an example for it. The work is based on the results of the investigations of about 17,500 fish and gives a survey of the spawning fertility and the development of the reproductive organs of 11 species (pike, ide, roach, bream, perch, silver bream, rudd, bleak, crucian carp, tench, ruff). The author has published many articles on these problems (Pihu 1958, 1959, 1960, 1961a, 1961b, 1962, 1963, etc.). The biology and food relations of the fish in Võrtsjärv have also been studied by Henn Haberman (1963b, 1968, 1968a), M. Kangur (1968a, 1969b, 1969c, etc.), A. Kirsipuu (1969) and others.

M. Kangur is completing his dissertation on the regulation of the reserves, food relations and number of rough fishes (perch, ruff, roach). The same problems on L. Peipsi-Pskov are being studied by Ervin Pihu who has published several works (with A. Shirkova) on the composition of the fish fauna and catches in L. Peipsi-Pskov (Shirkova, Pihu 1966, 1966a), on the dwarf smelt of the lake (Pihu 1966a), on the growth-rate of the Estonian fishes and factors having some influence on it (9 species from 100 lakes studied) (Pihu 1967, 1968). Ervin and Evi Pihu have treated the problems of the feeding rhythm of the fishes of the Estonian inland water bodies (Pihu, Pihu 1967), the growth of the burbot, its feeding questions, reproduction and industrial importance in L. Peipsi-Pskov (Pihu, Pihu 1968), seasonal changes in the feeding of the predatory fishes in Peipsi-Pskov (Pihu, Pihu 1969) and other questions.

Evi Pihu has published a survey of the nutrition of the roach in the Estonian lakes (Pihu 1965), a fishing industrial-biological characterization of the pike, perch, pike-perch and burbot of L. Peipsi-Pskov (Pihu 1966). At present Evi Pihu has completed work on her candidate's dissertation treating the nutrition of predatory fishes in L. Peipsi-Pskov.

Russian authors Petrov (1947), A. Shirkova and A. Yefimova (see Hydrobiological Researches, IV) have also published several articles on the fish fauna of Peipsi-Pskov.

Works on the growth of the perch in Estonian lakes (Pahkla 1958, 1962, 1962a), on the *Vimba* (Erm 1926b, 1966, 1967, 1970), *Carassius carassius gibelio* (Kruusel 1959), *Coregonus peled* (Kruusel 1961, Ristkok 1963), *Alburoides bipunctatus* (Kossatkin 1959), *Cottus gobio* (Kossatkin 1962), and others are also at our disposal.

Of great interest are A. Oissar's works (1964, 1965) on the biology and morphology of the perch and crucian carp in the Estonian humus

Dystrophic lakes of Udriku (North Estonia). *Scapholeberis microcephala* and *Orthoclaaius Naumanni* and other rare species occur here.

lakes. It appeared (Oissar 1964) that the perch of the raised bog lakes has some specific morphological peculiarities (diverged lateral-line etc.).

During the Soviet period V. Erm (1961a) and I. Veldre (1963) have continued the work on the genesis of the Estonian inland water fish fauna initiated by J. Lepiksaar (1938). Henn Haberman (1961a) and V. Erm (1967, 1968, etc.) have carried on the tagging of fish, work initiated by H. Riikoja (1931).

An extensive summary of the fish fauna of the Estonian lakes is a survey of the fish fauna and fishing industry of 150 lakes in the monograph "Eesti järved". Rather thorough data on the composition of the

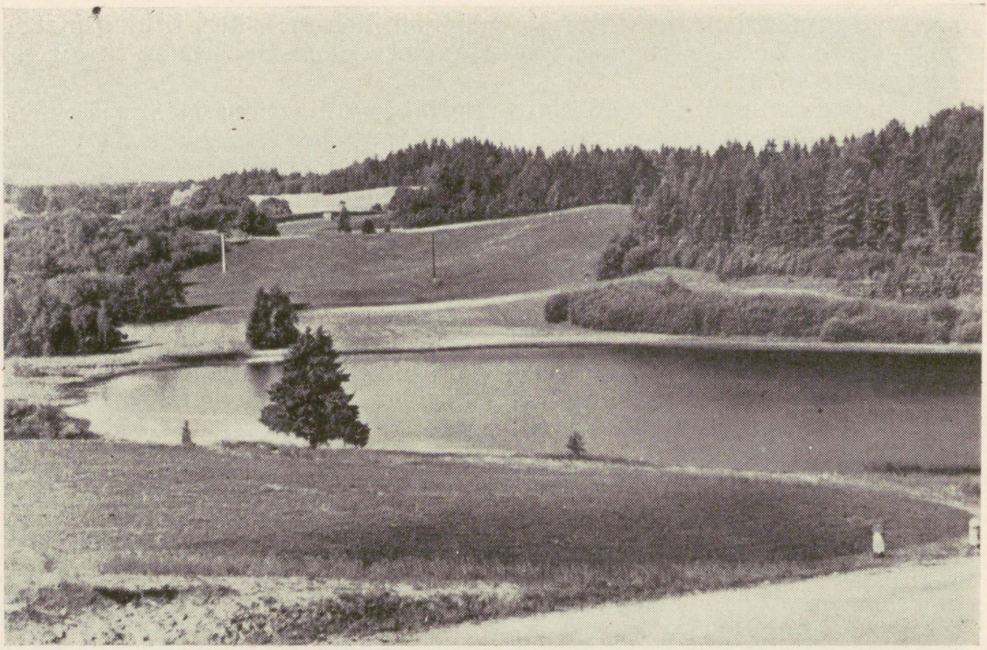
species introductions, growth rate, nutrition, fish parasites, fishing industrial type of the lake, etc. are given (authors Henn Haberman, N. Mikelsaar, Ervin Pihu).

An independent cycle of ichthyological investigations is formed by the work on the blood physiology of the Estonian fishes initiated by I. Veldre in 1952. In 1958 I. Veldre defended his candidate's dissertation on the seasonal changes in the quality of the blood of the roach and perch in Saadjärv and Soitsjärv. He has also published some other works in the same field (Veldre 1958a, 1960).

In 1965 A. Kirsipuu defended his dissertation on the protein fractions of the blood serum of the perch, pike-perch, bream and pike, where he, by the electrophoresis method, analyzes the composition of the blood proteins of different fish species and sexes. According to A. Kirsipuu the protein fractions of the blood serum differ both with fish species and sexes. Seasonal changeability of them was also determined (Kirsipuu 1964, 1964a, 1966, 1967, 1969a, et al.).

The above mentioned physiological work and morphometrical investigations have been joined at the Võrtsjärv Limnological Station and it has resulted in the formation of a research group studying the production biological character of the fish. The group is studying the relations between morphometrical, biological, parasitological, physiological, cytological, biochemical and genetic characters in fish populations (Haberman, Kirsipuu, Tammert 1968; Haberman, Kirsipuu, Laugaste, Tell 1968; Kangur, Haberman 1968, etc.). As a part of these studies Alla Kangur defended her candidate's dissertation in 1969. The subject of the dissertation was a comparative biochemical characterization of some nitrogen fractions of the muscle tissue and ATP-activity of the bream, pike, perch and pike-perch. She has written several articles on the same subject (A. Kangur 1968, 1969). K. Laugaste has completed his dissertation and published some articles (Laugaste 1969b, Laugaste, Kärner 1970) on the seasonal dynamics of the histology of the liver and on the sexual differences of the bream. L. Seppa is working on her dissertation on the sexual differences and seasonal changes in the electrophoretic fractions of the soluble proteins of the liver of the bream. The subject of M. Tammert's dissertation is on the genetic polymorphism of the blood plasma of the fish. Cellular elements of fish blood have been studied by H. Tell (1969).

Investigations of the fishing industry, prerequisites for which have been created by many years of studies on the abiotic and biotic conditions in the lakes, and which to a large extent are based on hydrobiological materials, form an independent research field. N. Mikelsaar has been the most prolific author here (1958, 1962, 1962a, 1963, 1963a, 1964, 1968, etc.). Henn Haberman (1963c, 1963d), J. Ristkok (1969a), etc. follow. Many works have been published on piscicultural questions, such as a

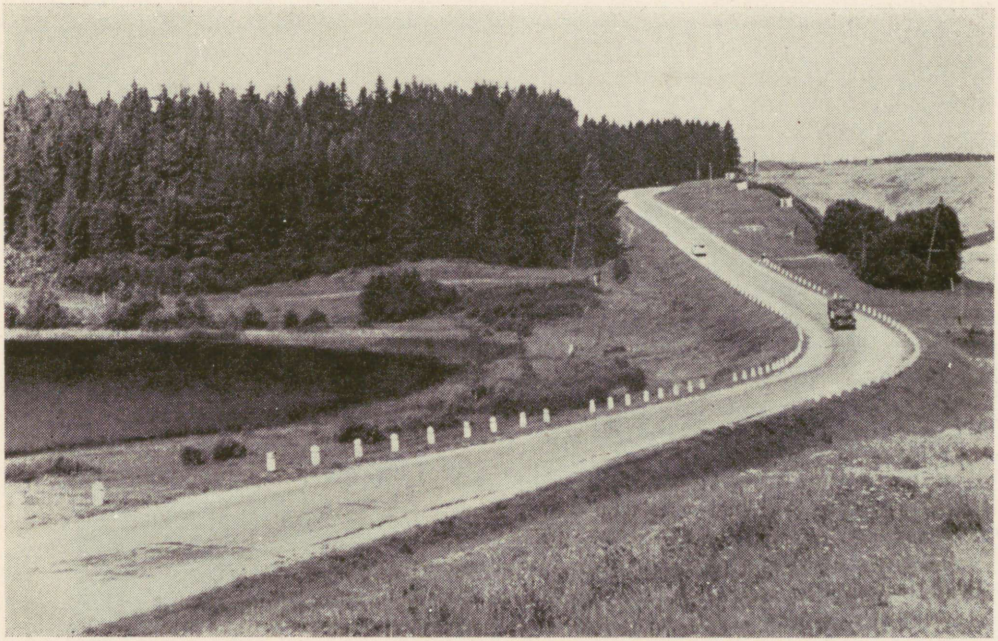


L. Kurnakese. An eutrophic small lake in the

work on the breeding of the *Coregonus peled* (Kruusel 1961), on the breeding of the *Salmo trutta irrideus* (Põder 1960, Post 1969) and others. Many articles of similar kind have been published in the magazine "Abiks Kalurile" ("For Fishermen").

Thanks to Assistant Professor J. Ristkok and the Naturalists' Society a network of ichthyophenological observers has been created in Estonia (about 80 people). Results of their work have partially been published (Ristkok 1958, 1961, 1964, 1969b, 1969c).

Ichtyological investigations at the Võrtsjärv Limnological Station are carried out in two main directions. On the one hand materials on the fish fauna of lakes are being summarized for Part II of the collection of writings "Eesti järved" (E. Pihu, Henn Haberman, N. Mikelsaar, M. Kangur). The characteristic fish coenoses of the lakes are described, the growth rate of the fish and their nutrition relations, etc. characterized. Simultaneously



Otepää Uplands (South Estonia).

production-biological characters of the fish are studied (Henn Haberman's research group) in order to find some fixed points for distinguishing between fish breeds and for the improvement of the breed.

RESEARCHES OF FISH-PARASITOLOGY

The oldest fundamental studies on the Estonian fish parasites are G. Schneider's works on lakes Ülemiste (Schneider 1908) and Võrtsjärv (Schneider, M. zur Mühlen 1920). Rather extensive materials both on endoparasites and ectoparasites can be found here. The groups *Trematoda* and *Cestoda* are treated most thoroughly.

L. Suurjärv at Kooraste. An eutrophic lake with mesotrophic features in the Otepää Uplands.

In addition to them several articles on the *Ligula* (Treimann 1938, 1938a, Voore 1950), parasitic *Copepoda* and other ectoparasites (Voore 1939, 1940), etc. have been published.

In 1955 H. Tell defended her candidate's dissertation on the fish parasites. It contains a survey of 83 fish parasite species, of which 49 were new ones for Estonia. H. Tell gives a survey of the parasitofauna of the more important fishes of Võrtsjärv, its dependence on the age of the fish and season. The problem of the specific nature of parasites as regards their host and the development dynamics of parasites are treated and parasitary diseases of the fish of Võrtsjärv described. According to the zoogeographical division elaborated by V. A. Dogel about 75% of the fish parasites of Võrtsjärv belong to the group of fish parasites of the Arctic Ocean area and 20% of them to the Mediterranean group.

H. Tell is the author of several articles on the parasitofauna of the

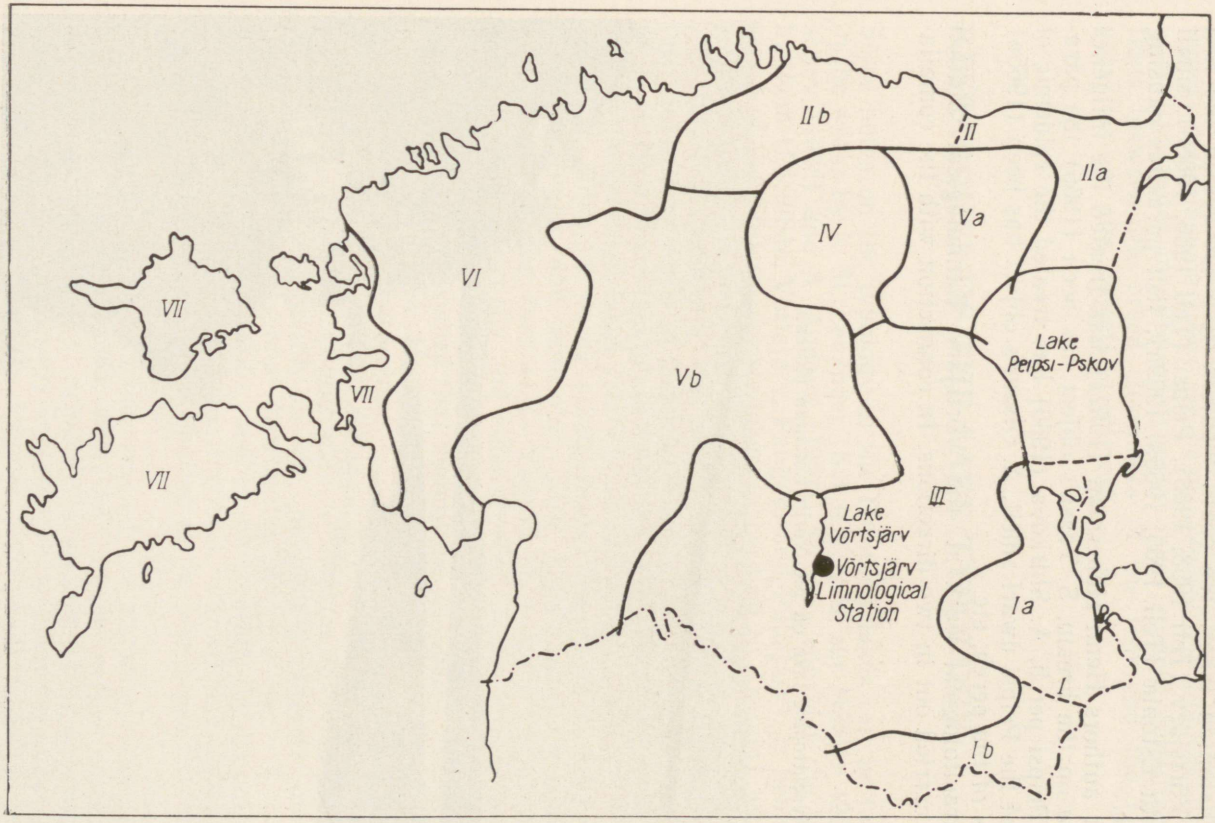


FIG. 2. THE LIMNOLOGICAL REGIONS OF THE ESTONIAN S.S.R. (BY A. MÄEMETS): **I** — the region of the oligo- and dystrophic lakes of South-East Estonia (Ia — the subregion of *Palumaa* Area, Ib — the subregion of Mõniste-Misso), **II** — the region of the oligo- and dystrophic lakes of North-East Estonia (IIa — the subregion of Kurtna, IIb — the subregion of the *North-Kõrvemaa* Area), **III** — the region of the eutrophic lakes of Upper Estonia, **IV** — the region of the alkalitrophic lakes of Pandivere, **V** — the region of the dystrophic lakes of Intermediate Estonia (Va — the subregion of *Alutaguse* Area, Vb — the subregion of Middle and South-West Estonia), **VI** — the region of the dyseutrophic lakes of Lower Estonia, **VII** — the region of the halotrophic lakes of West Estonia.

fish of the Estonian lakes. We could mention here surveys of the fish parasites of Võrtsjärv (Tell 1958, 1968), Peipsi (Tell 1966, 1968b), small lakes of South Estonia (Tell 1965, 1968a, 1969a), fish parasites causing epizotiae, etc.

Of other authors Henn Haberman (1962a) has treated the influence of the *Ligula* on the bream, S. Tassa's object has been (1966) the parasites of the Peipsi perch, A. Shirkova (1966) has treated the epidemic of *Tetracotyle* of the Peipsi dwarf smelt, A. Oissar's object has been (1965a) the parasites of the perch, etc.

Fish parasitological work at the Võrtsjärv Limnological Station (H. Tell) is carried out in two directions. In connection with the compila-

L. Järlepa. A dyseutrophic lake on the North Estonian plateau.

tion of Part II of the collection of writings "Eesti järved" fish parasitological materials on lakes are being generalized and seasonal dynamics of fish parasites in different types of lakes studied. Simultaneously relations between the breed characters of the fish and the fauna of fish parasites are also objects of interest.

RESEARCHES OF THE LAKE TYPOLOGY

Some notes on the typology of the Estonian lakes can be found already in the works by K. M. Levander (Schneider, M. zur Mühlen 1920), N. Samsonov (1908) and A. Audova (1923). So they consider the lakes studied by them (Ülemiste, Võrtsjärv, Pangodi and Pühajärv) as belonging to the group of the *Chroococcaceae*-lakes (according to Apstein) which in general corresponds to the eutrophic type.

Harald Haberman (1932) and R. Voore (1937a, 1937b) distinguished three main lake types in Estonia, oligotrophic, eutrophic and dystrophic, while H. Haberman also pointed out the existence of the eu-dys succession among the Estonian lakes (Haberman 1937).

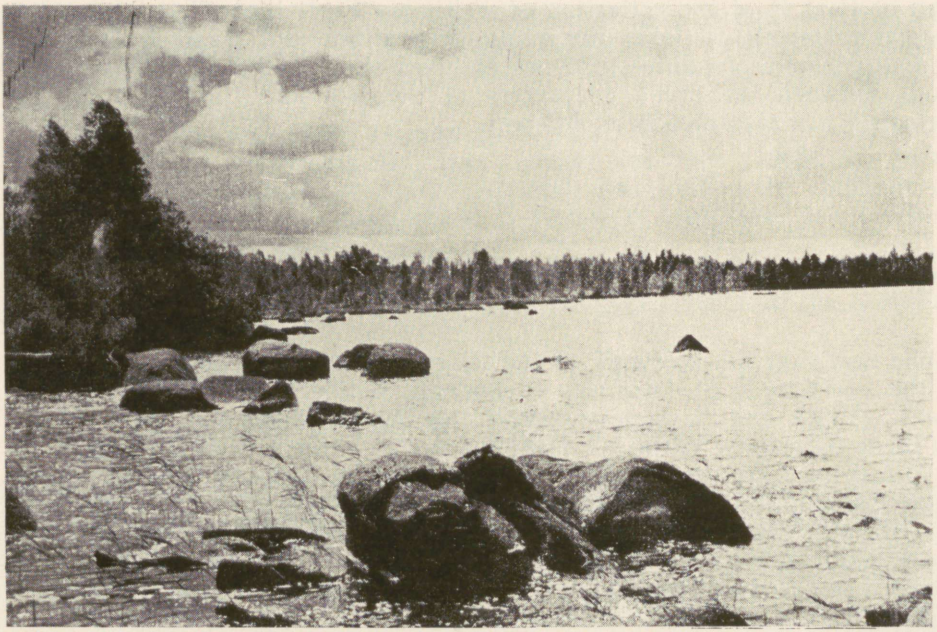
In H. Riikoja's works (1940, 1940a) the Estonian lakes are divided into oligotrophic and eutrophic, also oligohumous, mesohumous and polyhumous. In the case of L. Vagula H. Riikoja (1936) refers to the combination of eutrophy and siderotrophy.

R. Treiman (1937) has divided the Estonian lakes on the basis of prevailing fishes. He assumed that mainly the pike-perch, bream and crucian carp occur in Estonia. He was justified in stressing that the two first mentioned types are eutrophic.

K. Mölder (1943a) who distinguished four lake types in Estonia (eutrophic, dystrophic, oligotrophic or *Lobelia* lakes and alkalitrophic) based his division mainly on the phytoplanktological materials. He also referred to the regional distribution of the types.

In L. Laasimer's (1965) monograph treating the Estonian flora five lake types are given (eutrophic, lagoonic, oligotrophic, dystrophic, mixed type). On the basis of the distribution of the lake types Estonia is divided into 8 regions.

Lately Aare Mäemets has studied the Estonian lake types. In his works (Mäemets 1961, 1965, 1969) he, like the earlier authors, has proceeded from the ecological principle in distinguishing between lake types and has taken the universally accepted Thienemann-Naumann's system for the basis. A. Mäemets has slightly perfected the system and adapted



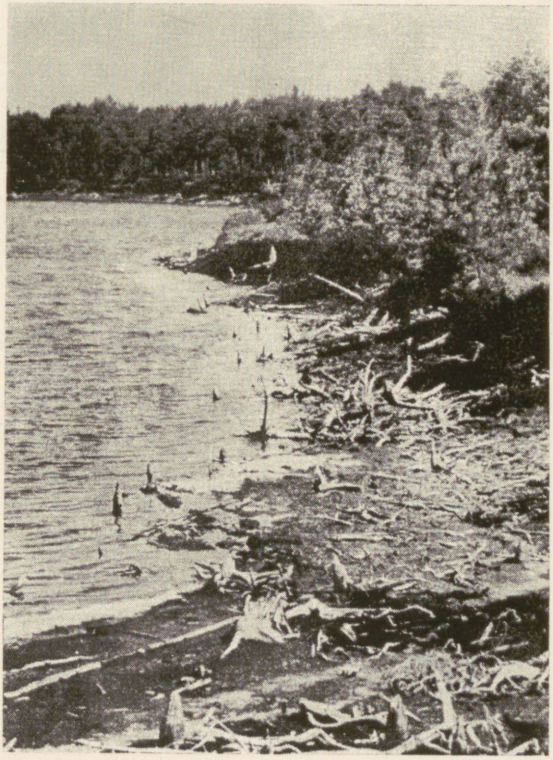
L. Kaisma. A dyseutrophic lake in the West Estonian lowlands.

it to the Estonian conditions (see Table 4). He offers 6 main types and 9 subtypes. The intermediate stage between the oligotrophic and dystrophic lakes has been treated as an independent semidystrophic succession. Dyseutrophic lakes are not regarded as a succession but as an independent type due to the fact that in very many cases they form the last stage in the evolution of lakes before a swamp is formed. Dyseutrophic and dystrophic lakes clearly differ as regards the mineralization and the composition of the biota. Therefore they cannot form one point group. The author demonstrates that these types are in good accordance with the lake groups, distinguished according to the phytoplankton, zooplankton, *Oligochaeta* and other water organisms, also with the fishing industrial types of the Estonian lakes. For instance, the pike-perch and bream lakes mainly correspond to the eutrophic type, the perch and pike lakes to the oligotrophic and dystrophic while the crucian carp lakes correspond to the dyseutrophic type. It appeared (Mäemets 1970a) that these types are in good accordance even with the lake types distinguished by S. Onno

(1958) on the basis of waterfowls. On the basis of the dominating and characteristic lake type A. Mäemets divided Estonia into 7 limnological regions and 6 subregions (see Fig. 2) of which the region of Upper Estonian eutrophic lakes is of the greatest value as regards fishery.

The aim of the further typological studies is to clarify the regularities of the matter and energy circulation of the lake types distinguished according to the ecological principle as there is no doubt about the different character of the matter and energy flow in these lake types.

Work in this direction is in progress at the Võrtsjärv Limnological Station (Aare Mäemets' research group). In connection with the mathe-



L. Mustjärv at Kurtna. A dyseutrophic lake in North-East Estonia.

Table 4

Preliminary Types of Estonian Lakes

Type and Subtype	Oligotrophic (acidogenic oligotrophy)		Semidystrophic succession (SD)	Dystrophic	
	Typical (O^1)	Eutrophied (O^2)		Typical (D^1)	With acidotrophic features (D^1)
1	2	3	4	5	6
Maximum depth (m)	6—13	4—25	< 10	4—8	5—18
Water colour in summer	light-green or bluish-green	often yellow, greenish-yellow, rarely brownish	usually yellow or yellowish-brown	reddish-brown or brownish-red	reddish-brown or brownish-red
Transparency in summer (m) (with a Secchi disc 30 cm in diameter)	> 4	often 2—4, rarely < 2	1—2, rarely > 2	< 1.5	< 1 (1.5)
Winter deficit of oxygen	lacking	usually lacking	usually lacking	usually lacking	occurs
Nutrient content	oligotype	mesotype	oligotype	oligotype	oligotype
pH (in summer)	6—7	7—8(9)	5—8	4—6	4—5(6)
Concentration of electrolytes HCO_3 (mg Eq per litre)	< 0.5	< 1.3	usually, < 1.3	< 0.5, usually < 0.1	< 0.5, usually < 0.1
Cl' (mg/l)	< 10	< 10	< 10	< 10	< 10
Organic matters content (potassium dichromate consumption mg of oxygen per litre)	< 12	12—25 (rarely more)	usually 15—35	> 35 (many humic substances	> 60 (many humic substances)

Eutrophic			Alkalitrophic		Dyseutrophic (DE)	Halotrophic (H)
With soft water (E^1)	With hard water and mesotrophic features (E^2)	Typical with hard water (E^3)	Permanent (A^1)	Temporary (A^2)		
7	8	9	10	11	12	13
3—30	15(12)—38	< 10(15)	3—8	< 3	< 5(25)	< 3
usually yellowish-green or greenish-yellow	yellowish-green or greenish-yellow	yellowish-green or greenish-yellow	light-green or bluish-green	light-green	greenish-yellow, yellow, yellowish-brown, rarely reddish-brown	usually yellow-green, or greenish-yellow
usually < 2	usually 2—5	< 3	at least 5—6	till bottom (at least 2—3)	usually < 2	till bottom (2—3)
occurs	lacking	sometimes occurs (often in small lakes)	usually lacking	lakes become dry	occurs often	occurs rarely
mesotype or polytype	mesotype	mesotype or polytype	oligotype	oligotype (?)	mesotype or polytype	mesotype (?)
7—9	7—9	7—9	> 8	> 8	7—9, rarely < 7	> 8
< 1.3	> 1.3	> 1.3	> 3.4	> 3.4	usually > 0.5 (rarely 0.4—0.5)	> 1.3
< 10	< 10	< 10	< 10	< 10	< 10	> 10
< 35	< 35	< 35	< 15	< 15	usually > 35 (many humic substances)	> 35 (?)

Table 4 (järg)

1	2	3	4	5	6
Macroflora	poor in species; occur *Lobelia, Isoëtes, Sparganium affine*; lacking *Scirpus, Ceratophyllum, Potamogeton*	*Lobelia* and *Isoëtes* are scanty; occur *Potamogeton, Scirpus* etc.	Macroflora similar to that of oligotrophic or dystrophic lakes	Macrophytes are often lacking; *Nuphar, Nymphaea* occur sometimes	poor in species; *Carex, Nuphar luteum, Calla palustris,* occur sometimes *Acorus*
Water-bloom	lacking	occurs rarely and lasts for a short time	occurs seldom	lacking	lacking
Characteristic association of phytoplankton	*Dinobryon-Desmidiales (Staurodemus, Staurastrum)*	*Microcystis-Dinobryon-Ceratium* rich in desmids	*Tabellaria-Microcystis-Micrasterias*	*Tabellaria-Asterionella Staurastrum aciculiferum*	*Tabellaria-Dinobryon-Closterium*
Characteristic complex of zooplankton	*Holopedium-Daphnia-Ophryoxus*	*Holopedium-Daphnia-Ophryoxus* or *Holopedium-Daphnia cucullata-Bosmina coregoni*	*Holopedium-Daphnia-Ophryoxus*	*Holopedium*	*Holopedium-Daphnia longispina*
Fish fauna	only perch occurs	more species: perch, pike, roach, rudd, rarely bream	prevailing species is perch	occurs perch, seldom pike	occur perch, pike
Percentage of the investigated lakes	3	8	5	10	7
Examples	L. Nohipalu Valgejärv, L. Kurtna Ahnejärv, L. Viitna Pikkjärv	L. Vaskna, L. Kurgjärv, L. Urbukse	L. Kirikumäe, L. Uljaste, L. Mägialuse	L. Loosalu, L. Tudu, L. Kakerdaja	L. Viroste, L. Holvandi Kivijärv, L. Pikamäe

7	8	9	10	11	12	13
poor in species; *Acorus* and *Elodea* are dominating species	rich in species; zone of macrophytes is narrow; *Ceratophyllum, Scirpus,* many *Potamogeton* species occur	similar to that of E², but zone of macrophytes is broad	poor in species; many charophytes	very poor in species	macroflora is very diverse, and abundant; dominating are *Phragmites, Scirpus, Potamogeton natans, Chara sp. sp.*	*Phragmites, Scirpus, Tabernaemontani, Potamogeton pectinatus, P. filiformis, Chara sp. sp.* are prevailing
occurs often and abundantly	occurs	occurs often	lacking	lacking	occurs relatively often	occurs relatively seldom
Microcystis-Anabaena	*Dinobryon-Ceratium-Asterionella-Fragilaria crotonensis*	*Melosira granulata-Anabaena*	*Tabellaria-Dinobryon,* poor in species and sparse	phytoplankton is very poor	*Aphanchece-Microcystis or Tabellaria-Asterionella*	*Microcyctis-Fragilaria-brevistrata-Gloeocapsa*
often complex incomplete; sometimes *Daphnia cucullata-Bosmina coregoni-Chydorus sphaericus*	*Cyclops scutifer-Daphnia cucullata-Bosmina coregoni*	*Daphnia cucullata-Bosmina coregoni-Chydorus sphaericus*	*Heterocope appendiculata-Bosmina obtusirostris*	*Hemidiaptomus-Mixodiaptomus*	*Hetercope appendiculata-Daphnia galeata* or *Daphnia longispina* or complex of littoral species	*Eurytemora velox*
sometimes prevailing species is crucian carp, sometimes perch, roach, bream	many species; bream occurs, seldom pikeperch	similar to fish fauna of E²; in small lakes, prevailing species are perch, roach, bream, tench, crucian carp	prevailing species: perch, pike, occur roach, crucian carp	lacking	often prevailing species: crucian, carp, sometimes roach, perch, bream	relatively many species, population density is low, basic species pike, perch, etc.
6	11	25	1	1	17	6
L. Partsi Kõrtsjärv, L. Erastvere, L. Purgatsi	L. Rõuge, Suurjärv, L. Verijärv, L. Saadjärv	L. Pühajärv, L. Tamula, L. Nüpli	L. Äntu Sinijärv, L. Äntu Valgejärv, L. Porkuni	L. Võhmetu, L. Lemküla, L. Piisupi	L. Kautla, L. Endla, L. Rahkjärv	L. Käomardi laht, L. Oessaare laht, L. Mullutu laht

L. Suursilm. A halotrophic lake on Saaremaa Is.

matical processing of the physico-geographical, hydrochemical and hydrobiological material (extracted from 152 Estonian lakes) in computers, attempts are made to find some correlations between various characters of lakes, distinguish the types of lakes on this basis, describe them from the point of view of their ecology and biological productivity, bring forth the regularities of the distribution and the genesis of the lakes. Attempts are made to elaborate a corresponding complex of possibilities for the economic management and conservation conditions for each lake type.

INVESTIGATIONS OF THE SANITARY CONDITION AND NATURE CONSERVATION OF THE ESTONIAN WATER BODIES

Investigations of the sanitary condition of the Estonian water bodies have been carried out on a large scale during the last decades only. The main research centres are the Tallinn Polytechnical Institute (TPI), the Estonian Institute of Experimental and Clinical Medicine and Tartu State

The eutrophic lake Pühajärv in the Otepää Uplands. Under state protection as one of the most beautiful lakes in Estonia.

Of water plants both species of *Nymphaea* are under state protection in Estonia.

University (TRÜ), to some extent also the Estonian Agricultural Academy (EPA). During the recent years this problem has become the object of studies at the Võrtsjärv Limnological Station. So far mainly the man-made changes of rivers and bays have been studied, while the lakes and storage reservoirs have been subjected to investigations only in single cases.

Rather extensive work in the field of the evaluation of sanitary conditions of the Estonian water reserves is being done at the Tallinn Poly-

technical Institute by H. Velner and his assistants. They have published several summaries on the subject (Kaljumäe, Kirt, Velner, Välbe 1967; Velner, Kaljumäe 1969, etc.). Another research centre has been the Estonian Institute of Experimental and Clinical Medicine where Ingeborg Veldre, I. Maasik, etc. have studied sanitary hygienic conditions of several bigger rivers and Narva storage reservoir (Maasik 1962; Veldre, Maasik 1964 etc.).

Sanitary-hygienic condition of the South-Estonian water bodies have been studied by the Chair of Hygiene of Tartu State University (M. Kask, A. Saava, M. Uibo).

The purification equipment is constructed in the Estonian Agricultural Academy (A. Maastik) while possibilities of the purification of the water by means of the algae are studied by the Chair of Systematic Botany and Geobotany of Tartu State University (E. Kukk and others).

It is also necessary to find some means against the water-bloom, to study the role of aquatic plants and animals in the purification of water, to improve classifications of saprobes, etc.

Nature conservation problems of the Estonian lakes have been discussed by Aare Mäemets (1961a, 1969d) according to whose proposals some oligotrophic and dystrophic lakes are under the republican protection (the Nohipalu lakes). According to the author's data there are 44 lakes under the republican protection and about 80 lakes under the local protection and they represent all Estonian lake types. Of the plants growing in the lakes the *Nymphaea alba, N. candida* and *Littorella uniflora* are also under state protection. Proposals have been made to protect the *Aegagropila sauteri, Lobelia Dortmanna, Isoëtes lacustris, I. echinospora, Myriophyllum alterniforum* and *Najas marina*. A. Mäemets (1969d) recommends to preserve in the Estonian lakes such rare invertebrate animals as the *Pallasea quadrispinosa, Eurytemora lacustris* and *Hirudo medicinalis*. His recommendation is to divide the Estonian lakes into three categories (full protection, partial protection, ordinary regime). Each of such types would have its own protection regime depending on the type of the lake and the aim of protection.

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The following abbreviations are used in the following list of addresses

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EIAA — Estonian Institute of Agriculture and Amelioration, Saku, Harju Dist., Estonian S.S.R.

EICBVS — Estonian Institute for Cattle-Breeding and Veterinary Science. 1 Fr. R. Kreutzwaldi St., Tartu, Estonian S.S.R.

EIECM — Estonian Institute of Experimental and Clinical Medicine. 18/20 Ravi St., Tallinn, Estonian S.S.R.

ELMI — Estonian Laboratory of Marine Ichthyology (EMIL), 1—2 Apteegi St., Tallinn, Estonian S.S.R.

EN — Journal «Estonian Nature», 18 Riia St., Tartu, Estonian S.S.R.

IG — Institute of Geology, 7 Estonian Av., Tallinn, Estonian S.S.R.

IZB — Institute of Zoology and Botany (ZBI), 21 Vanemuise, Tartu, Estonian S.S.R.

IZB LS — Võrtsjärv Limnological Station of the Institute of Zoology and Botany, 202454 Rannu, Tartu Dist., Estonian S.S.R.

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Rbl. 1.29