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POLISH ARCHIVES OF HYDROBIOLOGY
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Polskie Archiwum Hydrobiologii existing as such since 1953, is a continuation of *Archiwum Hydrobiologii i Rybactwa* founded in 1926 under the editorship of A. Lityński; during the period 1926 to 1939 and in 1947; thirteen volumes of *Archiwum Hydrobiologii i Rybactwa* have appeared, volume XII, 3, 4, published in September 1939, being almost entirely destroyed due to war action.

The journal publishes original works reporting experimental results, descriptive works and theoretical investigations in every sphere of hydrobiology. The article must contain original research not already published and which is not being considered for publication elsewhere. Papers will be published in the official Congress languages of Societas Internationalis Limnologiae (at present; English, French, Italian and German).

The Editorial Board request that the manuscripts conform to the requirements set out below; those manuscripts not conforming to these will be returned to the author for alteration.

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Authors are requested to be as concise as possible and, in general, papers will be limited to 16 printed pages, including illustrations although in certain cases, longer papers may be accepted provided long tables and lists are avoided. (Irrespective of lenght of the published paper, authors will be paid for their paper up to 1 quire of type print). Manuscripts should be carefully checked so that proof correction (apart from printers errors) should be minimal.

Manuscripts, of which the original and one carbon copy complete with tables and figures should be sent, should be typewritten (double-spacing) on one side of a sheet only, with a left-band margin of 4 cm and about 30 lines per page; pages should be numbered. The title of the paper (in the language of the text and in the author's native language) should be indicated at the top of the paper together with the author's name (surname and first name), address; name and address of the laboratory (institute or department where the work was carried out.

The article should be arranged as follows; 1) a brief introduction, 2) a section on methods, 3) the results, 4) discussion, 5) a summary (which is an integral part of the paper), giving the main results, of not more than 200 words in the language of the text, 6) a summary, some text as in point 5 but in the author's native language

POLSKIE ARCHIWUM HYDROBIOLOGII (Pol. Arch. Hydrobiol.)	14 (27)	3	1—16	1967

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HYDROCHEMICAL OUTLINE OF THE LAKE WIERZYSKO

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ABSTRACT

The present paper deals with the results of measurements and hydrochemical studies carried out during an annual cycle on the Lake Wierzysko (Kaszuby Lake District) in 1957—1958. In the light of both morphological and hydrological characteristics of the basin examined, thermic and chemical conditions in the lake and tributaries are discussed in detail, and compared with those of the other lakes of Poland.

The results of the studies have demonstrated that the river Wierzyca is of fundamental importance in the development of biotope in the lake examined. Moreover, it has also been found that the municipal sewage of the town Kościerzyna strongly influence the eutrophic nature of the lake. In addition, the extent of the activity of the sewage affecting the lake has been discussed, and changes which are a result of this activity in water environment, taken into consideration.

Oxygen budget of the lake is calculated and characteristics of ionic composition of water in the individual seasons are given.

CONTENTS

1. INTRODUCTION

The present work is a continuation of a cycle of the researches on hydrochemical conditions that predominate in lakes contaminated with sewage i.e. in those which are particularly subject to strong changes in environment properties (JANUSZKIEWICZ, JAKUBOWSKA 1963, JANUSZKIEWICZ 1965).

To the objects of these researches belongs also the Lake Wierzysko characterized by running water. So far, the lake was not elaborated from the limnological point of view, thus information is restricted only to general-fishing data (SELIGO 1902), to description of near-shore vegetation and of cladocera fauna (RAMUŁT 1930), as well as to fundamental morphometric data (Catalogue of Polish Lake, 1954). It appears that such an elaboration of hydrochemical characteristics should bridge a gap in the data on biotope properties of the Lake Wierzysko, and augment the number of the lakes investigated chemically within the Kaszuby Lake District.

2. PHYSIOGRAPHY OF THE LAKE AND OF THE ADJACENT AREAS

The Lake Wierzysko, also called Lake Wierzkowskie, or Wierszyńskie (Kulmatycki, Gabański 1929), occurs within the Kaszuby Lake District, about 3 km south of the town Kościerzyna, and about 50 km south-west of Gdańsk. Its geographical position is determined by the following co-ordinates: $\lambda = 17°59''5'$ and $\varphi = 54°6''4'$. This lake, situated within the catchment basin of the river Wierzyca, belongs to the type of open, drainage lakes. The area of its hydrographical basin, amounting to 143 km², is drained off by streams and ditches that run along channel-like lowerings of the terrain, and drain away excess water to the river Wierzyca, or just to the lake Wierzysko.

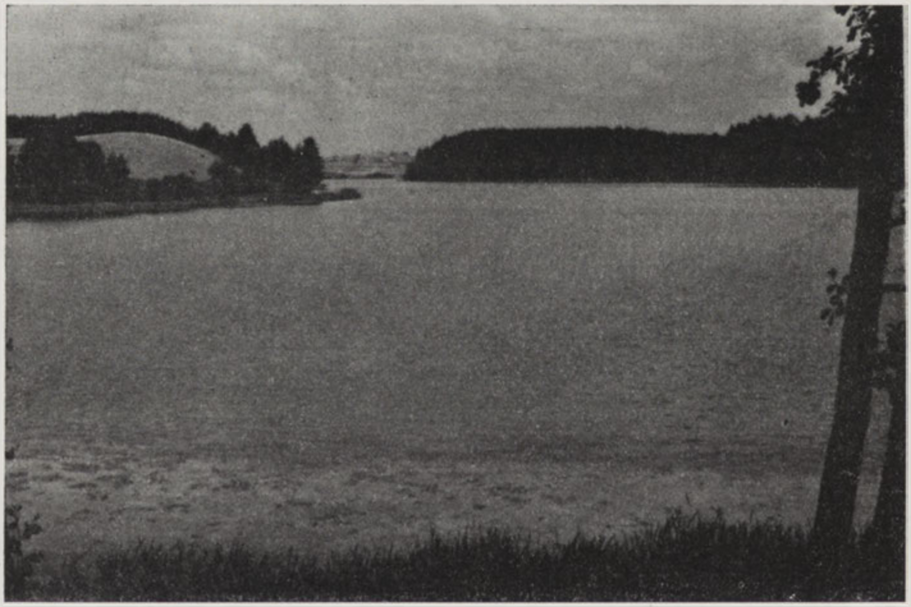

Fig. 1. Lake Wierzysko — viewed from the western shore

This channel-type lake is of post-glacial origin, direction of its long axis being NE-SW. It is surrounded by morainic hills, 150—170 m in height above sea level. Shores of the lake are steep, frequently rising even 20 m above the water level, which is here at a height of 147,1 m a.s.l. (data from Military Institute of Geography, 1937). Hillsides on the southern shore are covered with a coniferous forest, the opposite shore being arable land (Fig. 1). In its eastern part, the lake borders a vast, peaty and boggy meadow. The area of the lake is 61,5 ha, its length amounts to 2.257 m, width — 375 m, mean width — 274 m, maximum depth 7.6 m, length of shore line — 5.180 m, index of the shore line development — 1.862, volume of the lake basin — 2.723 thousand m³, and mean relative depth — 0,0097. The mean depth amounts to 58,4% of the maximum depth, and the area of littoral zone, down to 4 m, is 25 ha, this being 40,7% of the total area of the bottom. Mean dip of the basin slopes is 2°41′ (Michalski et al. 1958).

The river Wierzyca is the main tributary of the lake. It flows across the lake at 24 km of its course, i.e. at a distance of about 130 km off its mouth into the Vistula river. Two drainage ditches, running from north, are its secondary tributaries. Ditch 1, which is a continuation of a channel that drains off both the Lake Bibrowskie and the Lake Kapliczne, is 6 km in length. In the area of Kościerzyna, it collects industrial wastes from a dairy, and from a factory of forest products, as well as a small amount of municipal sewage and, at a distance of about 2 km off its mouth to the Lake Wierzysko — the main mass of manicipal sewage of the town Kościerzyna. The sewage comes from 2/3 of the town that, at the time of the study, numbered approximately 10.900 inhabitants (Statistical Annual Report of the Gdańsk Voivodeship). A small part of the sewage that flows through the ditch in the area of its mouth is used for provisory irrigation of the meadow, a greater part, howewer, flows into the lake, practically in raw state. Ditch 2, about 1 km in length, carrying sewage waters from a locomotive shed, is of a minor importance in pollution of the lake in study.

A low value of the ratio between the lake area and catchment basin area can be an evidence that the processes taking place within this area are of decisive importance for water balance of the lake. If we accept that annual precipitation in this area is 620 mm, the annual amount of precipitation water would be 88.660 thousand m^3, 382 thousand m^3 of which would fall directly onto the lake surface. Simultaneously, about 436 thousand m^3 of water per year evaporates from the Lake Wierzysko, the annual mean evaporation rate amounting to 700 mm. Thus, evaporated water slightly exceeds here precipitation water. Annually, the river Wierzyca carries about 11 mil. m^3 water into the lake, whereas the outflowing water amounts to about 12 mil. m^3. Consequently, the exchange coefficient is here 0.23. Theoretically, the whole water volume in the basin is exchanged around every 85 days.

Climate of the catchment area of the Lake Wierzysko is referred by Romer (1949) to a lake-district type of the so-called Bytów region which, as compared with the adjacent regions, is characterized by more continental nature. The main elements of climatic conditions for a period of 1881—1930 are given by Wiszniewski et al. (1949), Wiszniewski (1953) and, for the period of the present study in the Statistical Annual Reports for the Gdańsk Voivodeship (1958, 1959). It results from these data that in this area westerly (13,4%) and south-westerly (11,5%) winds prevail, although the eastern winds slightly increase in winters. The winds of maximum velocities are frequently observed, approximately 48 days per year. For the most part they blow from west and south-west. The mean values of maximum velocities, recorded at Kościerzyna, amount to 17 m/sec., and are observed mainly in winters. Extreme temperatures in the years 1957—1958 were: maximum 29,1°C and 28,8°C, respectively.

3. METHODS AND RESULTS

The study of the Lake Wierzysko was carried out in a period from August 1957 to August 1958, thus it covered all the phenomena that take place within an annual cycle.

Table I. Results of physical and chemical analyses of water of the Lake Wierzysko and of

Basin			Ditch 1		Ditch 2	River Wierzyca	
Sampling sites			I		II	III	
Date			070258	240658	240658	270358	24068
Air temperature		°C	−4	24,6	19,4	3,1	25,98
Water temperature		°C	1,1	17,9	14,7	2,7	17,8
Colour		mg/l Pt	60	70	50	40	50
Turbidity		mg/l SiO_2	100	150	10	20	20
pH Value			7,4	7,2	7,9	8,0	7,9
Alkalinity		mval/l	4,2	4,1	3,8	2,1	2,8
Dissolved oxygen		mg/l O_2	7,9	2,5	7,6	12,7	9,9
Percentage of saturation with oxygen			56	26	76	134	108
Free carbon dioxide		st mg/l CO_2	16,5	18,0	11,5	3,0	5,0
BOD_5		mg/l O_2	33,5	19,0	1,4	2,9	2,7
Permanganate Value		mg/l O_2	14,8	14,4	10,5	6,8	9,9
Filtrable residue mg/l	total amount		552,8	319,0	295,4	135,0	212,3
	volatile matter		317,6	126,9	134,5	56,3	114,6
	fixed matter		235,2	192,1	160,9	78,7	97,7
Nonfiltrable residue mg/l	total amount		56,0	48,7	5,3	16,3	15,3
	volatile matter		29,2	37,3	3,0	7,0	7,2
	fixed matter		26,8	11,4	2,3	9,3	8,1
Ammonia		mg/l N	4,0	3,0	0,08	0,08	0,06
Nitrites		mg/l N	0,16	0,005	0,003	0,007	0,010
Nitrates		mg/l N	0,30	0,08	0,10	0,60	0,40
Total nitrogen		mg/l N	13,3	7,16	0,84	1,76	1,54
Hydrogen carborates		mg/l HCO_3	256	250	232	128	171
Chlorides		mg/l Cl	150,0	27,5	14,5	7,8	7,0
Sulphates		mg/l SO_4	29,6	24,3	29,2	13,1	16,7
Phosphates		mg/l P	0,70	0,75	0,01	0,03	0,06
Calcium		mg/l Ca	75,7	—	71,4	41,0	52,9
Magnesium		mg/l Mg	9,1	—	7,6	4,8	4,8
Iron		mg/l Fe	0,26	0,40	0,12	0,16	0,16
Manganese		mg/l Mn	0,33	0,10	0,08	0,08	0,0

From the first decade of January 1957 to the end of April 1958, the lake was covered with ice, up to 50 cm in thickness. Only a small area in the regions of mouths and outflows of the streams was free of ice cover. Spring melting began in the eastern part of the lake. In the vegetative period a strong blooming was observed that decreased the visibility of Secchi's disk to 0.6—0.8 m.

During the study, westerly and north-westerly winds prevailed and atmospheric pressure ranged from 740 mm (October 1957, and March 1958) to 755 mm (August 1958).

The lake was examined at five sites selected according to hydrological situation and morphometric conditions of the basin. In addition, the examinations were made in tributaries as well. The sites were selected as follows (Fig. 2).

On account of a small depth of the lake, the samples for examinations were taken mainly at a depth from 0,5 to 1,0 m. At the deepest place (site 8), measurements of temperature, pH and oxygen contents were made every 1 m of depth.

its tributaries

Lake Wierzysko										
IV						V	VI			
290857	181057	070258	270358	130658	110858	240658	290857	181057	070258	290358
13,0	12,0	−4,0	3,1	12,0	17,0	19,6	13,0	12,0	−4	1,0
16,0	9,0	0,8	1,2	13,6	17,4	17,0	16,0	9,5	0,8	1,8
35	25	30	35	30	45	40	35	25	25	30
30	15	10	5	20	20	20	30	15	10	15
8,0	7,5	7,8	7,9	8,4	8,4	8,4	8,4	7,5	7,3	7,2
3,2	3,3	2,9	2,3	2,9	2,8	2,9	3,3	3,3	3,4	2,5
13,3	8,4	9,3	11,4	11,3	9,7	11,9	8,4	7,5	8,5	6,5
135	75	68	105	110	102	125	85	66	60	67
5,0	4,5	5,5	3,5	0,0	0	0	2,0	4,0	10,0	4,5
4,3	5,4	2,8	3,5	4,7	6,0	10,7	3,0	4,0	3,6	2,6
8,9	8,0	5,1	5,7	6,8	8,6	9,4	7,6	8,0	5,1	8,0
262,4	240,0	244,0	154,0	190,4	216,8	255,7	250,4	281,6	278,4	185,2
149,6	96,8	85,6	55,0	72,0	101,6	111,9	120,0	132,8	113,6	69,5
112,8	143,2	158,4	99,0	118,4	115,2	143,8	130,4	148,8	164,8	115,7
27,2	10,4	8,8	6,0	11,2	10,8	9,5	25,4	9,6	9,6	8,1
12,0	4,4	4,0	3,0	3,2	4,8	5,0	10,6	4,0	4,4	3,2
15,2	6,0	4,8	3,0	8,0	6,0	4,5	14,8	5,6	5,2	4,9
0,06	0,44	0,20	0,12	0,08	0,04	0,08	0,50	0,50	0,20	0,60
0,007	0,16	0,012	0,010	0,003	0,003	0,007	0,007	0,015	0,005	0,020
0,10	0,20	0,50	0,60	0,10	0,06	0,08	0,10	0,20	0,50	0,50
2,0	0,95	1,43	2,17	2,63	1,68	1,74	1,3	1,68	1,62	1,40
195	202	177	140	176	170	177	202	202	207	152
16,6	14,5	13,8	9,2	13,5	14,8	15,0	16,6	17,0	17,4	14,8
16,4	18,4	20,7	15,4	15,7	11,5	16,7	13,8	17,4	22,3	15,7
0,15	0,13	0,06	0,04	0,075	0,15	0,05	0,20	0,15	0,07	0,04
58,0	61,1	55,5	45,5	51,9	50,5	52,9	58,0	60,3	65,9	45,9
4,5	5,8	6,1	4,9	5,6	6,5	6,3	5,2	5,4	7,4	5,4
0,06	0,06	0,1	0,14	0,06	0,04	0,08	0,06	0,06	0,04	0,14
0,04	0,08	0,08	0,08	0,04	0,04	0,0	0,04	0,08	0,08	0,12

Methods described in the previous publications (Januszkiewicz, Jakubowska 1963) were employed both in the field and laboratory investigations.

The results of the studies that concern more important physical and chemical data are presented in Table I. Diagrams of vertical thermal and oxygen cross-sections are given in Fig. 3.

4. DISCUSSION OF THE RESULTS

Thermic and dynamic features of water masses. The results show that thermal conditions observed in the lake under study are not characterized by any particular differentiation, neither as to their vertical distribution, nor as to the occurrence of greater vertical changes in temperature. Thermal curves (Fig. 3) point to the fact that a stable stratification prevailed during the winter stagnation only. Maximum temperature of deep water strata was, Continued Table I

Basin							
Site		VI		VII	VII	
Date		130658	110858	240658	290857	181057
Air temperature	°C	12,0	17,0	21,3	13	12
Water temperature	°C	15,1	18,0	17,4	16,0	9,0
Colour	mg/l Pt	45	40	40	35	25
Turbidity	mg/l SiO_2	20	20	20	30	15
pH Value		8,4	8,4	8,4	8,0	7,5
Alkalinity	mval/l	2,9	2,8	3,0	3,3	3,3
Dissolved oxygen	mg/l O_2	13,7	10,2	11,2	8,7	8,0
Percentage of saturation with oxygen		136	108	119	88	69
Free carbon dioxide	st mg/l CO_2	0,0	0,0	0	4,0	4,5
BOD_5	mg/l O_2	7,9	10,0	8,6	5,1	5,9
Permanage Value	mg/l O_2	6,4	8,3	9,4	8,3	7,3
Filtrable residue mg/l	total amount	200,8	204,0	209,8	229,6	263,2
	volatile matter	68,0	82,4	103,2	116,0	120,8
	fixed matter	132,8	121,6	106,6	113,6	142,4
Nonfiltrable residue mg/l	total amount	10,0	11,6	14,8	24,8	9,6
	volatile matter	4,4	4,4	8,2	10,4	4,4
	fixed matter	5,6	7,2	6,6	14,4	5,2
Ammonia	mg/l N	0,08	0,04	0,06	0,46	0,60
Nitrites	mg/l N	0,003	0,003	0,007	0,005	0,015
Nitrates	mg/l N	0,08	0,06	0,06	0,10	0,20
Total nitrogen	mg/l N	1,68	1,79	1,9	—	1,23
Hydrogen carbonates	mg/l HCO_3	176	170	183	202	202
Chlorides	mg/l Cl	14,8	15,5	15,0	16,6	15,5
Sulphates	mg/l SO_4	15,4	10,8	13,8	13,8	15,0
Phosphates	mg/l P	0,15	0,15	0,07	0,20	0,15
Calcium	mg/l Ca	52,9	49,9	53,4	58,0	59,3
Magnesium	mg/l Mg	6,1	6,9	5,8	5,0	5,8
Iron	mg/l Fe	0,06	0,04	0,08	0,06	0,06
Manganese	mg/l Mn	0,04	0,04	0,04	0,04	0,08

at the beginning of winter, 2.5°C, and then was gradually increasing to reach a value of 3.6°C, shortly before melting. In the remaining seasons the conditions similar to homothermy predominated, with the maximum differences in temperature at the surface and at the bottom, not exceeding 1.4°C. A certain decrease in temperature at the bottom, illustrated by the summer thermal curves, can be considered as remains of thermocline. Thermal gradients were insignificant since they did not exceed 0.5°C. Such conditions could not have had greater stability. The degree of surface layer heating was characterized by an increase in temperature towards SE. However, the greater differences between the extreme sites did not exceed 1.5°C. The maximum water temperatures recorded in the summer periods of 1957 and 1958, were 16.0°C and 18.2°C respectively, depending on the atmospheric conditions that prevailed at the time of measurements. The frequency of a similar temperature range was, in the Mazury Lake District, 3.5%, whereas temperatures ranging from 19°C to 21°C were characteristic of about 37% of all basins (Olszewski, Paschalski 1959). Hence, the Lake Wierzysko should be regarded rather as a cool basin. In this respect, it even differs from the neighbouring Lake

Lake Wierzysko								River Wierzyca	
VIII			IX					X	
070258	130658	110858	290857	181057	070258	130658	110858	270358	240658
−4	12	17	13	12	−4	12	17	3,0	17,0
0,8	14,7	17,6	16,0	9,0	0,8	14,5	17,5	2,5	18,2
25	45	40	35	25	20	45	40	35	40
10	20	20	30	15	5	20	20	15	20
7,6	8,4	8,4	8,0	7,5	7,6	8,4	8,4	8,0	8,4
3,4	2,9	2,8	3,3	3,3	3,2	2,9	2,8	2,5	2,9
8,2	11,5	8,7	9,4	7,6	7,5	10,7	9,0	9,7	13,6
58	114	91	95	66	53	105	94	102	147
6,6	0,0	0	4,0	4,7	5,5	0,0	0,0	4,0	0
1,9	6,8	8,7	5,9	5,2	2,0	7,6	7,4	2,0	10,5
5,1	6,2	8,4	8,0	8,0	3,8	6,7	8,9	5,9	8,8
272,0	192,0	213,6	225,6	268,8	259,2	188,6	200,8	142,0	201,1
110,4	60,0	89,6	107,2	127,2	96,8	61,4	74,4	50,8	84,9
161,6	132,0	124,0	118,4	141,6	162,4	127,2	126,4	91,2	116,2
9,2	11,6	10,4	24,4	10,8	6,8	10,4	11,2	6,0	5,4
4,0	3,6	4,8	10,0	4,8	3,2	3,2	4,8	2,5	2,5
5,2	8,0	5,6	14,4	6,0	3,6	7,2	6,4	3,5	2,9
0,50	0,08	0,04	0,46	0,60	0,04	0,08	0,04	0,55	0,06
0,018	0,003	0,003	0,007	0,015	0,010	0,003	0,003	0,012	0,005
0,50	0,08	0,06	0,10	0,20	0,50	0,10	0,06	0,60	0,06
1,81	2,02	1,84	1,0	1,29	1,39	1,62	1,76	1,89	1,91
207	176	170	202	202	195	176	170	152	177
17,4	14,1	15,5	16,6	15,5	13,8	14,1	15,5	11,8	15,5
24,6	15,7	11,1	14,8	13,1	17,7	14,8	10,2	16,1	15,7
0,09	0,11	0,15	0,20	0,15	0,07	0,10	0,15	0,06	0,06
65,3	52,9	50,7	58,6	60,3	60,4	52,3	49,7	48,0	52,3
7,2	6,7	6,5	4,8	5,2	6,1	5,6	7,2	4,9	6,2
0,1	0,06	0,04	0,06	0,06	0,1	0,06	0,04	0,14	0,08
0,13	0,04	0,4	0,04	0,08	0,08	0,04	0,04	0,08	0,04

Klasztorne, characterized by a similar depth (Januszkiewicz, Jakubowska 1963). The annual thermal budget of the Lake Wierzysko, computed according to Birge (1915), amounts to 6.960 g cal/cm², and summer heat input is 5.950 g cal/cm². The presence of running water resulted in some thermal specificity of the lake. The river Wierzyca, characterized in its upper course by a rapid current (river gradient amounts to 1.46‰), is responsible for an increase in temperature during winter periods, and for a decrease in other seasons. Thus, the water flow levels, to some degree, the annual amplitudes of water temperature oscillations, and smoothes the thermal gradients, similarly as that in the Lake Rożnowskie (Olszewski 1953). The Wierzyca river outflow, situated in the middle part of the lake, causes a slight isolation of its western area, and is responsible for feebly increased temperatures in this area, particularly at the time of windless weather, or under conditions of wind that blow from a direction perpendicular to the long axis of the lake. The forest which covers the southern shore makes the lake less exposed to the wind and sun action, however, a predominance of the winds that blow along the longer axis of the lake gives a lesser importance of this screen.

It results from the thermal conditions presented above that the water masses of the lake Wierzysko highly circulate during the summer. According to Wiszniewski (1953), the lake is considered to be similar to those of polymictic type, with many periods of water stagnation. Thickness of epilimnion, i.e. theoretical extent of water circulation, computed from empirical formula of Patalas (1960a) is 6.8 m, with a tolerance amounting to ±1.3 m. Thus, the supposed extent of the epilimnion has proved to exist. Consequently, one can

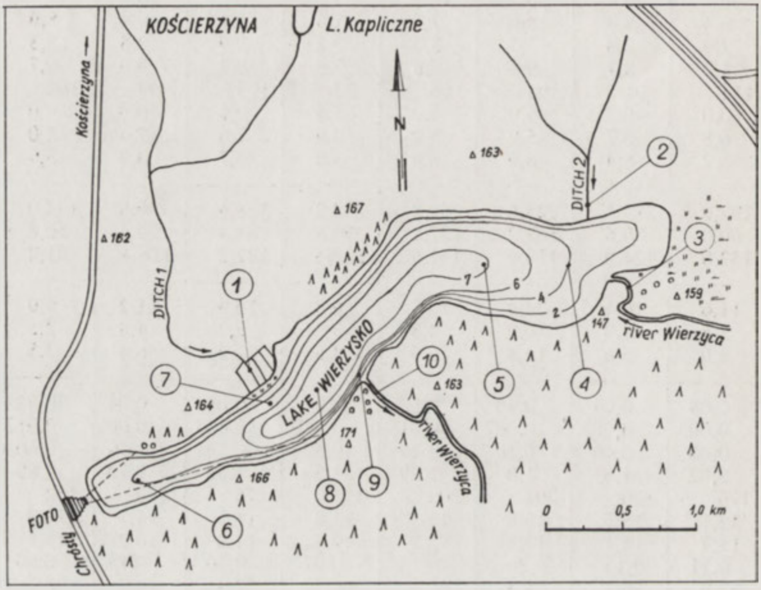

Fig. 2. Diagrammatic sketch of the Lake Wierzysko and distribution of sampling sites. Dotted line shows the segment seen in Fig. 1

1 — ditch 1, at its mounth into the Lake Wierzysko; 2 — ditch 2, at its mouth into the Lake Wierzysko; 3 — river Wierzyca at its mouth into the Lake Wierzysko; 4 — Lake Wierzysko in the region of the mouths of both the river Wierzyca and ditch 2; 5 — Lake Wierzysko, about 700 m west of the Wierzyca river mouth; 6 — Lake Wierzysko, its south-western part; 7 — Lake Wierzysko, the region of the mouth of ditch 1; 8 — Lake Wierzysko at the midway between the mouth of ditch 1 and the outflow of the river Wierzyca; 9 — Lake Wierzysko, near the outflow of the river Wierzyca; 10 — river Wierzyca, directly downstream of its outflow from the Lake Wierzysko

infer from this fact that wind action is here the main factor responsible for the water circulation in the lake, and water flow is of a secondary importance only. The relation between the maximum theoretical depth of water circulation and the maximum depth of the lake amounts to about 1. This proves the presence of favourable conditions for mutual relations between the water masses and the bottom of the lake.

Oxygen content in water of the lake was, during the period of examinations, strongly differentiated. Saturation ranged from 53 to 136%. As a rule, more favourable oxygen conditions prevailed in the north-eastern part of the lake, where the oxygen content had never droped below 8.4 mg/l. This is thought to be a result of well oxygen-saturated water of the river Wierzyca. Favourable, although fairly changing oxygen conditions prevailed during the vegeta-

Table II

Comparison of seasonal oxygen budgets with some morphometric data

Layer m	Area m²	Dip of basin slopes	Volume m³	Dissolved oxygen kg O_2				
				Summer 1957	Autumn 1957	Winter 1958	Spring 1958	Summer 1958
0—1	55437	43°33′	58762	5110	4700	5525	6640	5990
1—2	49969	5°34′	535260	4440	4060	4390	5890	4700
2—3	60407	4°25′	479885	3740	3740	1390	5230	4130
3—4	84125	2°53′	407211	3020	3180	175	4270	3300
4—5	80280	2°32′	312339	2660	2250	87	3200	1970
5—6	74969	2°17′	247159	2150	1900	35	1060	420
6—7	134625	1°0,3′	137608	920	986	0	110	178
7—7,6	76000	0°50′	15200	99	103	0	0	0
0—7,6	615812	—	2722524	22139	20919	11602	26400	20688
Average concentration of oxygen (mg/l O_2)				8,12	7,69	4,26	9,70	7,57

tive period in an opposite end of the lake. This resulted from intense processes of photosynthesis, as proved by the blooming observed in this part of the lake.

Apart from good hydrodynamical conditions, there was a distinct stratification observed in vertical distribution of oxygen (Fig. 3). Although the autumnal oxygen distribution was approximating the homogeneous state, the

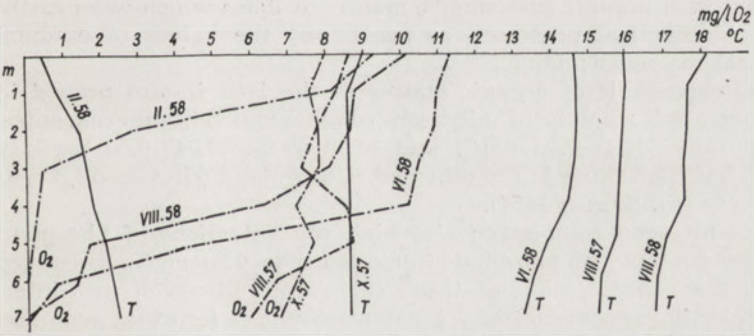

Fig. 3. Vertical distribution of temperature and oxygen in the Lake Wierzysko

oxygen curve showed a series of irregularities that proved a considerable variability of the system. In winter, at a depth of 1 m, a sharp oxycline began, having a gradient of 5.3 mg/l/m O_2. Between the isobaths 3—5 m only trace amounts of oxygen were preserved, so that at a depth of 5.0 m an anaerobic zone began.

In summer, oxygen conditions developed according to meteorological ones.

For example, differences in vertical oxygen distribution were lower during the summer period 1957 than in the analogous season of 1958, and the range of concentrations was from 6.5 to 8.7 mg/l O_2. Oxygen curve was irregular in shape and showed its minimum at a depth of 3.0 m. An analogous curve for 1958 was of clinograde character: the layer betwen 0.0 and 3.0 m was characterized by 10.2—8.1 mg/l O_2; below, there was an oxycline with a gradient amounting to 4.6 mg/l/m O_2, and at the bottom an anaerobic layer appeared. A more intense heating of the lake in 1958 caused an increase in mineralization processes in the deep zone. This, under conditions of a somewhat stronger stagnation, must have led to a considerable oxygen deficiency at the bottom. A great reduction potential of the sediments which, in the deepest area, show the presence of hydrogen sulphide and some variations in circulation intensity cause that the summer oxygen distribution is differentiated and unstable.

Table II presents the approximate values of oxygen resources in the lake, calculated on the basis of distribution of concentration in the deepest area, assuming a horizontal course of isoxygenes (Patalas 1960b). They illustrate that the greatest oxygen resources of the lake were found in spring, when they amounted to 26.4 tons O_2. In summer, they decreased to 22.1 t in 1957, and 20.7 t in 1958.

In the period from June to August about of 5.7 t oxygen was used. Winter resources of oxygen amounted to 11.6 t, this being approximately 50% of the summer supply.

5. CHEMICAL COMPOSITION OF LAKE WATER

Concentration of the substances dissolved in water of the Lake Wierzysko (154—281 mg/l) is thought to be an average one. Fairly considerable amount was observed of organic compounds, mainly of those which were easily decomposed at biochemical processes, as proved by the values of oxidability and biochemical oxygen demands.

A greater content of organic matter in the lake is also proved indirectly by an increased amount of nitrogen compounds. So, the concentrations of ammonia salts (0.04—0.60 mg/l) and of nitrates (0.04—0.60 mg/l) were, as a rule, higher than those in the other lakes of Poland (Gieysztor, Odechowska 1958, Olszewski, Solski 1964).

Besides nitrogen compounds also high concentrations of phosphorus were found. The contents of phosphates amounted to 0.20 mg/l. An untypical decrease in the concentration of these compounds observed in winter can be explained by the appearance of a greater amount of iron that generates hardly soluble phosphates (Einsele 1938). On the other hand, an increased content of phosphorus during the period of free water may be related with the run-off from the fertilized, arable fields, and with the mineralization of phosphorous organic compounds, which is accelerated by higher temperatures. The substances are brought into the lake together with municipal sewage.

Among cations, calcium predominated in water of the Lake Wierzysko (44.7—65.9 mg/l). The calcium resources of the lake can be estimated as high, both on a comparative scale by Thienemann (1925), and on that by Ohle (1934). The high level of these resources is due to the water masses that run across the lake, and due to a field character of the catchment basin. Calcium concentrations in the lake would correspond to a mezotype of Naumann's classification (1932). Their values, as compared with the conditions prevailing in the majority of the lakes in Poland (STANGENBERG 1936, OLSZEWSKI, PASCHALSKI 1959, PATALAS 1960c, GIEYSZTOR, ODECHOWSKA 1958, SOLSKI 1964), corresponded to the upper boundary of the mezotype.

The remaining cations were found to occur in considerably smaller quantities: magnesium — from 4.5 to 7.6 mg/l Mg and iron and manganese in concentrations amounting to 0.04—0.13 mg/l.

Table III

Characteristics of ionic composition of water in the Lake Wierzysko

Components			Summer 290857	Autumn 181057	Winter 070258	Spring 130658	Summer 110858
Dissolved matter mg/l			242,0	263,4	263,4	192,9	233,8
Minerals per cent of dissolved matter		SO_4''	6,0	6,1	8,1	8,0	4,7
		Cl'	6,8	5,9	5,9	7,3	6,5
		HCO_3'	40,6	37,8	36,8	44,6	36,0
		Ca''	24,0	22,9	23,4	27,2	21,5
		Mg''	2,0	2,1	2,5	3,1	2,9
		$Na'+K'$	7,1	5,5	4,2	5,9	3,8
Anions	Sulphates	mg/l SO_4	14,7	16,0	21,3	15,4	11,1
		mval/l	0,31	0,33	0,44	0,32	0,23
		% mval	7,5	8,1	10,8	8,9	6,6
	Chlorides	mg/l Cl	16,6	15,6	15,6	14,1	15,3
		mval/l	0,47	0,44	0,44	0,40	0,43
		% mval	11,5	10,8	10,7	11,0	12,5
	Hydrogen carbonates	mg/l HCO_3	200	202	197	176	170
		mval/l	3,28	3,31	3,23	2,89	2,79
		% mval	81,0	81,1	78,5	80,1	80,9
Cations	Calcium	mg/l Ca	58,1	60,2	61,8	52,5	50,2
		mval/l	2,90	3,00	3,00	2,62	2,50
		% mval	71,5	73,6	75,0	72,6	72,6
	Magnesium	mg/l Mg	4,9	5,5	6,7	6,0	6,8
		mval/l	0,40	0,45	0,55	0,49	0,56
		% mval	9,9	11,0	13,4	13,6	16,2
	Sodium + potassium	mg/l Na	17,3	14,4	11,0	11,4	9,0
		mval/l	0,75	0,63	0,48	0,50	0,39
		% mval	18,6	15,4	11,6	13,8	11,2

In the group of anions, hydrogen carbonates prevailed quantitatively (143—207 mgl HCO_3'), chlorides and sulphates occured in markedly lower concentrations (13.5—17.4 mg/l Cl′ and 10.2—24.6 mg/l SO_4).

Table III presents quantitative characteristics of ionic composition of water in the Lake Wierzysko. Arithmetical means of concentrations of respective ions of the sites 4, 6, 8 and 9 were taken here as a basis for calculations. Natrium and potassium concentrations were calculated from the sums of ionic equivalents.

It results from the data presented in Table III that the average ratio of equivalents of the main cations that occur in water of the Lake Wierzysko is as follows: Ca : Mg : Na = 72 : 13 : 5, and that of anions: $HCO_3 : SO_4 : Cl$ =

= 81 : 8 : 11. According to Alekin's (1956) hydrochemical classification of natural waters, water of the Lake Wierzysko should be referred to the hydrogen-carbonate class of calcium group, type II.

6. CHEMICAL RELATIONS IN TRIBUTARIES FEEDING THE LAKE

Chemical composition of water in the river Wierzyca and in both ditches carrying water into the lake is given in Table II. During examinations, water from the Wierzyca river revealed a high oxygen content (approximate to saturation state), low biochemical demand for oxygen, and not too high other coefficients of organic pollution. It showed an average degree of mineralization, its content of lithon being 135—212 mg/l. Biogenic elements were found in average quantities and in harmonic relations, a fact proving the mean eutrophic degree of water, characteristic of a stream in natural state.

Ditch 1 carried on water characterized by a fairly high concentration of dissolved substances (278—553 mg/l) with a predominance of mineral components that contain biogenic elements in an easily assimilable form. The organic pollution, computed from mean BOD_5 (40 mg/l O_2) corresponded to 430 kg O_2 per day. Water discharged into the lake through ditch 1 revealed a troubled-grey colour, a specific smell of municipal sewage, and contained a great deal of suspension, particularly, however, numerous fragments of so-colled sewage fungi. Dith 2 carried on water with increased amount of lithon (29.4 mg/l) and of higher oxidability (10.5 mg/l O_2). Relatively low BOD_5 (1.4 mg/l O_2) proves the presence of a considerable content of humus type substance.

7. CONCLUSIONS

The features of water milieu of the Lake Wierzysko, discussed in this paper, originated mainly due to the natural conditions and artificial factors that, for the most part, were connected with the sewage of the town Kościerzyna. For a long time, it has affected the water basin under consideration. Running water and vast catchment basin caused that the lake acquired a considerable fertility, particularly if we take into account that the catchment area consisted of fields. (Olszewski, Tadajewski 1959). The river Wierzyca, beside dissolved substances, carried also large amounts of bottom drift, organic suspension and detritus. This material was laid down in the lake, thus causing a strong and quick shallowing of the basin. These processes involved also autochthonous material and that eroded of the adjacent hills. Sewage carried on through ditch 1 still deepened the process of eutrophization, and in the zone adjacent to the mouth caused a strong shallowing of the basin owing to a deposition of decaying organic matter. Dissolved sewage substances, characterized by a greater specific weight than that of lake water, flowed down the basin slopes into a channel, where they accumulated and amassed. The rate of the shallowing of the basin can be best illustrated when comparing the changes in maximum depth: in 1902 it was 10 m (Seligo 1902), in 1930 — 9 m (Ramułt 1931), and at present only 7.6 m. A strong biological production, developing on the substratum of natural and artificial fertility, exceeded any possibility to mineralize the originating organic substance, and contributed to the increase in deposition of material, and to a formation of rich deposits of bottom sapropels. These deposits influenced the conditions that prevailed in water environment, in particular the gas balance of the basin, and caused, even under conditions of short-lasting stagnation, a decline in oxygen concentration in deep layers, as well as formation of sulphide hydrogen layer. This is why there is such a considerable difference in oxygen content between the surface and bottom layers (11.3—0.0 mg/l O_2), in spite of a small depth (7.6 m), and a fairly good water exchange. The sapropel deposits are absent only within a narrow littoral zone that, for the most part, is covered with numerous fragments of higher plants and of animal remains (shell mud).

A striking deficiency in oxygen in winter, and partly in summer seasons, and the presence of sulphide hydrogen in the near-bottom zone, made greater part of the bottom inaccessible for fish, thus excluded it from fish production. The lake area under the direct influence of the sewage is estimated to be about 20 ha. The remaining part of the basin shows some traces of secondary influence, seen in composition of water and sediments. The horizontal distribution of chemical indices of pollution does not show any distinct expansion in a definite direction. The extent of pollution seems to depend upon the direction of water movement due to wind action. Uncovered southern shore markedly weakens the wind action from side directions, and causes that decisive effects are due to the winds blowing along the lake axis. Thus, the direction of produced currents is perpendicular to the line which connects the point of sewage outlet and the region of the Wierzyca river outflow. Such a situation was favourable for the pollution that extended over the western and middle parts of the lake, in particular along the maximum depth, as it is reflected in the chemical relations prevailing in that area. Site IV, i.e. the north-eastern part of the lake, where water of the Wierzyca river is of a considerable importance, belongs to the poorest regions. Both the middle and south-western (site VI) parts were most polluted; a highly developed eutrophy was observed there, since just along these directions the compensation currents pushed down the bottom layers of water charged with sewage compounds. In the south-western part of the Lake, the situation was deteriorated by stagnant water.

The evaluation of the trophic level of water could not have been made on the basis of a decrease in contents of nutrients during vegetative period (Minder 1926) since their loss was continuously completed by the tributaries. A restricted use of this factor has been considered by Ohle (1934), who stressed its dependence upon a number of other factors. In the Lake Wierzysko, the processes of biological production and those of decomposition of organic substance take place under dynamical conditions and under a continuous inflow of substrates and outflow of some portion of the matter produced and transformed. According to Findenegg (1955), the processes in such an environment can be estimated by means of average concentrations of the substance in trophogenic zone. Some biogenic elements were always found in this layer, even in the periods of maximum intensity of vegetation.

Both high temperature of deep layers and low thermal gradients of metalimnion point to a low stability of stratification, thus proving a possibility of easy interstratal exchange of water, i.e. the favourable conditions for supply of nutrients from bottom resources.

The lake is at the boundary of polymixy, and shows an intermediate type between the II and III degrees of stability in Patalas classification

(1960 a). According to Aoberg and Rhcde scheme (1942), the lake can be referred to metastable stratified basins.

The markedly developed epilimnion of the lake strongly charged the deep layer and caused a considerable deficiency in oxygen, also a great accumulation of bottom sediments. The inflow of sewage increased these processes markedly and caused that under conditions of feebly developed thermal stratification, i.e. under fairly good dynamical conditions, a distinct oxygen stratification appeared.

Based on four main coefficients applied for typology of the lakes in the Suwałki region (Stangenberg 1936), we can include the Lake Wierzysko among eutrophic basins. This classification is also proved by the evaluation made, according to Yoshimura (1931) on the basis of pH of water.

The changes that appeared in the last 28 years in the water environment of the Lake Wierzysko are considerably high. It results from the paper by Ramułt (1931) that in the thirties the lake under consideration could have been qualified to type II of Lityński classification (1925); this could correspond to a not too far advanced eutrophy. The present degree of eutrophization is rather high. Further increase of this process considerably depends upon the sewage problems to be solved in the town Kościerzyna.

8. SUMMARY

The present work is a fragment of the studies on the development of hydrochemical relations in the lakes polluted with sewage waters. The Lake Wierzysko, situated within the Kaszuby Lake District, was an object of the studies. Its area is about 60 ha, and maximum depth amounts to 7.6 m. Owing to the river Wierzyca, it represents a open drainage lake. Municipal sewage of the town Kościerzyna is the source material of pollution in the basin investigated.

Observations on the lake and on its tributaries were carried out at sites selected on the basis of hydrological situation and of morphological conditions. The results of the investigations were presented in the form of tables and diagrams.

Measurements have demonstrated that thermal conditions in the lake are not characterized by any more considerable changes in temperature in both vertical and horizontal extents. Thermal stratification was found to appear only during winter stagnation, at the maximum temperatures, from 2.5°C to 3.6°C, in deep water layers.

The thermal character of the lake points to a good mixing of its water masses. This is why we should regard it as a lake approximate to polymictic type (Wiszniewski 1953).

During the period of study, oxygen conditions of lake water ranged from 53% to 136% of saturation. A distinct stratification was ascertained in the vertical distribution of oxygen. In winter, a sharp oxycycline commenced at a depth of 1 m with a gradient amounting to 5.3 mg/l/m O_2; at a depth of 5 m already anaerobic zone began. On the basis of the distribution of oxygen concentrations at the deepest site it was calculated that the greatest oxygen reserves appeared in spring (26.4 t O_2). In the period from June to August, a volume of about 5.7 t oxygen was used.

The total amount of substances dissolved in lake water was 154—281 mg/l. Organic compounds, easily decomposing under conditions of biochemical processes were fairly important (BOD_5 reached a value of 10.7 mg/l O_2). High concentrations were also found of such biogenic substances as nitrogen (up to 2.63 mg/l N og) and phosphorus (up to 0.20 mg/l P_{PO_4}). Among cations calcium predominated (44.7—65.9 mg/l Ca) and among anions hydrogen carbonates were 143—207 mg/l HCO_3. Average ratio of equivalents of main cations was as follows: Ca : Mg : Na = 72 : 13 : 5, and that of anions — $HCO_3 : SO_4 : Cl$ = 81 : 8 : 11.

According to Aleksin's hydrochemical classification (1956) the Lake Wierzysko should be referred to the calcium group, type II.

The analysis of the results also illustrated that the river Wierzyca, characterized by poor water, had been of fundamental importance in development of biotope of the lake in study. On the other hand, the municipal sewage, flowing into the lake, were responsible for the strong eutrophic character of this basin.

9. STRESZCZENIE

Praca omawia wyniki pomiarów i badań hydrochemicznych przeprowadzonych w pełnym cyklu rocznym na jeziorze Wierzysko (Pojezierze Kaszubskie) w latach 1957—1958. Na tle charakterystyki morfologicznej i hydrologicznej zbiornika rozpatrzono szczegółowo termikę i chemizm wód jeziora oraz cieków z nim związanych, porównując ze stosunkami panującymi w innych jeziorach Polski.

Wyniki badań wykazały, że zasadnicze znaczenie dla formowania się własności biotopu jeziora posiada rzeka Wierzyca, a poza tym silny wpływ eutrofizujący wywierają odprowadzane do jeziora ścieki miasta Kościerzyny.

Rozpatrzono zakres oddziaływania ścieków na jezioro oraz zmiany zachodzące pod ich wpływem w środowisku wodnym.

Obliczono budżet tlenowy jeziora oraz podano charakterystykę składu jonowego wody w poszczególnych porach roku.

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DISTRIBUTION OF NITROGEN BACTERIA IN WATER OF THE OŁAWA RIVER IN RELATION TO ITS CHEMICAL CHARACTER

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ABSTRACT

Studies were made of chemical and bacteriological characteristics of the Oława river at eleven sites. Observations were made of the activity of protein hydrolyzing, nitrifying, denitrifying and fixing free nitrogen bacteria. The quantitative and qualitative changes were especially conspicuous during the sugar campain. In this period highest numbers of proteolitic bacteria were found, in the remaining periods the non-sporing ammonifying bacteria predominated. The nitrifying processes were hindered in the periods of strong pollution of the river. Denitrificators were found to be most abundant in the region of sugar factory wastes. A clear dependence was observed between numbers of denitrifying bacteria and BOD_5.

CONTENTS

1. INTRODUCTION AND PROBLEM

Circulation of nitrogen has been studied extensively as regards soil environment. Data concerning water environment are relatively scarce and, for the most part, based on the results of soil science.

Metabolism of nitrogen compounds by bacteria in lakes was studied by KLEIN and STEINER (1929), RAKESTRAW (1936), COOPER (1937/38) and recently by KUZNIETZOV (1952). The number of nitrogen bacteria in relation to fertilization was examined by Rodina (1958, 1959). Transformations of nitrogen compounds and microbiological characteristics of small astatic ponds were investigated by Fischer (1960, 1961).

The importance of such researches in rivers was stressed by Stundl (1943), who performed laboratory experiments with polluted river water. During seasonal studies Dijanova and Voroshilova (1952) analysed the influence of temperature on the number of saprophytic bacteria in river. Nitrogen fixing was investigated by Jensen (1955), who isolated 12 strains of Azotobacter from Danish rivers. Recently, an attempt was made (Pawlaczyk and Solski 1965) to examine quantitative changes of nitrogen bacteria in the river Ślęża, in the light of chemical composition of water during the season 1962/63.

Analogically to the paper mentioned above, 4 groups of nitrogen bacteria have been distinguished in the Oława river: (1) protein-decomposing, (2) nitrifying, (3) denitrifying and (4) nitrogen-fixing bacteria.

On the basis of the number of bacterial cells in the individual physiological groups, and of the content of mineral (nitrites, nitrates, ammonia) and organic nitrogen, an attempt was made to explain certain processes occurring in the river.

2. MATERIALS AND METHODS

The investigations discussed in this paper were carried out from May 28, 1962 to May 28, 1963. Water samples were taken monthly at 11 stations situated along the river course (Fig. 1).

Samples for bacteriological examinations were taken at the surface, directly into sterile bottles, and those for chemical analyses — at the depth

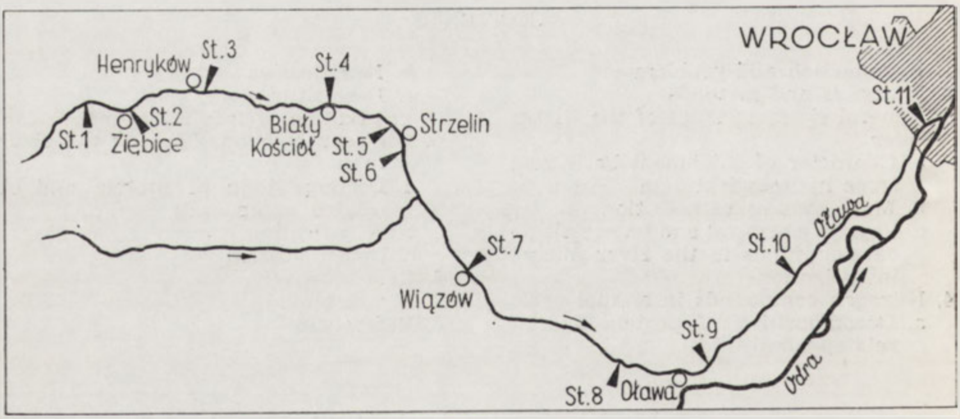

Fig. 1. Location of water sampling sites along the Oława river course during investigations from 28.V.1962 to 28.V.1963

of 30 cm, by means of Ruttner sampler. In summer, the bacteriological samples were kept during transportation in thermos-flasks with ice. The chemical analysis ow water were made at the Chair of Limnology and Fishery, College of Agriculture in Wrocław, according to Just and Hermanowicz (1955).

Microbiological tests were executed at the Chair of Biology and Hygiene, Technical University, Wrocław. The total number of bacteria in water was determined by means of plates with agar medium.

Cultures were incubated at 20°C for 72 hours and at 37°C for 24 hours. Coli titre was determined as well. From definite physiological groups only nitrogen bacteria were distinguished using selective media.

The number of protein-hydrolyzing bacteria was determined on broth solidified with 15—20% gelatine. Approximate amount of ammonifying microorganisms was evaluated by means of dilution method on broth with 3% peptone. The appearance of ammonia, hydrogen sulphide or indole in these cultures was demonstrated according to Fiodorov (1952). In addition, the examined water in dilutions 10^{-1}—10^{-4} was inoculated in three parallel replications on nutrient agar and colonies were counted after a four-day incubation at 28°C. In order to detect spore-forming ammonifying bacteria similar dilutions of water were heated in a water bath at 80°C for 10 min., inoculated and incubated analogically to non-sporing ammonifying bacteria.

The number of both groups of nitrifying bacteria was estimated by means of dilution method on selective media prepared according to Wincgradski (19.). The production of nitrite from ammonia was proved using sulphanilic acid and alphanaphtylamine, that of nitrate from nitrite was shown using concentrated sulphuric acid and diphenylamine.

The number of denitrifying bacteria was estimated by means of dilution method on broth with potassium nitrate added. The reduction of nitrate was checked using starch and acidified potassium iodide after Rosanov (1957).

The determination of the number of nitrogen-fixing bacteria was made by inoculation (in three parallel replications) of water in dilutions 10^{-1}—10^{-4} on a nitrogen-free medium according to Fiodorov (1952), and by subsequent counting of colonies.

3. GENERAL CHARACTERISTICS OF THE OŁAWA RIVER

A. CHARACTER OF CATCHMENT BASIN AND SOME HYDROLOGICAL DATA

The total length of the river in study is 99.5 km, the catchment area to the left of the Odra river being 989 km². In the upper course of the river (stations 1—4), the bottom is built up of boulders and gravels. In the middle and lower courses (stations 5—8) it is sandy, and downstream of the town Oława (stations 9—11) silt has been found to appear in many places. Both boulder bottom and banks of the river are found only at a few places of the upper course. At both middle and lower sections, the bottom is built up of humus clay and of peats.

At the upper course, the river gradient amounts to 3.53‰, at the middle one — 0.9‰, whereas at the lower course it is 0.36‰. The upper portion of the river reveals a submountain nature characterized by a low annual discharge; near Wrocław, the stream flow is insignificant.

Hydrological observations on the Oława river are conducted by the State Hydrological and Meteorological Institute at only one water-level gauge section near Oława (Tables I and II).

It results from the comparison of the water-levels recorded at Oława

Table I

Water level and amount of flow of Oława river at the Oława watergauge-section, in the period from 28 May, 1962, to 28 May, 1963, as reported by PIHM of Wrocław

Date	water-gauge indication cm.	flow m^3/sec	Date	water-gauge indication cm.	flow m^3/sec
28.V.62	182	4,13	28.XII.62	145	1,66
23.VI.62	134	1,04	14.II.63	176	3,68
3.VIII.62	126	0,644	7.III.63	190	4,78
30.VIII.62	122	0,468	2.IV.63	199	5,61
2.X.62	132	0,930	29.IV.63	148	1,84
29.XI.62	146	1,72	28.V.63	172	3,39

Table II

Characteristic water level data of Oława river at the Oława water-gauge-section in the period from 1953 to 1962, as reported by PIHM of Wrocław

Year	Min	average	Max	Year	Min	average	Max
1953	120	153	310	1958	120	156	352
1954	120	146	260	1959	104	139	216
1955	120	150	266	1960	107	142	230
1956	—	149	350	1961	114	141	207
1957	120	156	240	1962	119	151	288

Max. absol. 380 cm. 4.IX.1938. Min. absol. 80 cm. 8—9.VII.1940

during the investigations with the characteristic water levels noted from 1953 to 1962 (Table II) that in three cases the water levels were lower than those of the last decade, three times they corresponded to their mean value, and in the remaining periods of sampling they exceeded the mean level. Both water levels and flows from 14.2. and 7.3.1963 should be accepted tentatively, since at that time the river was frozen and ice cover was 35 and 52 cm in thickness. The winter 1962/63 was unusually severe, and ice cover of the river near the town Oława was observed from 28.12.1962 to about mid March 1963.

Mean values of the characteristic water levels of the Oława river near Oława in the last decade (1953—1962), and calculated flows of water were as follows:

	Min.	Mean	Max.
water-gauge indication (cm)	116	148	272
flow (m^3/sec)	0,28	1,84	19,20

Ratio — Minimum : Average : Maximum = 1 : 6.6 : 69.

It can be inferred from the data mentioned above that the amount of water carried on by the Oława river is insignificant.

B. MAIN SOURCES OF POLLUTION

A list of main sources of pollution, and their short characteristics are presented on Table III. A comparison shows that the main centres of pollution

Table III

Characteristics of the more important pollution

Source of pollution	Treatment of waste waters	Recipient
Sugar — factory "Ziębice"	sedimentation pools, filtration fields	Oława river
Vegetable-food conserve factory, Ziębice-Town	partly sewage canals, partly filtration fields	Oława river
Ziębice—Town (Ceramics, Brewery) and Gas factories	mechanical and biological, sedimentation pools	Oława river
Village—Henryków	mechanical and biological, filtration fields	Oława river
Sugar factory "Strzelin'	sedimentation pools, filtration fields	Oława river Ślęza river
Strzelin—Town (Stone mine, Gas and Food conserve factories)	mechanical and biological, sedimentation pools irigated fields	Oława river
Village—Wiązów (Infectious Hospital)	local treatment plant	Oława river
Oława—Town (Mineral pigments Synthetic stuffs, Gas and Railway factories)	local treatment plant	Oława river Odra river
Village — Siechnica	local treatment plant	Oława river
Electric power station "Czechnica"	circulation reservoir	Oława river
Steel factory in Siechnica	local treatment plant	Oława river
Wrocław—Town, Quarter Brochów vegetable-food conserve factory	sedimentation pools	Stream—Brochów (Oława affluent)
Soap factory, Wrocław—Town	nonpurified	Oława river
Refrigerating stocks, Wrocław—Town	nonpurified	Oława river

are found in four regions almost regularly distributed along the entire river course (Fig. 1): 1 — Ziębice (90 km), 2 — Strzelin (62 km), 3 — Oława (32 km), 4 — near-mouth sector Wrocław-Brochów.

The list (Table III) disregards the industrial works that release their waste waters to the municipal sewage system, or whose waste waters are produced in small amounts.

C. PHYSICO-CHEMICAL AND BACTERIOLOGICAL CONDITIONS IN THE RIVER DURING INVESTIGATION

Table IV illustrates the range of variations of the individual chemical substances in water, and of bacteriological data ascertained during the investigations carried on in two periods: a period of sugar industry campaign and an inter-campaign period.

Range of variation of chemical composition and bacterial indicators of Oława river, from the

Determination	Site along the river	1 (94.0)	2 (87.0)	3 (79.0)	4 (69.0)
Colour mg/l Pt	A	20—70	30—60	25—50	30—90
	B	10—35	60—150	60—150	50—90
pH	A	7.6—8.2	7.9—8.2	7.5—8.05	7.3—8.0
	B	7.9—8.0	7.5—7.6	7.5—7,7	7.5—7.7
Oxygen saturation %	A	71.9—101.7	80.3—109.2	10.7—73.6	26.6—76.1
	B	81—86.4	21.2—38.9	8.6—37.5	17.2—28.9
Ammonium mgN_{NH_4}/l	A	0.06—0.50	0.44—0.70	1.20—5.40	0.80—3.60
	B	0.01—0.04	0.03—11.00	3.80—7.50	0.96—6.00
Nitrite mgN_{NO_2}/l	A	0.006—0.030	0.010—0.024	0.000—0.160	0.020—0.200
	B	0.006—0.014	0.280—0.700	0.000—0.015	0.006—0.080
Nitrate mgN_{NO_3}/l	A	0.15—2.70	0.60—1.60	0.10—2.50	0.20—1.50
	B	0.35—0.70	0.10—0.70	0.10—0.20	0.05—0.20
Organic nitrogen mgN/l	A	0.30—1.80	0.76—1.06	0.50—2.54	0.60—2.50
	B	0.40—0.82	2.66—8.76	3.50—7.26	2.90—3.76
Total Hardness mg $CaCO_3/l$	A	275—325	305—330	310—340	280—295
	B	305—320	405—850	445—635	390—455
Dry residue mg/l	A	420—748	446—594	460—633	422—634
	B	433—478	598—1446	769—1191	642—705
Oxygen demand mgO_2/l	A	8.0—21.4	10.2—17.4	12.6—30.0	12.0—27.6
	B	2.8—6.1	24.2—123.0	40.0—113	20.4—36.5
$BOD_5 20°C$ mgO_2/l	A	0.8—4.5	3.0—6.9	4.3—36.5	1.6—16.6
	B	2.2—3.0	59—474	134—336	70.4—118
Number of bacterial colonies on agar, 37°C, 24h $\times 10_3$	A	0.6—72	3.7—15	0.6—260	0.9—135
	B	0.1—7	37—2000	674—3619	19—1450
Number of bacterial colonies on agar, 20°C, 72h $\times 10^3$	A	2.1—162	21.8—29.5	27.8—279	4—127
	B	1—54	125—4744	864—8000	37—3850
Coli titre	A	10^{-1}—10^{-7}	10^{-1}—10^{-3}	10^{-3}—10^{-8}	10^{-2}—10^{-8}
	B	10^{-1}—10^{-3}	10^{-5}—10^{-10}	10^{-6}—10^{-10}	10^{-4}—10^{8}
Temperature 0°C	A	2.0—18.0	2.3—15.6	2.1—18.2	0.4—18.4
	B	0.3—6.8	5.6—9.8	0.8—9.2	0.2—7.3

This division results from a considerable quantitative and qualitative differences in both chemical and bacteriological features of water, and stresses the value of river contamination brought about by two sugar factories (Ziębice and Strzelin) during their work season.

The influence of sewage water upon the Oława river is expressed by an increase in value of various chemical indices of pollution. The highest pollution was observed at station 2, where organic nitrogen contents reached up to 8.76 mg/l, ammonium salts (as ammonia nitrogen) — up to about 11 mg/l, and BOD_5 — 474 mg/l O_2. The quantity of the bacterial colonies grown up on agar at a temperature of 20°C reached, after 72 hours, about 4.700.000 in 1 ml water.

A short river sector (about 10 km), stretching from the river head to Ziębice, was found to be slightly polluted or completely pure. Downstream of the locality Ziębice, as far as Biały Kościół, the river was strongly, periodic-

Table IV

springs to mouth, within one-year observation, 1962/63. A — intercampain period, B — sugar period

6 (60.5)	7 (51.0)	8 (35.5)	9 (31.0)	10 (18.5)	11 (1.0)
25—85	35—50	20—35	10—45	20—35	10—30
80—100	50—65	40—45	35—45	35	20—35
7.25—7.9	7.5—7.95	7.2—8.0	7.2—7.9	7.3—7.9	7.0—7.9
7.4—7.6	7.4—7.7	7.4—8.0	7.4—7.8	7.3	7.1—7.6
22.6—74.8	49.7—79.8	45.5—81.7	48.8—83.8	10.8—77.4	11.7—15.6
1.6—25.7	13.1—51.2	42.6—79.6	59.5—82.8	32.2	50.1—62.9
1.60—6.40	0.30—2.20	0.06—1.20	0.50—12.00	0.30—6.50	0.06—3.10
0.28—6.80	0.08—1.60	0.04—1.20	2.20—6.80	7.20	0.40—3.60
0.000—0.700	0.017—0.200	0.008—0.180	0.020—0.450	0.017—0.800	0.008—0.160
0.000—0.040	0.044—0.052	0.016—0.028	0.012—0.024	0.120	0.012—0.064
0.20—2.10	0.30—3.00	0.30—5.00	0.35—3.50	1.80—5.00	0.30—4.00
0.05—0.50	0.30—1.50	0.70—1.70	1.50—2.00	8.00	0.70—4.00
0.90—2.86	0.81—2.50	0.54—2.10	0.62—2.70	0.60—1.60	0.48—1.48
3.16—4.80	1.16—1.98	0.60—1.64	1.16—2.70	—	0.48—0.86
275—345	240—265	215—265	220—325	215—260	250—285
385—430	260—310	270—300	275—305	260	300—380
441—627	402—765	367—454	418—549	403—531	433—648
583—709	425—446	416—467	450—480	448	494—727
12.0—37.2	10.0—30.2	5.6—14.8	7.5—18.0	9.2—16.2	8.4—17.6
33.0—41.2	8.6—14.4	6.3—14.2	7.0—11.4	7.5—11.4	6.7—10.8
1.6—44.2	1.5—6.5	1.2—6.2	1.0—6.2	1.4—4.6	1.4—9.6
62.4—112	5.1—18.0	2.8—4.2	4.2—4.7	4.1	1.4—3.1
1.6—171	0.7—141	0.1—24.8	0.4—95	0.1—36	0.2—72
226—1513	63—1004	19—179	8—194		1—10
22—426	1—157	1.4—56	4.7—180	0.7—149	0.3—109
585—4426	76—975	158—1177	11—839		10—56
10^{-4}—10^{-9}	10^{-1}—10^{-6}	10^{-1}—10^{-6}	10^{-1}—10^{-6}	10^{-1}—10^{-4}	10^{-1}—10^{-6}
10^{-6}—10^{10}	10^{-1}—10^{-6}	10^{-2}—10^{-5}	10^{-1}—10^{-3}		10^{-1}—10^{-2}
0.8—18.2	2.4—18.8	0.5—18.1	0.4—18.2	2.6—19.0	0.4—25.5
0.4—7.7	0.4—6.7	0.4—6.6	0.6—6.5	—	0.8—7.0

ally, even very strongly polluted. The same was observed at a sector between Biały Kościół and Strzelin. Downstream of Strzelin, water revealed also a high degree, periodically, very high degree of pollution. Beginning from Wiązów (51 km), a considerable improvement was observed, as far as the town Oława. Downstream of the town (31 km), the river disclosed at times a conspicuous pollution, too, whereas near Groblice (18 km) again an improvement was noted.

At the embouchure to the Odra river, water of the Oława river was practically pure, showing some features of stagnant water, and traces of previous contamination (high content of ammonium salts, nitrates, sodium and calcium). It is evident from Stangenberg's elaboration (1962) that the sewage flowing into the Oława river within the Wrocław area does not exert any considerable negative influence on the chemical composition of water.

Between Ziębice and Wiązów, the Oława river is highly polluted also during the inter-campaign period. This is due to the industrial wastes (Table III) and municipal sewage, and to a feeble water flow in the river, as well.

4. NITROGEN COMPOUNDS IN ANNUAL CYCLE

A. DECOMPOSITION OF PROTEIN AND OF RELATED COMPOUNDS

Organic nitrogen compounds that occur in water of the Oława river and include both proteins and products of their partial decomposition, have been determined as organic nitrogen. In estimating the mineralization intensity of proteins, the following groups of bacteria were taken into account: proteolytic as well as non-sporing and spore-forming ammonifying bacteria.

Since in natural microbe associations typical proteolytic bacteria compete with typical ammonifying bacteria, and metabiosis of these two groups coincides, some difficulties arise in drawing a detailed boundary between the groups of microorganisms, that are responsible for preliminary hydrolysis of proteins, and the group of ammonifying bacteria. Thus, in our considerations, the entire process of protein decomposition, up to ammonia, has been discussed together.

To find a relation between the content of organic nitrogen in water and the number of protein-decomposing bacteria, a series of diagrams were made for the individual stations (Figs. 2a—5a). A positive correlation was found to occur between organic nitrogen and the number of protein-hydrolyzing bacteria at 3 stations (Figs. 2, 3 and 4) strongly contaminated by sugar wastes at the autumn-winter season (Figs. 3a—5a). Among the three determined physiological groups of bacteria, the most stable non-sporing ammonifying bacteria prevailed, showing the greatest dependence upon the content of organic compound in water.

A group of proteolytic bacteria predominated only during the sugar industry compaign (Figs. 3a, 5a) — a period characterized by the highest content of organic nitrogen found in the Oława river.

On the other hand, a strong quantitative increase in proteolytic bacteria at all the stations on the 28.5.1963 (Figs. 2—5a) can hardly be explained.

The highest content of ammonia in water, found along with the maximum quantities of organic nitrogen and of protein-hydrolyzing bacteria proved the intense process of decomposition of organic nitrogen compounds (Figs. 3—5b). The optimum fell on December (28.12.1962), when water temperature was lower than that in the previous periods and did not exceed 1°C, and nevertheless did not hinder the development of protein-decomposing bacteria. Viehl (1935) states that decomposition of organic substances found in the sewage waters can proceed in a river also under low temperature and under high oxygen concentration.

B. NITRIFICATION

The quantitative changes in nitrifying bacteria of both phases were examined in relation to the concentrations of ammonium, nitrite and nitrate ions. A high correlation was ascertained between the contents of nitrates in water the number of bacteria of the second phase (Fig. 5b), although this relation between the nitrites and bacteria of the first phase was not observed.

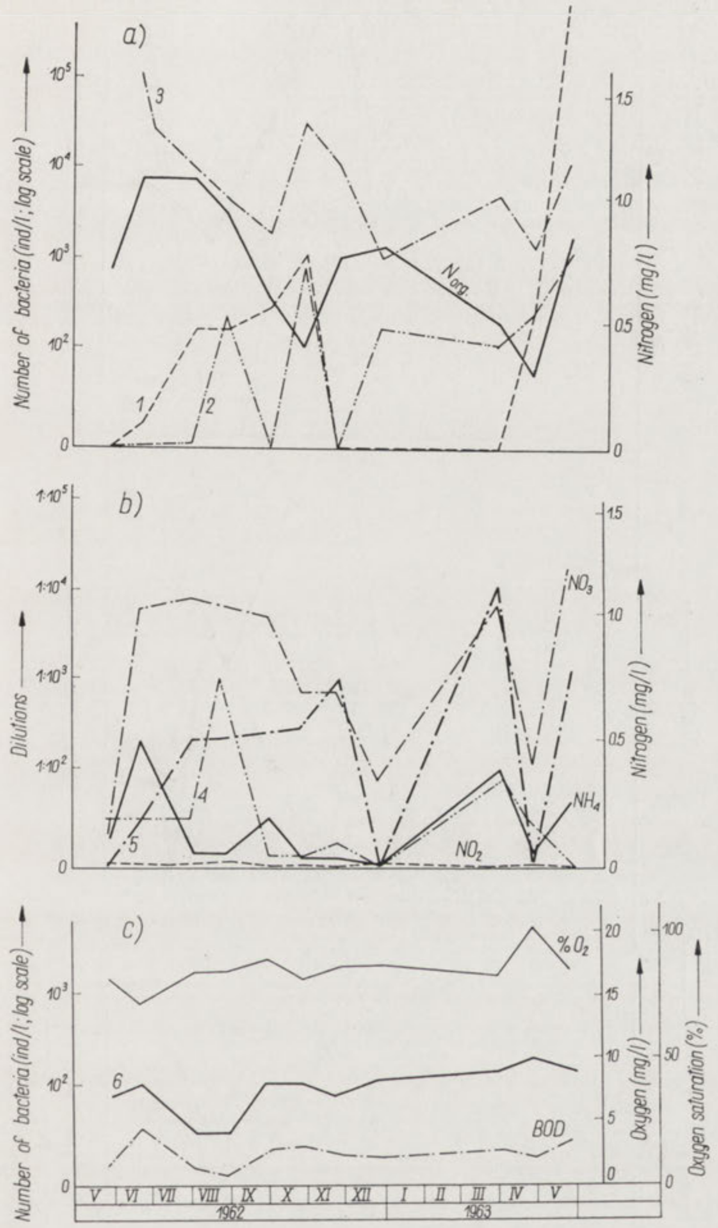

Fig. 2. Development of nitrifying bacteria in the light of some chemical components in water of the Oława river at station 1, from 28.5.1962 to 28.5.1963
a — incipient decomposition of protein, b — nitrification, c — denitrification. 1 — proteolysing bact., 2 — deamin. c. bact. (spore-form.) 3 — deamin. c. bact. (non spore-form.) 4 — nitrifying bacteria I, 5 — nitrifying bacteria II, 6 — denitrifying bacteria.

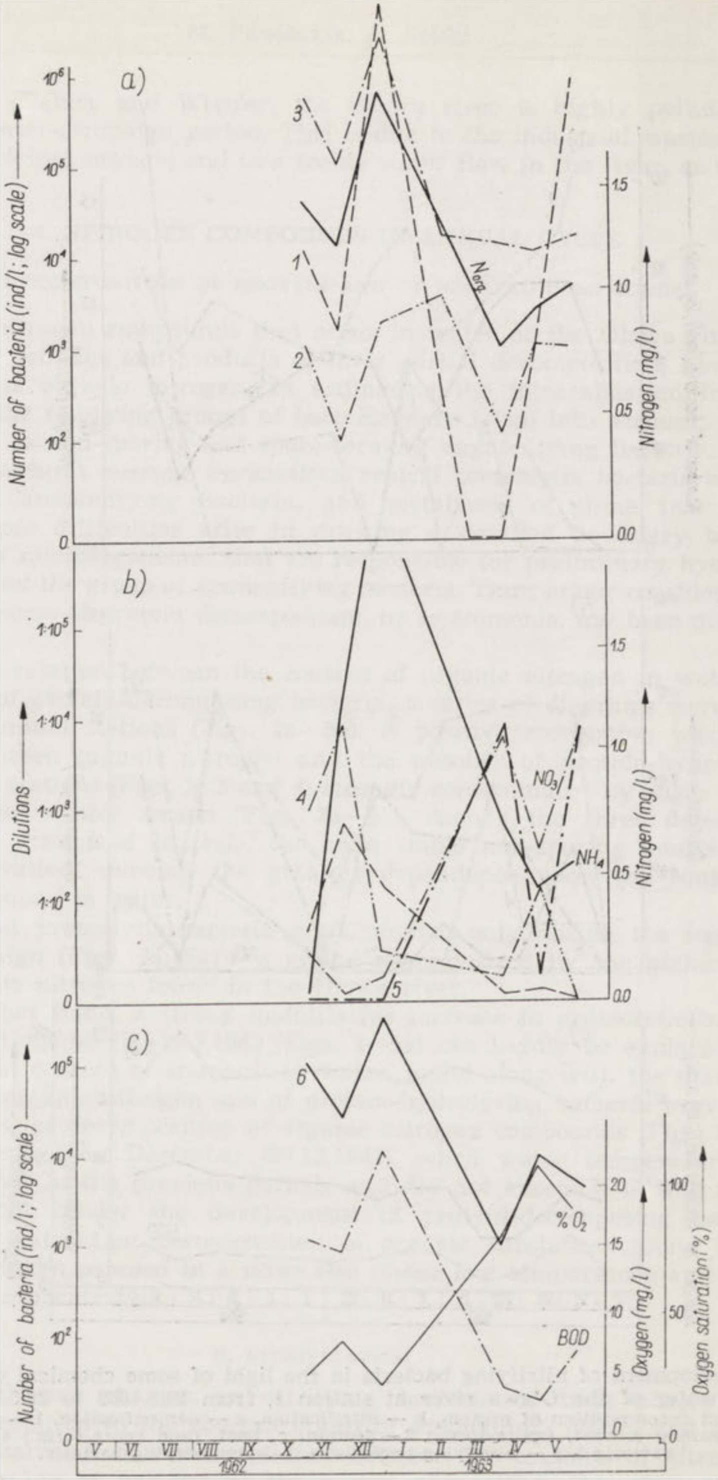

Fig. 3. Development of nitrifying bacteria in the light of some chemical components in water of the Oława river at station 2, from 28.5.1962 to 28.5.1963

a — incipient decomposition of protein, b — nitrification, c — denitrification. 1 — proteolysing bact., 2 — deamin. c. bact. (spore-form.) 3 — deamin. c. bact. (non spore-form.) 4 — nitrifying bacteria I, 5 — nitrifying bacteria II, 6 — denitrifying bacteria.

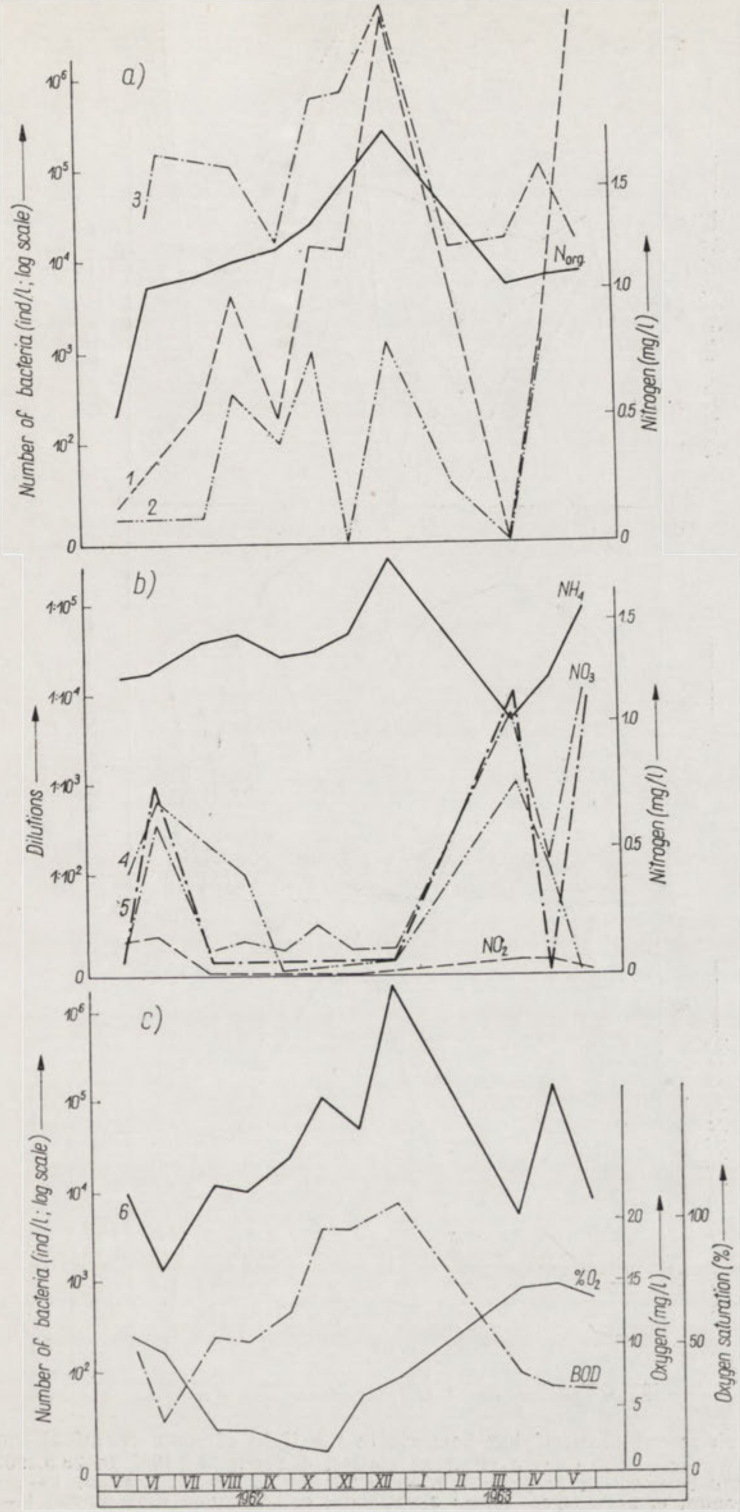

Fig. 4. Development of nitrifying bacteria in the light of some chemical components in water of the Oława river at station 3, from 28.5.1962 to 28.5.1963
a — incipient decomposition of protein, b — nitrification, c — denitrification. 1 — proteolysing bact., 2 — deamin, c. bact. (spore-form.) 3 — deamin. c. bact. (non spore-form.) 4 — nitrifying bacteria I, 5 — nitrifying bacteria II, 6 — denitrifying bacteria.

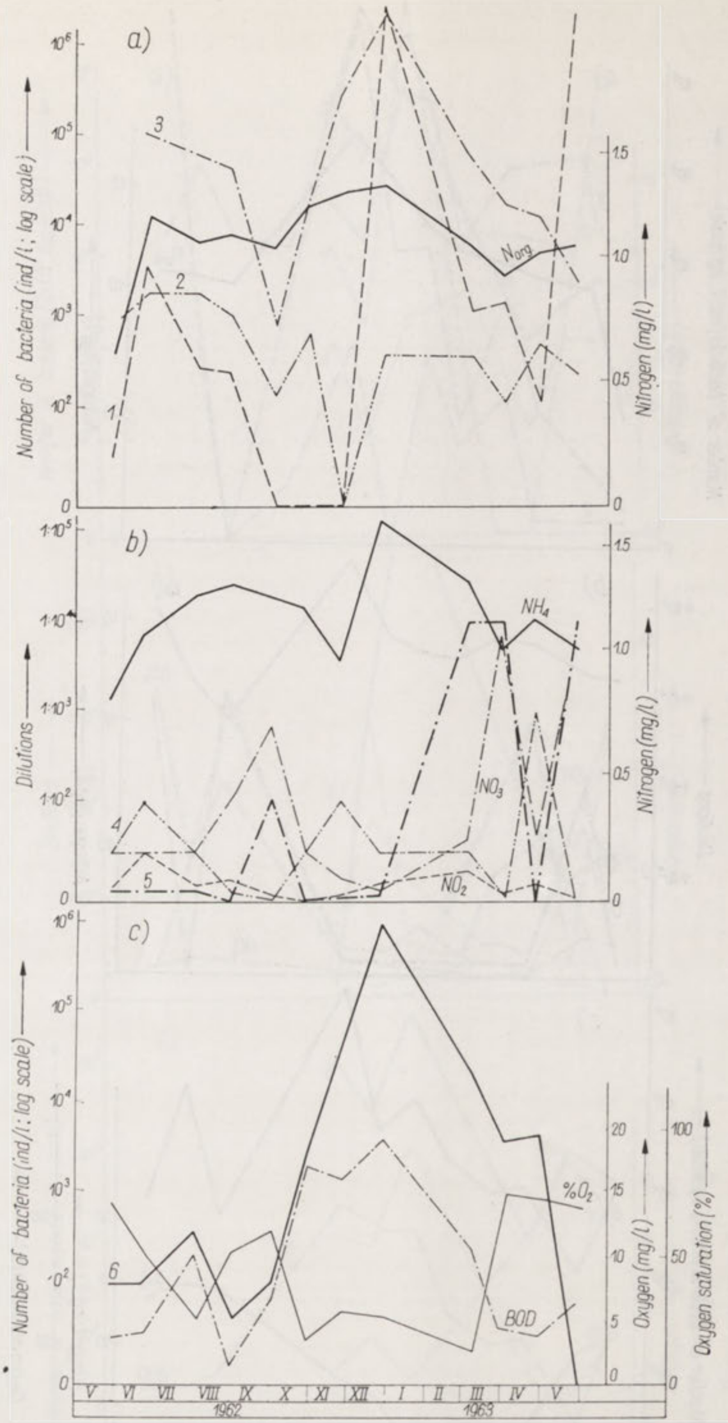

Fig. 5. Development of nitrifying bacteria in the light of some chemical components in water of the Oława river at station 4, from 28.5.1962 to 28.5.1963

a — incipient decomposition of protein, b — nitrification, ç — denitrification. 1 — proteolysing bact., 2 — deamin. c. bact. (spore-form.) 3 — deamin. c. bact. (non spore-form.) 4 — nitrifying bacteria I, 5 — nitrifying bacteria II, 6 — denitrifying bacteria.

This might have resulted from a fact that oxidation of nitrites proceeds very fast, mainly due to favourable energetical conditions that, in turn, lead to a rapid transition of nitrites into nitrates. In water with abundant phytoplankton, or with higher plants, nitrates are quickly absorbed during nutrition process and, therefore, nitrification can hardly be observed. In our case, the picture of this process has not been obliterated due to the reasons mentioned above, particularly as concerns winter seasons.

The studies of Rodina (1959) show that nitrifying bacteria are fairly common in water basins. In rivers were found cells from 10 to 1000 in number, in ponds from 1 to 1000 per 10 ml water. With a combined organic mineral manuring, these numbers increased 250 to 500 times. The quantities of the nitrifying bacteria of the first and second phases were, for the most part, equal, or those of the second phase were somewhat lower.

In water of the Oława river the bacteria of the second phase as a rule prevailed over these of the first phase.

Various factors had influenced the nitrification process in the Oława river. This was distinctly observed at stations 2, 3, and 4 during the sugar industry campaign, when the nitrification process ceased owing to the accumulation of considerable quantities of organic compounds (Figs. 3—5b), low temperature of water, and lowering of oxygen content (Figs. 3—5c).

Metabolic products of Nitrobacter restrain biological activity of Nitrosomonas. A similar influence upon Nitrobacter exerts ammonia that forms substrate for Nitrosomonas. Numerous cases of such a dependence have been ascertained to appear in the Oława river (Figs. 3 and 5). According to Rodina (1958) the content of ammonium salts in water, amounting to 5 mg/l, decreases the activity of the bacteria of the second phase. However, even a quantity amounting to 6,8 mg/l of ammonia nitrogen did not hinder the intensity of metabolic processes of nitrifying bacteria of the second phase.

C. DENITRIFICATION

During the investigations, the quantity of denitrifying bacteria in the Oława river ranged from some scores to about 1.500.000 cells in 1 ml water. In lakes, Kuznietzov (1952) has found 6—10 thousand cells of denitrifying bacteria in 1 ml water, whereas in ponds their amount can, according to Rodina (1958), reach up to 100 thousand cells in 1 ml water.

Denitrifying bacteria that occur in water belong mainly to the group facultative anaerobes. For their denitrification activity they need carbohydrates. Lack of these compounds hinders the development of this group of bacteria. Such a phenomenon distinctly appeared within the influence area of sugar industry wastes, where a strong development of denitrifying bacteria was observed (Figs. 3—5c). The number of the bacteria investigated at the station 3 (Fig. 4c) reached 1.5 mil; on the other hand, along the non-contaminated sector of the river (station 1, Fig. 2c), these microorganisms ranged at the time investigations, from 50 to 300 cells in 1 ml water.

This is why a distinct correlation between the number of denitrifying bacteria and BOD_5 (an index of fast decomposing organic pollution) is comprehensible (Figs. 2—5c).

Numerous cases of reverse dependence between the denitrifying bacteria and nitrifying bacteria of the second phase, and the nitrates have also been ascertained (Figs. 3—5bc).

The example given in the present paper and that of the Ślęza river (Pawlaczyk, Solski 1965) allow to state that an intense denitrification took place at the stations strongly contaminated by sugar industry wastes, and led to an impoverishment of water in nitrates. The amount of denitrifying bacteria reflects a high content of organic substances and unfavourable oxygen conditions. The facts mentioned above prove the opinion of Rodina (1959) that after all, the high degree of water saturation in oxygen does not hinder the process of denitrification.

pH of water from the Oława river ranged, at the time of investigations, from 7.0 to 8.2. Thus, it exactly corresponds to the optimum of activity of the bacteria under consideration.

D. FIXATION OF FREE NITROGEN

Fixation of free nitrogen in water is due to aerobes, mainly to Azotobacter and anaerobes — Clostridium pasteurianum (Waksman et al. 1933). Azotobacter is thought to be an oxyphilous organism, but it can occur in water characterized by various oxygen contents, too (Rodina 1959). Since water samples taken at the surface and the incubation conditions corresponded to the requirements of aerobes, the numbers of bacteria given in Table V

Table V

Quantitative variations of free nitrogen fixing bacteria in water of Oława river, in the period from 28 May, 1962, to 28 May, 1963

Date / Site	28.V.62	22.VI.62	2.VII.62	29.VIII.62	2.X.62	29.X.62	26.XI.62	28.XII.62	7.III.63	2.IV.63	29.IV.63	28.V.63
I	no data	300	100	108	280	3,310	13,000	4,000	no data	1,500		9,300
II		no data		no data		940	64,000	2,900,000		4,900		12,400
III		30	40	60	50	1,280	131,000	2,087,000		2,600		8,900
IV		100	80	109	1,410	340	55,000	1,895,000		18,000	11,600	1,500
V		no data					64,000	1,848,000		no data		
VI		102	84	92	60	1,160	50,000	1,221,000		6,500	32,900	9,600
VII		205	100	100	500	390	14,000	750,00		600	20,900	15,400
VIII		32	67	85	650	900	118,000	265,000		5,000	5,200	17,500
IX		54	60	57	3,120	1,800	7,000	636,000		1,900	36,000	28,700
X		105	120	198	2,300	790				200	—	12,300
XI		94	100	102	130	1,430	20,000	23,000		100	2,900	1,700

should be regarded as those of aerobes. The quantities of the bacteria fixing free nitrogen in water of the Oława river, recorded at the time of observations, i.e. from 28.5.1962 to 28.5.1963, ranged from 30 to 2.900 thousands in 1 ml water. The greatest quantities were found to occur at the stations of highest pollution, and during the sugar campaign season.

5. NITROGEN COMPOUNDS ALONG THE RIVER COURSE

A. DECOMPOSITION OF PROTEIN AND OF RELATED COMPOUNDS

It has been ascertained, when analysing the number of protein-hydrolyzing bacteria and the amount of organic nitrogen in water that a considerable differentiation in these bacteria exists along the river course examined (Figs. 6—9a) in spite of a strong water flow due to the river gradient amounting, at a 46 km long sector in the upper course, between head water and Wiązów, to 3.53‰ (coll. work 1948).

Station 1, representing a non-polluted sectors of the river, proved to be poorest in nitrogen. Begining with station 2 (downstream of Ziębice), where organic nitrogen in water reached its maximum during the sugar campaign, a slow decrease was observed in nitrogen quantity, followed by a slight increase at station 6 (downtstream of Strzelin) and at station 9 (downstream of the town Oława). The changes in nitrogen contents in water were accompanied by quantitative changes in proteolytic and ammonifying bacteria. The content of ammonium salts that, as a rule, was correlated with the number of the microorganisms of the group mentioned before, was a proof of an intense activity of bacteria. Fairly distinct positive dependence has been reported to occur between the amount of organic nitrogen and the number of non-sporing ammonifying bacteria (Figs. 7—9a). In addition, the group of these bacteria dominated over the remaining microorganisms along the entire river course (Figs. 6—9a).

B. NITRIFICATION

The degree of water pollution along the river course is reflected in the content of ammonium salts, nitrites and nitrates, as well as in the number of nitrifying bacteria. A sector stretching between Ziębice and Strzelin was characterized during the sugar campaign, by the lowest content of nitrates and nitrifying bacteria of the second phase, a fact caused by a considerable water pollution due to organic compounds (Figs. 7—9b). Downstream of this zone, an increase was observed in both number of nitrifying bacteria and concentration of nitrates (Figs. 7—9b).

C. DENITRIFICATION

The zonation in occurrence of protein-decomposing and nitrifying bacteria, which appears in dependence of the chemical composition of water, was proved by the occurrence of denitrifying bacteria. In contrast to the nitrifying bacteria, the denitrifying ones developed along the most heavily polluted sector rich in carbohydrates, and insufficiently saturated with oxygen (Figs. 7—9c). A correlation found to appear between the denitrifying bacteria and BOD_5 (cf. Chapter 4. C.) was here ascertained, too (Figs. 7—9c). Certain exceptions were, however, encountered, particularly in a sector between Więzów and Wrocław (Fig. 6).

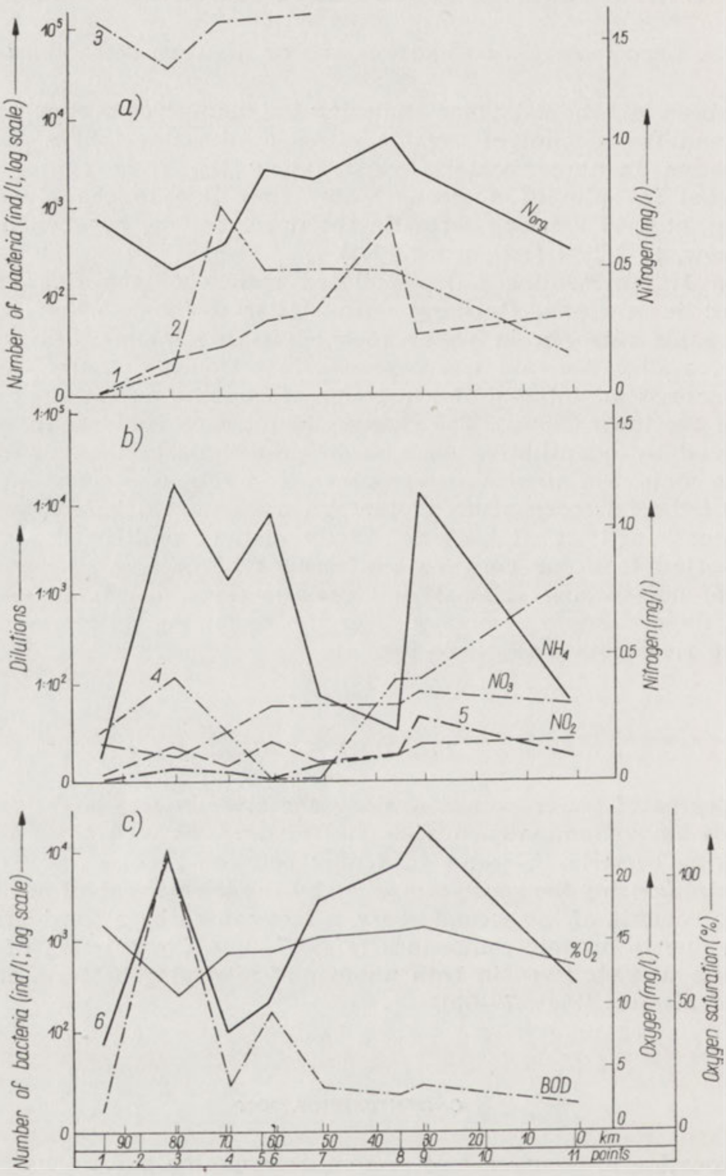

Fig. 6. Development of nitrifying bacteria in the light of some chemical components along the Oława river course on 28.5.1962

a — incipient decomposition of protein, b — nitrification, c — denitrification. 1 — proteolysing bact., 2 — deamin. c. bact. (spore-form.) 3 — deamin. c. bact. (non spore-form.) 4 — nitrifying bacteria I, 5 — nitrifying bacteria II, 6 — denitrifying bacteria.

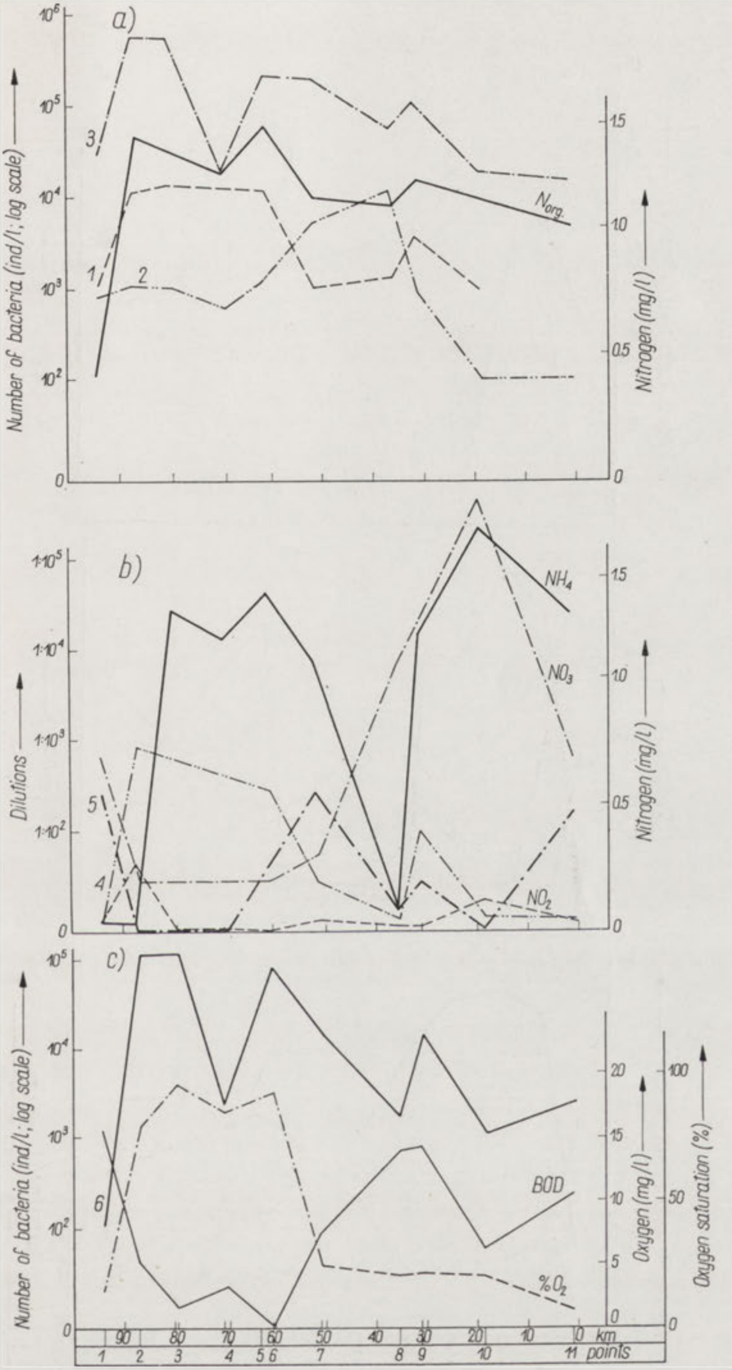

Fig. 7. Development of nitrifying bacteria in the light of some chemical components along the Oława river course on 29.10.1962

a — incipient decomposition of protein, b — nitrification, c — denitrification. 1 — proteolysing bact., 2 — deamin, c. bact. (spore-form.) 3 — deamin. c. bact. (non spore-form.) 4 — nitrifying bacteria I, 5 — nitrifying bacteria II, 6 — denitrifying bacteria.

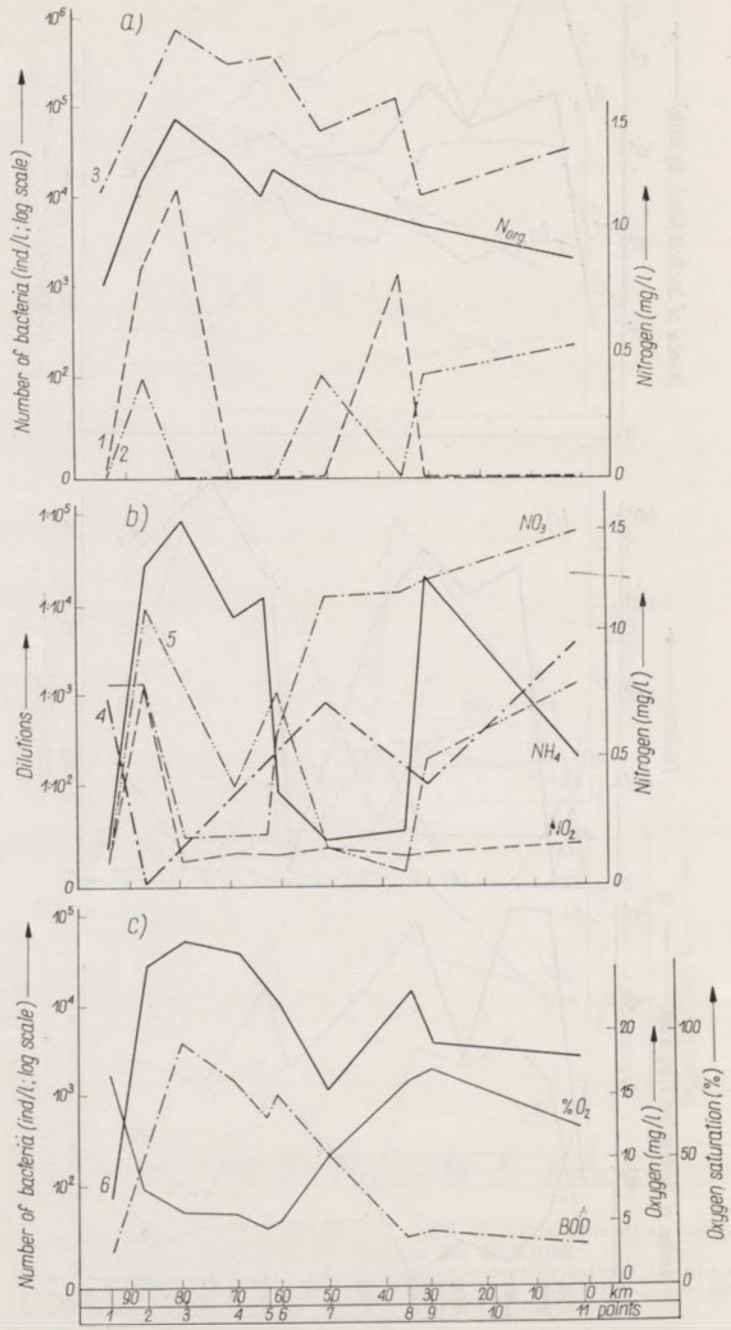

Fig. 8. Development of nitrifying bacteria in the light of some chemical components along the Oława river course on 26.12.1962

a — incipient decomposition of protein, b — nitrification, c — denitrification. 1 — proteolysing bact., 2 — deamin. c. bact. (spore-form.) 3 — deamin. c. bact. (non spore-form.) 4 — nitrifying bacteria I, 5 — nitrifying bacteria II, 6 — denitrifying bacteria.

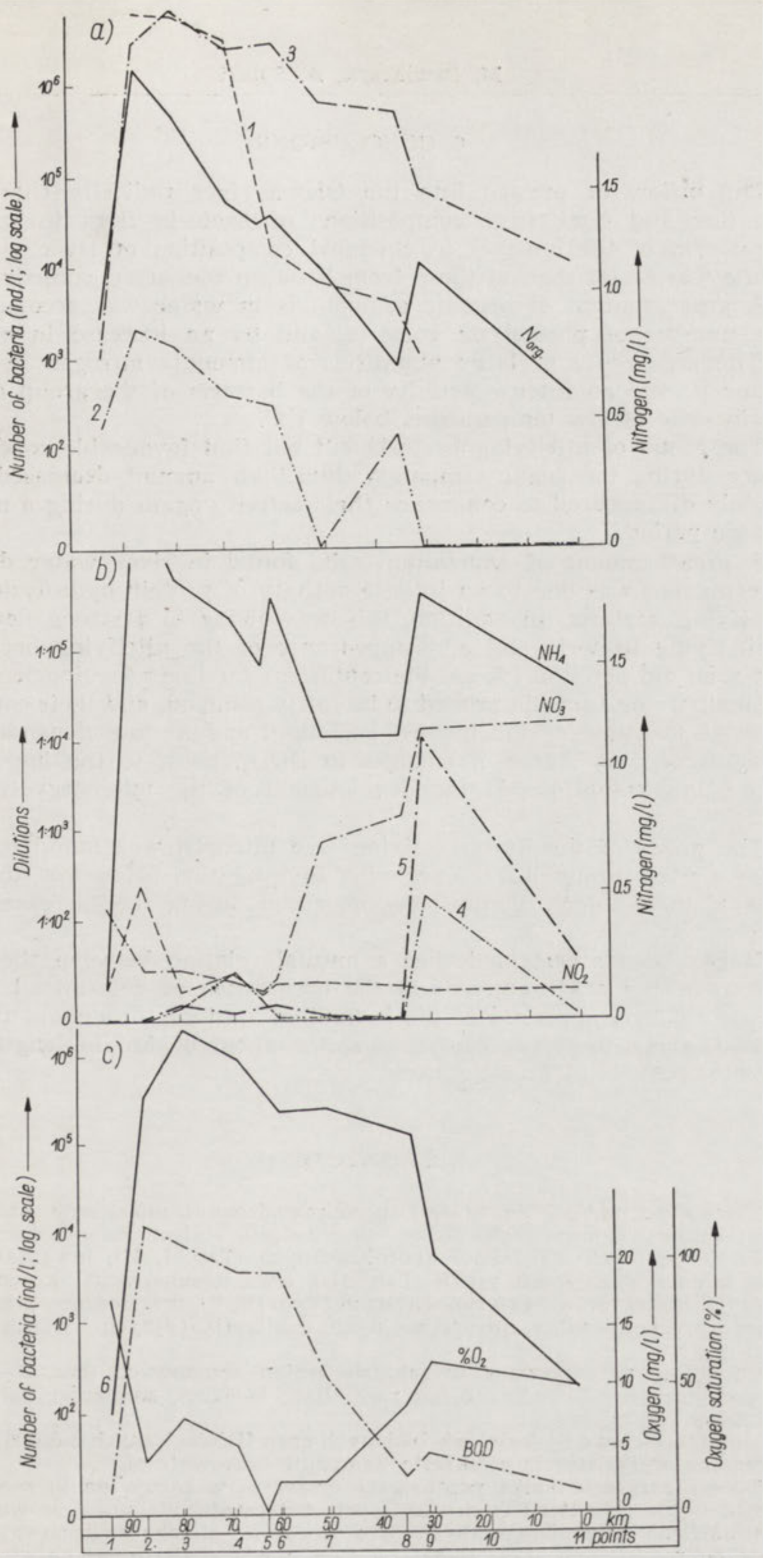

Fig. 9. Development of nitrifying bacteria in the light of some chemical components along the Oława river course on 28.12.1962

a — incipient decomposition of protein, b — nitrification, c — denitrification. 1 — proteolysing bact., 2 — deamin. c. bact. (spore-form.) 3 — deamin. c. bact. (non spore-form.) 4 — nitrifying bacteria I, 5 — nitrifying bacteria II, 6 — denitrifying bacteria.

6. CONCLUSIONS

1. The inflow of sewage into the Oława river radically changed both quantitative and qualitative compositions of bacteria flora in water. The interpretation of the changes in chemical composition of river water from that time was easier than of those from between the sugar campaign periods.

2. A great content of organic compounds in water was accompanied by a high number of proteolytic bacteria, and by an increase in ammonium salts. The occurrence of large quantities of ammonia nitrogen in water at that time proved an intense activity of the bacteria of the group mentioned above, in spite of low temperature, below 1°C.

3. The group of nitrifying bacteria did not find favourable conditions for existence during the sugar campaign, thus their amount decreased, or they completely disappeared to commence their activity again during a new inter--campaign period.

4. A great amount of ammonium salts found in river water during the sugar campaign was due to an intense activity of protein-hydrolyzing and of ammonifying bacteria. In addition, this was owing to a strong development of denitrifying bacteria and a disappearance of the nitrifying bacteria that at that time did not find favourable conditions for their development.

5. Denitrifying bacteria proved to be fairly common, and their considerable increase at the time of the highest pollution, and a close dependence upon the magnitude and course of changes in BOD_5, point to the importance of these ecologic conditions in the development of the microorganisms considered.

6. The group of the bacteria fixing free nitrogen was found to occur in the Oława river throughout the period of investigations. However, the greatest amount of these microorganims was observed during the increase of water polution.

7. It has been ascertained that a mutual relation between the chemical conditions of the environment and the occurrence of determined groups of nitrifying bacteria appeared at the individual stations throughout the annual cycle and, along the river course (a sector about 85 km in length), during the several periods of investigations.

7. STRESZCZENIE

W okresie od 28.V.62 do 28.V.63. przeprowadzono comiesięczne badania chemiczne i bakteriologiczne rzeki Oławy na jedenastu stałych stanowiskach (rys. 1.).

2. Na tle ogólnych warunków hydrologicznych (Tab. I, II), inwentaryzacji ośrodków zanieczyszczających rzekę (Tab. III) oraz stosunków fizyko-chemicznych i niektórych wskaźników bakteriologicznych (Tab. IV, V), prześledzono pracę bakterii wstępnego rozkładu białka, nitryfikacyjnych, denitryfikacyjnych i wiążących wolny azot.

3. Procesy te rozpatrywane w zakresie zmian sezonowych (rys. 2—5abc) oraz zmian przebiegających wzdłuż biegu rzeki (rys. 6—9abc), analizując cały materiał przy pomocy wykresów.

4. Zmiany ilościowe i jakościowe badanych grup fizjologicznych bakterii wystąpiły ze szczególną wyrazistością w okresie kampanii cukrowniczej.

5. Procesy rozkładu białka przebiegały sprawnie, wskazują na to znaczne ilości soli amonowych i bakterii hydrolizujących połączenia białkowe w wodzie. Największe nasilenie przemian miało miejsce w okresie silnego zanieczyszczenia rzeki ściekami cukrowniczymi (rys. 3—5a). W tym czasie stwierdzono największe ilości

bakterii proteolitycznych. W pozostałych okresach dominowały amonifikatory niezarodnikujące (rys. 2—5b). Niska temperatura w okresie jesienno-zimowym nie hamowała tych procesów.

6. Nitryfikacja intensywnie prowadzona przez bakterie I i II fazy w okresie międzykampanijnym (rys. 2—5b), hamowana była w okresach silnego zanieczyszczenia rzeki, obecnością dużych ilości związków organicznych oraz produktami metabolizmu innych grup mikroorganizmów i prawdopodobnie niską temperaturą wody (rys. 3—5b).

7. Bakterie denitryfikacyjne dość powszechne w rzece Oławie najliczniej wystąpiły w okresie kampanijnym, na stanowiskach będących w zasięgu ścieków cukrowniczych. Najważniejszym czynnikiem stymulującym ich rozwój były znaczne ilość związków organicznych na co wskazuje dość wyraźna zależność między ilością bakterii denitryfikacyjnych a BZT_5 (rys. 3—5c).

8. Bakterie wiążące wolny azot napotykano w Oławie w szerokich granicach ilościowych (0—1,5 mil. komórek w 1 ml wody). Grupa ta wystąpiła najliczniej w okresie wysokiego stanu zanieczyszczenia rzeki i niedostatecznego natlenienia.

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A. GIZIŃSKI

BOTTOM FAUNA AS TYPOLOGICAL INDICATOR OF LAKES. PART I. ECOLOGICAL CHARACTER OF BOTTOM FAUNA OF TEN LAKES IN THE IŁAWA LAKELAND

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ABSTRACT

Bottom fauna of the open water regions of ten lakes selected in Iława Lakeland was investigated. 24 more abundant and more frequent forms were submitted to mathematical and ecological analysis. For that purpose, the "method of dendrites" was used. Further, species and number analysis of the bottom fauna of particular lakes, its horizontal distribution and seasonal changes as well as the possibility of applying of these elements for classification of the lakes will be taken in consideration in the second part of this paper.

CONTENTS

1. INTRODUCTION

Typology of lakes was, and still is, one of the major problems of limnology. It has been discussed by THIENEMANN (1922, 1925), LENZ (1925), LUNDBECK (1926), DECKBACH (1929), NAUMANN (1929), FINDENEGG (1955), BRUNDIN (1958), STANGENBERG (1938), WISZNIEWSKI (1953) and others. Many authors based their typological systems on studies regarding bottom fauna (e.g. THIENEMANN, LUNDBECK, DECKSBACH).

Lake typology, based on faunistic conditions, has been sharply critisized. According to LANG (1931) it is rather doubtful to build typological systems on faunistic elements, and lake typology should be worked out on complex studies. A similar attitude represents WESENBERG-LUND (1943). BRUNDIN (1949) drew our attention to the fact, that the larvae of *Sergentia* and *Sictochironomus* which are considered to be indicatory in the typology of lakes, might belong to the different species of different ecological character. He then concludes rightly that mistakes may occur in classifying the type of lakes by the presence of *Sergentia* or *Stictochironomus* larvae in them. BRUNDIN also points towards the importance of the historical factor, which often has decided on the kind of bottom fauna in the particular region. Hence, the typology of lakes, based on investigations of bottom fauna, might be of regional importance.

Lenz (1933) and Thienemann (1954) claim, that typology of lakes cannot be based exclusively on investigations of bottom fauna, especially chironomids larvae, but these should be considered as an additional index, very helpful and useful in defining a type of a lake.

Patalas (1955) stated that, at defining a type of lake in the plankton investigations, not only the qualitative composition should be taken into consideration, but also the aboundance and the frequency of a given form.

It seems that this attitude of Patalas should be, at the same degree, applied to the solution of typological problems by means of studies and investigations on bottom fauna.

This paper is an attempt to make an ecologic anlysis of the bottom fauna of ten lakes situated in the Iława Lake District. Following factors were taken into consideration in selecting, for investigations, the lakes described in the next chapter: The selected lakes differ considerably with their environments, with morphometric features, physico-chemical properties of their water and composition of bottom fauna. All these basins are situated in a relatively small area of the same, postglacial origin. The lakes mentioned are situated in the neighbourhood of lake Jeziorak, which is investigated by the Limnological Station at Iława attached to the N. Copernicus University in Toruń.

After getting the general knowledge of the bottom fauna groupings it will be possible to take them under consideration of typology and classification of the lakes. This will be a subject of the second part of this paper.

2. TERRAIN DESCRIPTION AND METHODS

The neighbourhood of Iława are lowlands, cut by several postglacial channels, in which numerous lakes are situated. The largest among them (27 km in length) is lake Jeziorak Wielki. The investigated lakes are situated in the west and east of the Jeziorak glacial channel. Their distribution is shown in Fig. 1. The essential environmental features of the investigated lakes are shown in Tab. 1. (after "Katalog Jezior Polskich" (1952) and based on materials from Inland Fisheries Institute and Department of Geography of the N. Copernicus University in Toruń).

Investigations were started in July 1960. Further field works followed during the time of: 14—24 II, 2—14 V, 20 VII—3 IX, 17—27 XI 1961 and 13 II—1 III 1962.

On most of the investigated lakes no boat was available. Instead, the pontoon was used. Out of necessity, only a limited of sampling stations was assigned, and only the more important observations and measurements were carried out.

Samples of bottom fauna were taken mostly from three stations, placed along a straight line, running usually from the middle of the lake (station "A") to the inner edge of the reed belt (station "C"). Station "B" was placed between A and C, where the depth of lake and character of bottom deposits (degree of decay, consistence etc) represented an average. In larger lakes more sta-

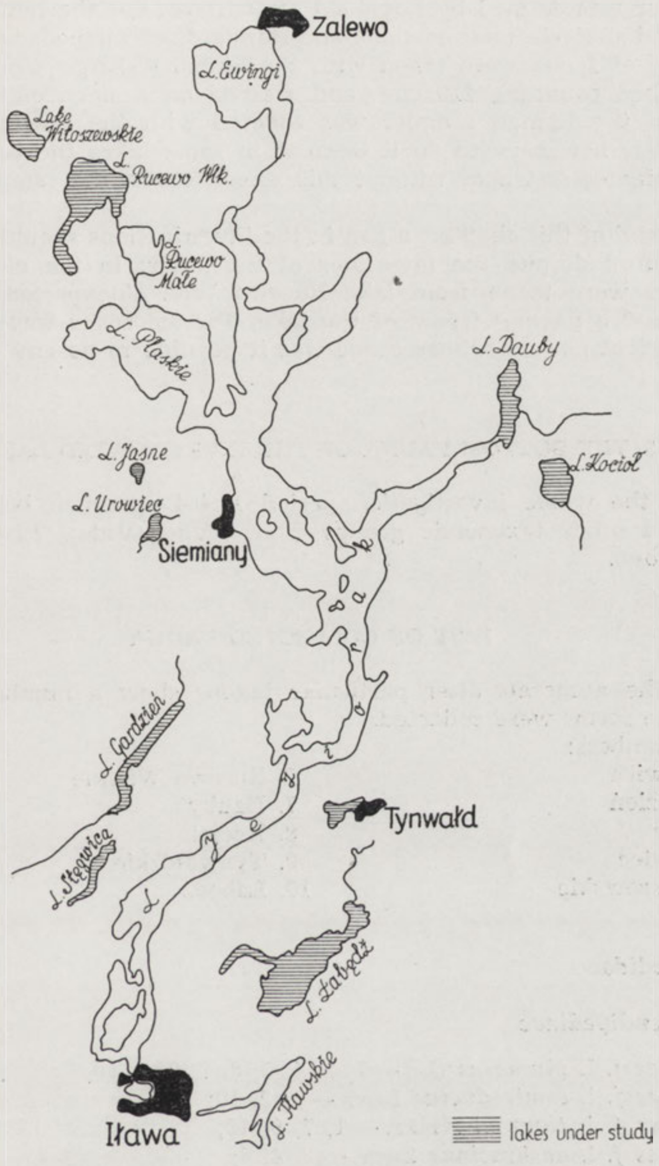

Fig. 1. Map of the study area

tions were put up. Additional stations, in between the existing ones, were assignated if required. In Summer of 1961 fauna was sampled from some additional stations situated also in other parts of the lakes.

Physico-chemical measurements of the properties of water was carried out at stations A. These were usually places of a depth close to the maximum depth of the particular lake (except Urowiec Lake). Samples of water were taken with Ruttner's and Patalas's apparatus from above the bottom of lake.

pH of water was defined by Lovibond comparator. For the remaining measurements and analysis, most common and standardized methods have been used.

Samples of fauna were taken with the Ekman — Birge sampler of a catching surface equalling 210 cm², and washed on a sieve of 0.5 mm mesh. The top of the Ekman sampler was covered with the screen of the same mesh. It was necessary to do it because in some lakes the bottom deposits were gelatinous, soft and, without this screen cover, the sampler immerged to deep.

At the end of this chapter, a gap in the investigations should be explained, which occured despite the intentions of the autor: In the autumn of 1961 no samples were taken from lake Rucewo Wlk. Unexpected frost on the 26.XI. caused a passing freeze of the lake. The ice cover was quite thin so, neither on foot nor by rubber canoe was it possible to do any work.

3. THE BOTTOM FAUNA OF THE INVESTIGATED LAKES

During the whole investigation period 17,454 specimen belonging to 86 species and other taxonomic groups were found (Vide: "List of collected fauna" below).

LIST OF COLLECTED FAUNA

Note: The numerals after particular taxons show a number of lake in which these forms were collected.

Lake numbers:

1. Stęgwica
2. Gardzień
3. Jasne
4. Urowiec
5. Witoszewskie
6. Rucewo Wielkie
7. Dauby
8. Kocioł
9. Tynwałdzkie
10. Łabędź

Tendipedidae

Tendipedinae

1. *Tendipes f. l. plumosus* (L.) — 1, 2, 4, 5, 6, 7, 8, 9, 10;
2. *Tendipes f. l. semireductus* Lenz — 1, 2, 10;
3. *Tendipes f. l. thummi* Kieff. — 1, 7, 9, 10;
4. *Tendipes f. l. anthracinus* Zett. — 3, 4, 5;
5. *Tendipes f. l. salinarius* Kieff. — 5, 9;
6. *Cryptochironomus ex gr. pararostratus* Harn. — 1, 2, 4, 5, 6, 8, 9, 10;
7. *Cryptochironomus ex gr. defectus* (Kieff.) — 2, 6, 8, 9, 10;
8. *Cryptochironomus ex gr. viridulus* (Fabr.) — 1, 5, 9, 10;
9. *Cryptochironomus ex gr. vulneratus* (Zett.) — 8, 9, 10;
10. *Cryptochironomus ex gr. conjugens* (Kieff.) — 7, 10;
11. *Glyptotendipes ex gr. gripekoveni* (Kieff.) — 1, 2, 4, 6, 8, 9, 10;
12. *Polypedilum ex gr. nubeculosum* (Meig.) — 1, 2, 4, 5, 6, 7, 9, 10;
13. *Polypedilum ex. gr. convictum* (Wakl.) — 1, 9, 10;

14. *Polypedilum ex gr. scalaenum* (SCHR.) — 2;
15. *Microtendipes ex gr. chloris* (MEIG.) — 2, 3, 4, 7, 8, 9, 10;
16. *Endochironomus ex gr. tendens* (FABR.) — 2, 4, 5, 6, 10;
17. *Allochironomus crassiforceps* (KIEFF.) — 1, 2, 7, 8;
18. *Limnochironomus tritomus* (KIEFF.) — 2, 4, 5, 6, 7, 8, 10;
19. *Limnochironomus ex gr. nervosus* (STAEG.) — 2, 10;
20. *Stenochironomus gibbus* (FABR.) — 3, 10;
21. *Stictochironomus sp.* (TSHERN.) — 8, 9;
22. *Stictochironomus psammophilus* TSHERN. — 10;
23. *Einfeldia ex gr. carbonaria* (MEIG.) — 6, 10;
24. *Einfeldia f. l. pagana* (MEIG.) — 2;
25. *Sergentia coracina* (ZETT.) — 3;
26. *Paratendipes ex gr. albimanus* (MEIG.) — 5;
27. *Pseudochironomus ex gr. prasinatus* (STAEG.) — 8;
28. *Stempellina ex gr. bausei* (KIEFF.) — 6;
29. *Tendipedini gen? 1 minuta* KRUGL. — 2;
30. *Tendipedini gen? 1 macrophthalma* TSHERN. — 2;
31 *Tanytarsus ex gr. gregarius* KIEFF. — 2, 3, 5, 6, 7, 8, 9, 10;
32. *Tanytarsus ex gr. mancus* (WALK.) — 1, 2, 4, 6, 7, 8, 10;
33. *Tanytarsus ex gr. lauterborni* KIEFF. — 2, 4;

Pelopiinae

34. *Procladius* SKUSE — 1, 2, 3, 4, 6, 7, 8, 9, 10;
35. *Alabesmyia ex gr. monilis* (L.) — 2, 3, 4, 8, 10;
36. *Pelopia vilipennis* KIEFF. — 4, 5, 8, 9, 10;
37. *Pelopia kraatzi* KIEFF. — 8, 9, 10;
38. *Clinotanypus nervosus* (MEIG.) — 2, 4;

Orthocladiinae et Diamesinae

39. *Psectrocladius ex. gr. psilopterus* KIEFF. — 2;
40. *Psectrocladius medius* TSHERN. — 2;
41. *Trichocladius tibialis* (MEIG.) — 6;
42. *Paratrichocladius inaequalis* (KIEFF.) — 7;
43. *Epoicocladius ephemerae* (KIEFF.) — 8;
44. *Diamesa campestris* EDW. — 8;

Other groups

45. *Heleidae* (*Sphaeromias sp. et Culicoides sp.*) — all the lakes;
46. *Sialis flavilatera* (L.) — all the lakes;
47. *Trichoptera n. d.* — all the lakes;
48. *Phryganea grandis* L. — 1, 2, 3, 10;
49. *Molanna sp.* — 2, 7, 8;
50. *Limnophilus sp.* — 2;
51. *Glyphothelius sp.* — 3;
52. *Caenis moesta* BENGTSS. — 2, 4, 5, 8, 10;
53. *Caenis horaria* L. — 1, 4, 10;
54. *Ephemera vulgata* L. — 7, 8;
55. *Cloeon dipterum* (L.) — 2, 4;
56. *Odonata n. d.* — 8;
57. *Cordulia sp.* — 3;
58. *Aeschna sp.* — 3;

59. *Platycnemis pennipes* Pall. — 9;
60. *Agrion sp.* — 2, 4, 5;
61. *Coleoptera larvae n. d.* — 2, 6, 8, 10;
62. *Donacia sp.* — 10;
63. *Asellus aquaticus* L. — all the lakes;
64. *Gammarus pulex* L. — 5, 7;
65. *Hydracarina n. d.* — 1, 2, 3, 4, 5, 9, 10;
66. *Valvata piscinalis* Müll. — 2, 4, 6, 7, 8, 9, 10;
67. *Bithynia tentaculata* L. — 4, 5, 6, 7, 8, 10;
68. *Gyraulus albus* Müll. — 2, 4, 7;
69. *Acroloxus lacustris* L. — 6, 7, 10;
70. *Theodoxus fluviatilis* L. — 7, 8, 10;
71. *Radix auricularia* L. — 2, 10;
72. *Potamopyrgus jenkinsi* Smith — 7, 10;
73. *Viviparus viviparus* L. — 7;
74. *Lymnaea stagnalis* L. — 7;
75. *Pisidium sp.* — 2, 3, 5, 7, 8, 10;
76. *Anodonta anatina* L. — 1, 9;
77. *Unio tumidus* Retz. — 6, 8;
78. *Unio pictorum* L. — 8, 10;
79. *Dreissena polymorpha* Pall. — 8, 10;
80. *Herpobdella octooculata* L. — 2, 5, 6, 8, 10;
81. *Helobdella stagnalis* L. — 2, 5, 8, 9, 10;
82. *Glossiphonia complanata* L. — 2, 5, 7, 9;
83. *Piscicola geometra* L. — 2, 4, 10;
84. *Oligochaeta n. d.* — all the lakes;
85. *Nematomorpha n. d.* — 6, 9, 10;
86. *Turbellaria n. d.* — 3, 8, 9.

For the requirements of this paper regarding quantitative evaluation, only 24 more frequent and abundant forms were taken into consideration. Moreover, to make it possible to compare fauna of various lakes independently of the number of stations on these lakes in tables II—V only fauna from three stations — A, B, and C was considered. Evaluations were made for all four seasons: spring, summer and autumn of 1961 and winter, 1962.

In analysi of the fauna, the method of dendrities (Florek et al. 1951) has been used. This metod was already used in interpretation of hydrobiological investigations results (Romaniszyn 1953, Giziński 1958). As known, a dendrite is to be calculated by the following method: From the tables (in this case from tab. II—V) the sum of absolute differences between the elements, which should make the dendrite, is calculated. So, for example, the "sum of differences" between the *Tendipes f.l. plumosus* and *Tanytarsus e.g. gregarius* larvae, at all stations of ten lakes amounted in spring — 117, in summer — 36, in autumn — 152 and in winter — 118, which sums up to 423. This sum is put in table 6 as the basis for making up the dendrite. In the dendrite, closest to each other, are put those forms, which show the smallest differences toward themselves. The length of lines connecting the particular components of the dendrite is corresponding the differences between those components. As the components of dendrite are connected with each other by the shortest, possible, sections, the whole dendrite is named: "The Shortest".

In tables II—V both the absolute numbers equalling the number of specimen from four catchings with Ekman's sampler, and relative values were put in. These relative values were calculated by the following method.

The sum of specimen of the given taxon from all samples caught during the time from spring 1961 till winter 1962 at stations A, B and C was defined as 100, and then, in relation to that sum, the percentage of specimen of the given taxon, caught at the particular station, was calculated. The numbers so calculated resulted in most of the cases in fractions, and, with regard to more abundant forms, were smaller than 1. For this reason and also in order to simplify the calculations, all these numbers, representing per cent values were divided into classes along following patterns:

Value		class	Value		class
Below	0.5%	= 1	from	31— 40%	= 70
from	0.5—1%	= 2	„	41— 50%	= 90
„	1—3.5%	= 5	„	51— 60%	= 110
„	3.6—6%	= 10	„	61— 70%	= 130
„	7—9%	= 15	„	71— 80%	= 150
„	10—20%	= 30	„	81— 90%	= 170
„	21—30%	= 50	„	91—100%	= 190

The necessity of using, in the calculation of differences between the particular forms of fauna, relative per cent numbers may be illustrated by the example: Larvae of *Tendipes plumosus* amounted (in absolute numbers) to 940, larvae of *Chaoborus sp.* — to 2 128 specimen. The maximal similarity (in the dendrite sense) of these forms could amount to 2128 minus 940 = 1188. On the other hand, two forms ecologically very different, *Sergentia coracina* and *Allochironomus crassiforceps*, were noticed in numbers of 26 and 15 specimen. Therefore, the maximum difference between them (also in the dendrite sense) could amount to 26 plus 15 = 41. Both these forms would found themselves, in the dendrite, closer to each other than *Tendipes* and *Chaoborus* larvae. This possibility cannot occur when relative numbers are used. Forms, ecologically different cannot meet in the dendrite near each other, and, vice versa, forms of similar habitat requirements will in the dendrite belong to one group.

According to mathematical principles, dendrite may be divided into n parts: if $w_n > w_{n+1}$, where $w_2 = \frac{d_1}{d_2}$, $w_3 = \frac{d_2}{d_3} \ldots$, $w_n = \frac{d_{n+1}}{d_{n+1}}$. ($d_1$, d_2, ... etc = the length of sections connecting the particular components of the dendrite, from the longest to the shortest).

After this principle the dendrite of the fauna (Fig. 2) may be divided into 2, 5, 6, 8, 12, 14, 17 and 21 parts. From the ecological point of view, the most acceptable division is when the dendrite falls into the following 8 parts:

1. *Tendipes* f.l. *plumosus, Oligochaeta, Heleidae, Chaoborus sp.*
2. *Polypedilum e.g. nubeculosum, Microtendipes e.g. chloris, Tanytarsus e.g. mancus, Tendipes f.l. anthracinus, Glyptotendipes e.g. gripekoveni, Tanytarsus e.g. gregarius, Ablabesmyia e.g. monilis, Endochironomus e.g. tendens, Pelopia vilipennis, Bithynia tentaculata, Potamopyrgus jenkinsi, Trichopera, Caenis.*
3. *Sialis flavilatera* L.
4. *Procladius* Skuse
5. *Dreissena polymorpha* Pall.

6. *Asellus aquaticus* L.
7. *Allochironomus crassiforceps* K i e f f.
8. *Sergentia coracina* Z e t t.

In the first part of the dendrite there are forms, which are characteristic for the profundal zone* of most of the investigated lakes (Rucewo Wlk., Dauby, Kocioł, Stęgwica, Tynwałdzkie, Łabędź, Witoszewskie). The common feature

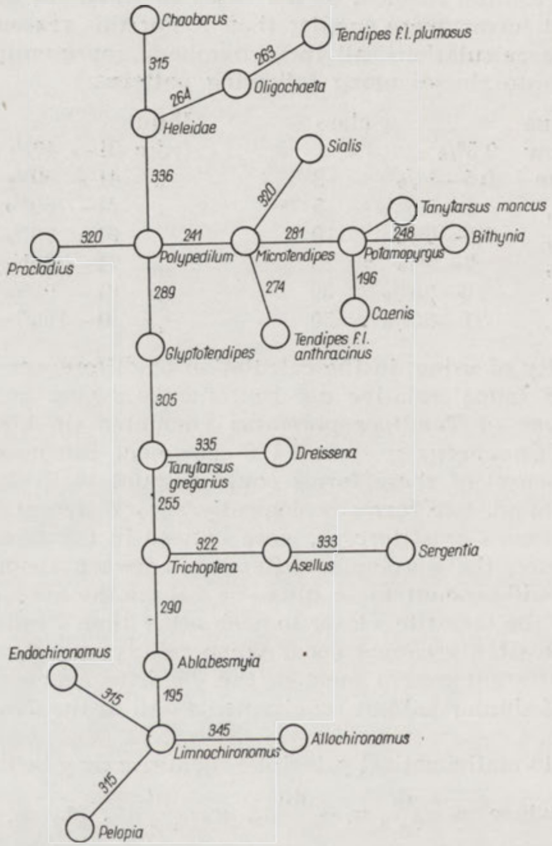

Fig. 2. Dendrite for particular forms of bottom fauna (cf. Table VI)

of these fauna forms is their relatively uniform appearance. All above mentioned forms (from first part of dendrite) were found in most of the samples, especially those, taken on stations A and B. The number of specimen of any component of this part of the dendrite, taken from one station, does not exceed 10% of all specimen of the given form. Only once, the larvae of *T. plumosus* appeared in a number amountng to 24.5% of the sum of specimen of that form. The group of bottom fauna forms, included in first part of the

* In some of the investigated lakes there is no "profundal" zone in the exact meaning of this word but, for the sake of simplificating matters, we shall continue to call, in this paper, "profundal" those parts of the lakes, which are represented by stations A and B.

dendrite is not very compact. *Chaoborus sp.* larvae differ relatively most distincly from the remaining components of this dendrite part. This form would be even placed outside this group by applying the 12 parts division of the dendrite. This may be explained by the slightly different ecologic character of the *Chaoborus sp.* larvae. As known, these larvae are not typically bottom forms (Wesenberg — Lund 1943, Berg 1936 — after McDonald 1956, Sikora 1956). In their earlier development stages the larvae of *Chaoborus sp.* live as plankters and later they either live in a stratum of water next to the bottom, or they are only partly dwelling in mud. Besides this, they are able to carry out the vertical migrations towards the surface of water. (Jonasson 1961). It causes that they are less, than the remaining forms, dependent on unfavourable oxygen conditions, especially in case of oxygen microstratification which may occur in a lake (Brundin 1951). Almost never *Chaborus sp.* larvae were caught at stations C, whereas other forms of the discussed group appeared there, especially in summer, in relatively great numbers. Greatest numbers of *Chaoborus sp.* larvae were noticed in autumn, smallest — in summer. This is in accordance with Kajak's (1961) observations concerning lakes of Tajty and Grajewko.

The larvae of *Tendipes f.l. plumosus* occurred in similar numbers at stations A (total — 347 specimen), B (279 specimen) and C (314 specimen). It does not mean that their distribution, in the particular seasons, was the same at all stations. In spring, summer and autumn, the distribution at stations A, B and C was more or less uniformed. Only in lake Tynwałdzkie a concentration of *T. plumosus* larvae near the edge of the reed belt has been observed.

In winter, concentrations of *T. plumosus* larvae were observed at deeper stations. At shallower stations (C) these larvae were not present at all, or only single specimen were noticed. This observations are in accordance with data supplied by Lundbeck (1926), Rzóska (1935), Romaniszyn (1950). No differences has been found in the distribution of older and younger larvae. It may be, probably, explained by the small differences in the depth of the particular stations, especially on those lakes with aboundance of these forms.

The larvae of *Heleidae* appeared in much smaller numbers than the remaining forms, included in the dendrite part here discussed. Through all four seasons of the year at all stations only 64 *Heleidae* larvae were caught. They appeared at a lesser number of stations, but always together with the *Tendipes plumosus* larvae, *Chaoborus sp.*, or *Oligochaeta*. *Heleidae* were represented mainly by the larvae of genus *Sphaeromias* and *Culicoides*. The *Heleidae* larvae are in Polish lakes, in general, present in small numbers, (e.g. Charzykowo Lake — Romaniszyn 1950) and rather at small depths. In lake Kierskie (Rzóska 1935) they were found at a depth of 14 m. Brundin (1949) found the larvae of genus *Sphaeromias*, in Swedish lakes, at a depth of up to 19 m (maximum at 5 m), but this concerns more oligotrophic lakes.

Oligochaeta. The numerical dynamics of specimen of this group, in the examined lakes, do not show any clear regularities. The minimum of *Oligochaeta* numbers was found in summer, the maximum — in the autumn. *Oligochaeta* were found at all examined lakes. Only in lake Jasne they were almost entirely absent (only 2 specimen were caught in summer, at station B).

In the second part of dendrite are all the forms which are peculiar for the littoral zone. About the littoral character of these fauna forms are giving evidence data supplied by Romaniszyn (1950, 1953, 1958), Tshernowski (1949), Thienemann (1951, 1954), Lundbeck (1926), Brundin (1949), Smoleńska (1963), Lepniewa (1950) et al. The majority of these forms has been caught exclusively at stations C, near the margin of reeds. Towards the limnetic zone of the lake, these forms were found in more abundant numbers only in lake Gardzień which, owing to its small depth, is actually fully littoral, and sometimes in lake Stęgwica (also of small depth, its bottom is overgrowned with nenuphars). Some of these forms occurred also at station B, in lake Jasne, among "meadows" of *Fontinalis antipyretica*. In spring and winter, at stations A of lakes Witoszewo and Rucewo Wlk. two larvae of *Endochironomus e.g. tendens* were found, but this should be acknowledged as accidentally.

Within the second part of dendrite some forms are less closely connected with the remaining components. As such should be considered *Endochironomus e.g. tendens* and *Pelopia vilipennis*. A certain distinctness of *E. tendens* could be explained by a greater "phytophily" of this midge in comparison with the remaining forms (Giziński 1958). Moreover, a certain influence on the mathematical aspect of the location *E. tendens* in the dendrite, had the above mentioned fact of finding these specimen at some stations A. *Pelopia vilipennis* differ from the remaining forms chiefly by the fact, that it appeared in greater numbers in one lake only (Urowiec), and more often at station B, than the other forms of this part of dendrite.

On the other hand there exist, in the discussed group of bottom fauna, certain forms which are especially closely connected with each other. Such very compact "subgroup" consists of: *Potamopyrgus jenkinsi*, larvae of *Tanytarsus e.g. mancus*, *Caenis macrura* and *C. horaria*. These forms have been most abundant at station C of lake Łabędź.

The larvae of *Limnochironomus e.g. tritomus* and *Ablabesmyia e.g. monilis* show also in the dendrite a significant proximity. This has been caused by the fact that both forms have demonstrated their maximum quantity at the same time and at the same station (spring, Urowiec, st. C). Also in the autumn, at stations A and C of lake Gardzień, these larvae demonstrated a similar numerosity. The bottom of the above mentioned stations was covered with submerged vegetation, so that in the samples there were found plants, as well as parts of bottom from the nearest proximity of these plants. Hence, in one sample, there might have been forms closer connected with vegetation (*Limnochironomus*) and also forms habitating rather on the bottom (*Ablabesmyia*).

It is worthwhile to discuss the fact of finding *Tendipes f.l. anthracinus* larvae in the second part of the dendrite, among forms of littoral character. The synonymous name of this form, "*bathophilus*", suggest that it is a depth — liking form. The majority of authors (Romaniszyn 1950, Thienemann 1951, Kajak 1953, Bohr and Giziński 1960) noticed the apearance of *T. anthracinus* larvae at greather depths, but data of these authors concern lakes moderately eutrophic. The majority of *T. anthracinus* larvae, for this investigations, has been sampled in lake Jasne, which is not eutrophic, as is shown if only by the presence of the larvae of *Sergentia sp.*. Lundbeck (1936) stated that in the mesotrophic lake Mamry, the larvae of *Tendipes f.l. anthracinus* appeared mainly at a depth of 13 m, whereas the *Sergentia* larvae habitated most numerously at the maximal depth of 40 m. In lake Jasne, being half deep as Mamry Lake, *T. anthracinus* larvae has been caught mainly in the littoral. It seems that in relatively shallow lakes, being nearer meso — than eutrophy, the littoral is the right habitat of the *Tendipes anthracinus* larvae.

The first and second part of the dendrite are connected through the larvae of *Polypedilum e.g. nubeculosum*. It is the proper form of sublittoral and littoral, but from the other hand, its way of feeding is similar to those of the profundal (KONSTANTINOV 1958). Thus, a conclusion may be drawn, the character of these larvae enables to treat them as a joining link between both the "littoral" and "profundal" parts of the dendrite.

The remaining parts (3—8) of the dendrite include the forms which differ ecologically from these belonging to the first and second part of the dendrite as well as among themselves.

Sialis lutaria (*flavilatera*) L. The larvae of this species were found mainly at station C of lake Gardzień, Jasne and Urowiec. The specific character of their appearance and their numerosity might be explained by the fact that *Sialis lutaria* lead, especially during their first larval stages, a very active and rapacious life. In search for food, they change often places, and thus do not show such a strict connection with the substratum, as other littoral and sublittoral forms (MIKULSKI 1951).

Procladius SKUSE. These larvae show a relatively small difference (in the dendrite sense) in relation to forms being in the second part of the dendrite. The *Procladius* SKUSE larvae were noticed mostly at stations C, but more frequent than any form of the second dendrite part, were also found at stations B. The larvae of *Procladius*, despite their ubiquistous occurrence, are considered to be sublittoral forms. In less eutrophized lakes they were noticed by many authors as an essential components of the profundal fauna (ROMANISZYN 1950, THIENEMANN 1951, DUNN 1961, MIKULSKI and GIZIŃSKI 1961). The larvae of *Procladius sp.* could be therefore considered, from the ecological point of view, as a certain intermediate link between profundal and littoral forms. In the investigated lakes, these larvae show a closer similarity to the littoral forms, because most of the lakes are eutrophic basins.

Dreissena polymorpha PALL. In samples considered at comparing calculations (Tab. II—V), *Dreissena* appeared only at st. C of lake Kocioł. Besides, it was noticed in lake Łabędź, at one supplementary station. In lake Kocioł, at station C, *Dreissena* appeared in relatively loose concentrations so that Ekman sampler met sometimes whole groups of these molluscs and sometimes caught none. Samples taken from *Dreissena* swarms with Ekman's sampler should not be considered as strictly quantitative, because the number of the molluscs caught in the particular samples might vary and also depend in a great degree on accidents. Any clear regularities in the mutual quantitative relations of other forms to the appearance of *Dreissena* have not been found. This fact decided about location of *Dreissena* in a distinct, separate part of the dendrite.

Asellus aquaticus L. is generally considered as a typically littoral form. Its distinctness in the dendrite arrangement may be only explained by the fact, that the greatest numbers on *Asellus* were found at station B in lake Jasne which differs in many respects from the remaining lakes. Moreover, among *Fontinalis antipyretica* meadows, where *Asellus* was most abundant other forms appeared in very small numbers only. It is significant that in similar samples, caught in lake Witoszewskie containing also *Fontinalis*, *Asellus aquaticus* specimen were either entirely absent or appeared in relatively small numbers. May be that here play a part certain microelements not yet defined.

Allochironomus crassiforceps KIEFF. From all among the forms considered at comparing calculations larvae of this species are one of the least abundant

Table I

Description of the lakes investigated

No.	Lake	Area, ha	Max. lenght, m	Max. breadth m	Depth and character of bottom deposits at station: A	B	C	The most abundant vascular plants	The lake is surrounded with
1	Stęgwica	47.5	2,265	290	1.30 m — Gelatioous brown und	1.10 m — Similar character as on station A	1 m — Plenty of undecayed plant remains	*Phragmites communis, Nymphaea alba, Nuphar luteum*	Close ring of mixed forests
1	Gardzień	85.5	4,175	350	0.80 m — Gelatinous, grey mud. Tufts of submerged vegetation	0.70 — 0.80 m — Similarly to station A	0.50 m — Similarly to station A, more undecyaed organic remains	*Phragmites communis, Carex sp. Ceratophyllum sp., Elodea canadensis*	as above
3	Jasne	11.2	450	320	20 m — Dark grey mud	20 m — ,,Meadow'' of Fontinalis antipyretica	2 m — Sand, gravel, stones. Abundant allochtonic remains	The lack of emergent plants. On shores — *Juncus, Carex, Sphagnum.* ,,Meadows'' of *Fontinalis antipyretica.*	Pine — and mixed forests. Southern shore — clearing
4	Urowiec	24.2	700	310	13 m — Grey-brown gelatinous mud	6 m — Mud and sand	2 m — Sandy bottom, few Elodea canadensis	*Phragmites communis, Elodea canadensis, Ceratophyllum sp.*	Close ring of mixed — and pine forests
5	Witoszewskie	78	1,500	750	8 m — Thin layer (20 cm?) of grey-brown mud	5 m — Similarly to st. A. Tufts of Fontinalis	1.5 m — Sandy, hard bottom with few Elodea and Myriophyllum sp.	*Phragmites communis, Schoenoplectus lacustris, Ceratophyllum, Myriophyllum sp.*	as above

6	Rucewo Wielkie	225	1,800	1700	3 m — Grey- brown gelatinous mud	3 m — Similarly to st. A	2 m — Similar to st. A and B, plenty of decaying organic remains	*Phragmites communis*, *Typha angustifolia*, *Equisetum limosum*, *Acorus calamus*	Meadows, pasture — grounds, settlement, forest, cultivated fields
7	Dauby	82	2,250	500	3.20 m — as above	2,40 m — Mud of similar character, with addition of shell remains	2 m — Mud, plenty of decaying allo — and autochtonic plant remains	*Phragmites communis*, *Typha angustifolia*, *Nuphar luteum*	Mixed and pine forests, meadows
8	Kocioł	85.5	1,200	800	6 m — Black- grey mud, typic „gyttja"	6 m — Similar as on station A	2 m — Sand, mud, shells, clumps of *Dreissena*	*Phragmites communis*, *Typha latifolia*, *Schoenoplectus lacustris*, *Characeae*, *Fontinalis*	Meadows, forest, settlement
9	Tynwałdzkie	29,9	1,060	550	2.80 m — Gelatinous, brown- grey mud	2.50 m — Similar as on station A	1.80 m — Plenty of decaying autochtonic plant remains	*Phragmites communis*, *Myriophyllum sp.*, *Ceratophyllum sp.*	Meadows, pasture grounds, cultivated fields
10	Łabędź	320	3,900	1,900	7 m — as above	7 m — as above	1,20 m — Fine sand, many shells, especially of *Potamopyrgus jenkinsi*	*Phragmites communis*, *Potamogeton perfoliatus*, *Myriophyllum sp.*	as above

Numbers and frequency of the bottom

Note: Upper numerals indicate numbers of individuals in 4 Ekman

Taxa \ Lakes / Stations	Stęgwica			Gardzień			Jasne			Urowiec		
	A	B	C	A	B	C	A	B	C	A	B	C
1. *Ablabesmyia e. g. monilis* L.									5 30			12 70
2. *Pelopia vilipennis* Kieff.											4 50	2 30
3. *Procladius* Skuse			1 1	9 5	6 5	7 5					2 2	
4. *Endochironomus e. g. tendens* Fabr.												
5. *Glyptotendipes e. g. gripekoveni* Kieff.												
6. *Tendipes f. l. plumosus* L.		1 1										
7. *Tend'pes f. l. anthracinus* Zett.									3 5			
8. *Limnochironomus tritomus* Kieff.												21 90
9. *Microtendipes e. g. chloris* Meig.												
10. *Polypedilum e. g. nubeculosum* Meig				1 1								
11. *Sergentia coracina* Zett.												
12. *Allochironomus crassiforceps* Kieff.												
13. *Tanytarsus e. g. gregarius* Kieff.				11 30	8 30	10 30						
14. *Tanytarsus e. g. mancus* Walk.				1 1	2 1							
15. *Heleidae*		8 30										
16. *Chaoboridae*	3 1	108 10	3 1								2 1	
17. *Sialis lutaria* L.						7 15			1 5			
18. *Trichoptera*				15 30	10 30			3 10	4 10			16 30
19. *Caenis* (*moesta* Bengt. *et horaria* L.)												
20. *Asellus aquaticus* L.						2 2		147 70	8 5			5 5
21. *Dreissena polymorpha* Pall.												
22. *Potamopyrgus jenkinsi* Smith												
23. *Bithynia tentaculata* L.												
24. *Oligochaeta*		1 1		1 1							23 10	4 2
Total, absolute numbers	3	118	4	38	26	26	—	150	21	—	31	60
Total, relative numbers	1	42	2	68	66	52	—	80	55	—	63	227

Table II

fauna in investigated lakes, in Spring
dredges. Lower numerals indicate relative numbers (see page 47)

Witoszewskie			Rucewo Wlk.			Dauby			Kocioł			Tynwałdzkie			Łabędź			Total absolute numbers	Total relative numbers
A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C		
																		17	100
														1 10				7	90
					6 5			1 1			3 5		4 5	27 30		1 1		67	65
1 2		1 2																2	4
					3 10			1 5			2 10							6	25
5 2			3 1	7 2		2 1	7 2	10 5	6 2	2 1	1 1		10 5	9 2	1 1	3 1		67	27
																		3	5
											1 5							22	95
																		0	0
								1 1					1 1	35 30		2 2		40	35
																		0	0
																		0	0
																		29	90
											1 1						2 1	6	4
			1 5	1 5			1 5	2 5	1 5	1 5	1 5		4 10	1 5				21	80
5 1			1 1	8 1		20 2	48 5		107 10	53 5		90 10	78 10	20 2	35 5	18 2		599	67
																		8	20
					1 5													49	115
		1 5															1 5	2	10
		35 15			2 2													199	99
											60 70							60	70
																659	659 30	659	30
																2 15	2 15	2	15
1 1		6 5	7 5	3 2	3 2		1 1		3 2	15 5	9 5		13 5	21 10	6 5	2 1	13 5	132	68
12	—	43	12	19	15	22	57	15	117	71	78	90	110	114	42	26	677	1997	
6	—	27	12	10	24	3	13	17	19	16	102	10	36	89	11	7	56		1114

Data as in table II

Lakes / Stations	Stęgwica A	Stęgwica B	Stęgwica C	Gardzień A	Gardzień B	Gardzień C	Jasne A	Jasne B	Jasne C	Urowiec A	Urowiec B	Urowiec C
1. *Ablabesmyia monilis* L.				11 50				1 5	1 5			
2. *Pelopia vilipennis* Kieff.											2 30	1 10
3. *Procladius* Skuse			4 5					2 2				1 1
4. *Endochironomus e. g. tendens* Fabr.				4 10		14 30						
5. *Glyptotendipes e. g. gripekoveni* Kieff.												
6. *Tendipes f. l. plumosus* L.					2 1						1 1	
7. *Tendipes f. l. anthracinus* Zett.									38 50		2 5	
8. *Limnochironomus tritomus* Kieff.												
9. *Microtendipes e. g. chloris* Meig									8 30			
10. *Polypedilum e. g. nubeculosum* Meig						4 5						
11. *Sergentia coracina* Zett.								23 170				
12. *Allochironomus crassiforceps* Kieff.												
13. *Tanytarsus e. g. gregarius* Kieff.									1 5			
14. *Tanytarsus e. g. mancus* Walk.												
15. *Heleidae*			1 5		2 5							2 5
16. *Chaoboridae*	60 5	44 5	7 1							10 1		
17. *Sialis lutaria* L.			2 5		4 10	23 50		5 10	4 10			13 30
18. *Trichoptera*						5 10		3 10	1 5			
19. *Caenis* (*moesta* Bengt. *et horaria* L.)						2 10						
20. *Asellus aquaticus* L.						5 5		58 30				8 5
21. *Dreissena polymorpha* Pall.												
22. *Potamopyrgus jenkinsi* Smith												
23. *Bithynia tentaculata* L.												1 10
24. *Oligochaeta*			1 1					2 1				
Total, absolute numbers	60	44	15	19	8	49	—	94	53	10	5	26
Total, relative numbers	5	5	17	65	16	105	—	228	105	1	36	61

Table III

— in Summer

Wito-szewskie			Rucewo Wlk.			Dauby			Kocioł			Tynwał-dzkie			Łabędź			Total abso-lute num-bers	Total rela-tive num-bers
A	B	C	A	B	C	Y	B	C	A	B	C	A	B	C	A	B	C		
											2 10							15	70
																		3	40
				3 5	2 2												1 1	13	16
		12 30																30	70
		3 10																3	10
	2 1		6 2	6 2		1 1	1 1	1 1		1 1	1 1	12 5	4 1	41 10	2 1	1 1	3 1	85	31
																		40	55
					4 15													4	15
																		8	30
					2 2									7 5			2 2	15	14
																		23	170
																		0	0
																		1	5
																	2 1	2	1
			2 5										2 5				1 5	10	30
5 1	1 1		1 1			15 2	26 5		17 2	23 5		2 1	6 1			3 1		220	32
																		51	115
																		9	25
																		2	10
		35 15																106	55
											80 110							80	110
																	513 15	513	15
											2 15						4 30	30	55
3 2			16 5	11 1	12 1				6 5	2 1	14 5	17 5	5 2	6 5	5 2	2 1	1 1	83	38
8	3	54	25	10	6	16	27	1	23	26	99	31	17	54	8	6	526	1323	
3	2	70	13	8	5	3	6	1	7	7	141	11	9	20	8	3	51		1012

Data as in table II

Taxa \ Lakes / Stations	Stęgwica			Gardzień			Jasne			Urowiec		
	A	B	C	A	B	C	A	B	C	A	B	C
1. *Ablabesmyvia e. g. monilis L.*				2 10		2 10		1 5				
2. *Pelopia vilipennis* Kieff.											1 5	
3. *Procladius* Skuse	14 10	14 10	23 15	27 30	26 15	11 10			7 5			
4. *Endochironomus e. g. tendens* Fabr.				5 10	2 5	32 70						
5. *Glyptotendipes e. g. gripekoveni* Kieff.						2 10						
6. *Tendipes f. l. plumosus* L.		1 1				2 1						1 1
7. *Tendipes f. l. anthracinus* Zett.									57 90	57	12 15	
8. *Limnochironomus tritomus* Kieff.				4 15	8 30	12 10						
9. *Microtendipes e. g. chloris* Meig.			1 5			2 5			3 10		8 30	
10. *Polypedilum e. g. nubeculosum* Meig.			1 1	1 1	1 5	24 15						
11. *Sergentia coracina* Zett.								1 5				
12. *Allochironomus crassiforceps* Kieff.			2 30									
13. *Tanytarsus e. g. gregarius* Kieff.												
14. *Tanytarsus e. g. mancus* Walk.			1 1									
15. *Heleidae*	1 5											
16. *Chaoboridae*	117 10	93 10	2 1	3 1		1 1	1 1			291 30		
17. *Sialis lutaria* L.						4 10			2 5			1 5
18. *Trichoptera*			2 5	4 15		3 10						
19. *Caenis* (*moesta* Bengt. *et horaria* L.)			3 15			4 30						5 30
20. *Asellus aquaticus* L.						3 2		19 10				2 2
21. *Dreissena polymorpha* Pall.												
22. *Potamopyrgus jenkinsi* Smith												
23. *Bithynia tentaculata* L.												1 5
24. *Oligochaeta*		1 1	3 2			2 1						
Total, absolute numbers	132	109	38	46	40	94	1	21	69	291	21	13
Total, relative numbers	25	22	75	82	55	185	1	20	110	30	50	48

Table IV

— in Autumn

Wito-szewskie			Rucewo Wlk*			Dauby			Kocioł			Tynwał-dzkie			Łabędź			Total absolute numbers	Total relative numbers
A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C		
																		5	
																			25
																		1	
																			5
							2	1				2	5		4	4	4	144	
							2	1				2	5		5	5	5		120
		10																49	
		30																	115
								9			12			7			1	31	
								30			50			30			5		125
7						24	17	3	18	22		83	52	230	10	8	4	482	
2						5	5	1	5	5		15	10	50	5	2	1		109
																		69	
																			105
		1															1	16	
		5															5		65
								3			1			4			12	34	
								10			5			15			30		110
3								1						32	2		32	100	
5								1						30	2		30		90
																		1	
																			5
											1							3	
											15								45
	1	1									10						1	13	
	5	5									30						5		45
											10						600	611	
											5						190		196
	1						1		2	2			2	3			8	20	
	5						5		5	5			5	10			30		70
4	2					62	52		87	83		35	57	2	12	4		908	
1	1					5	5		10	10		5	5	1	2	1			100
								1										8	
								5											25
								3										12	
								10											40
																	21	33	
																	110		185
		5						3										32	
		5						2											21
											11							11	
											15								15
																	3887	3887	
																	130		130
		1						2									1	5	
		5						15									5		30
1	7					9	3		2	3	5	25	36	41		4	35	177	
1	5					5	2		1	2	2	10	10	15		2	10		69
12	11	18				95	75	26	109	110	50	145	132	319	28	20	4607	6652	
4	16	50				15	19	75	21	22	122	32	35	151	14	10	556		1845

* No samples were taken.

Data as in table II

Lakes / Stations	Stęgwica A	Stęgwica B	Stęgwica C	Gardzień A	Gardzień B	Gardzień C	Jasne A	Jasne B	Jasne C	Urowiec A	Urowiec B	Urowiec C
1. *Ablabesmyia e.g. monilis* L.												
2. *Pelopia vilipennis* Kieff.											1 10	1 10
3. *Procladius* Skuse	9 5	11 10	5 5	2 2	1 1	7 5			2 2			
4. *Endochironomus e.g. tendens* Fabr.												
5. *Glyptotendipes e.g. gripekoveni* Kieff			1 5			5 15						1 5
6. *Tendipes f.l. plumosus* L.		1 1		17 5								
7. *Tendipes f.l. antrhacinus* Zett.									15 15	1 2	4 5	
8. *Limnochironomus tritomus* Kieff.					1 5							
9. *Microtendipes e.g. chlori*, Meig.						1 5						4 15
10. *Polypedilum nubeculosum* Meig.			1 1	48 30	8 5	13 10						4 5
11. *Sergentia coracina* Zett.							2 15					
12. *Allochironomus crassiforceps* Kieff.			12 150									
13. *Tanytarsus e.g. gregarius* Kieff.				2 10								
14. *Tanytarsus e.g. mancus* Walk.												
15. *Heleidae*				1 5								
16. *Chaoboridae*	85 10	27 5		5 1			5 1			22 5		
17. *Sialis lutaria* L.			4 10		1 5	4 10			5 10			4 10
18. *Trichoptera*		1 5						2 5				
19. *Caenis (moesta* Bengt. *et horaria L.)*				1 5								
20. *Asellus aquaticus* L.			1 1			5 5		23 10				
21. *Dreissena polymorpha* Pall.												
22. *Potamopyrgus jenkinsi* Smith												
23. *Bithynia tentaculata* L.												
24. *Oligochaeta*	1 1	3 2	7 5		2 1	1 1						1 1
Total, absolute numbers	95	43	31	76	13	36	7	25	22	23	5	15
Total, relative numbers	16	23	177	58	17	51	16	15	27	7	15	46

Table V

— in Winter

Witoszewskie			Rucewo Wlk.			Dauby			Kocioł			Tynwałdzkie			Łabędź			Total absolute numbers	Total relative numbers
A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C		
																		0 6	0 60
	1 10	3 30																	
			1 1	2 22	1 1			1 1			3 5	2 2	7 5	1 1		2 2		57	50
1 2		21 30	1 2															23 3	34
					1 5			5 15			1 5			1 5				15	55
16 5	4 1		12 5	8 2	1 1	10 5	23 5	3 1	15 5	9 2		94 30	79 15	2 1	3 1	7 2	2 1	306	88
1 2																		21	24
																		1	5
														1 5			12 30	18	55
														8 5			17 15	99	71
																		2	15
																		12	150
											9 30							11	40
											8 5						32 10	40	15
			1 5				2 5	1 5	3 10		1 5	2 5	1 5			1 5		13	50
24 5	7 1					61 10	26 5		49 10	31 10		26 5	24 5		1 1	8 1		401	75
								1 5						1 5				20	55
								3 10			1 5			1 5			1 5	9	35
		1 5									1 5							3	15
	5 5	6 5						1 1			1 1			15 10				57	38
											7 10							7	10
								4 1									1300 30	1300	31
		3 30						6 50									3 30	12	110
2 1	7 5		45 15	11 5	17 5	5 2	2 1		3 2	5 2	10 5	6 5	15 5	10 5	3 2	13 5	2 1	171	77
44	22	31	60	21	20	76	53	25	70	45	42	130	126	40	7	31	1369	2603	
15	22	100	28	9	12	17	16	89	27	14	76	47	35	42	4	15	122		1158

"Dendritic differences" between particular forms

	Ablabesmyia e.g. monilis L.	*Pelopia vilipennis* Kieff.	*Procladius* Skuse	*Endochironomus e.g. tendens* Fabr.	*Glyptotendipes e.g gripekoveni* Kieff	*Tendipes f. l. plumosus* L.	*Tendipes f.l. antrhacinus* Zett.	*Limnochironomus tritomus* Kieff.
Ablabesmyia e.g. monilis L.	0	330	402	358	390	446	364	195
Pelopia vilipennis Kieff.		0	420	358	400	442	354	315
Procladius Skuse			0	424	376	414	428	329
Endochironomus e.g. tendens Fabr.				0	398	464	408	313
Glyptotendipes e.g. gripekoveni Kieff.					0	386	404	335
Tendipes f.l. plumosus L.						0	438	429
Tendipes f.l. anthracinus Zett.							0	369
Limnochiromus tritomus Kieff.								0
Microtendipes e.g. chloris Meig.								
Polypedilum e.g. nubeculosum Meig.								
Sergentia coracina Zett.								
Allochironomus crassiforceps Kieff.								
Tanytarsus e.g. gregarius Kiweff.								
Tanytarsus e.g. mancus Walk.								
Heleidae								
Chaoboridae								
Sialis lutaria L.								
Trichoptera								
Caenis (moesta Bengt. et *horaria* L.*)*								
Asellus aquaticus L.								
Dreissena polymorpha Pall.								
Potamopyrgus jenkinsi Smith								
Bithynia tentaculata L.								
Oligochaeta								

of bottom fauna (to dendrite, Fig. 2) Table VI

Microtendipes e.g. *chloris* Meig.	*Polypedilum* e.g. *nubeculosum* Meig.	*Sergentia coracina* Zett.	*Allochironomus crassiforceps* Kieff.	*Tanytarsus* e.g. *gregarius* Kieff.	*Tanytarsus* e.g. *mancus* Walk.	*Heleidae*	*Chaoboridae*	*Sialis lutaria* L.	*Trichoptera*	*Caenis* (*moesta* Bengt. et *horaria* L.)	*Asellus aquaticus* L.	*Dreissena polymorpha* Pall.	*Potamopyrgus jenkinsi* Smith	*Bithynia tentaculata* L.	*Oligochaeta*
380	373	365	390	365	411	425	465	360	290	395	364	380	401	385	429
370	375	385	390	475	411	405	461	370	350	405	367	400	401	325	391
392	320	437	406	387	473	367	395	378	346	397	426	436	443	449	343
408	381	413	418	393	439	449	487	358	378	349	368	428	429	363	461
300	289	405	370	305	398	385	485	340	340	295	370	360	409	355	363
410	357	445	450	423	429	303	329	450	460	459	456	456	489	451	263
274	399	379	384	359	405	419	455	339	384	409	392	394	395	399	439
355	348	370	345	350	380	390	450	365	285	370	339	345	376	370	404
0	241	385	370	355	318	345	463	320	340	335	380	390	281	315	371
	0	400	401	358	358	340	436	360	341	377	391	415	322	364	348
		0	385	370	406	420	426	385	385	410	333	395	396	387	440
			0	345	399	425	467	390	399	385	406	370	401	405	429
				0	372	380	450	355	255	370	377	335	476	370	396
					0	374	488	431	405	202	427	399	138	292	422
						0	315	405	425	370	429	415	374	410	264
							0	485	475	488	483	479	480	484	354
								0	320	385	338	420	419	375	435
									0	375	322	410	409	375	423
										0	393	415	196	390	416
											0	416	417	383	417
												0	411	385	420
													0	284	424
														0	428
															0

ones. They show in the dendrite the greatest differences in relation to the remaining forms. Romaniszyn (1958) describes this species as living among the vegetation of ponds and lakes. Humphries (1938 — after Thienemann 1951) classifies *A. crassiforceps* to the most important among *Tendipedidae* of the Gr. Plöner See, and Mikulski (1961) noticed the presence of this species in the half — stagnant habitats of the river Wisła (Vistula). It is, however, a species which is rather uncommon and not as ubiquistic as the other forms of bottom fauna here discussed. In the samples taken from the investigated lakes the appearance of *Allochironomus* larvae proved very irregular. No catches of these larvae were made in spring and summer. They were most abundant in lake Stęgwica, in the autumn, at station C. The appearance of *Allochironomus sp.* larvae does not show any similarity with the appearance of any other forms. For this reason, the larvae of *Allochironomus crassiforceps* form a separate part of the dendrite, far away from the remaining parts of it.

Sergentia e.g. coracina Zett. This form, considered to be indicatory in the typology of lakes (Decksbach 1929), was found only in samples of lake Jasne. The fact that *Sergentia*, the only typically mesotrophic form among all other forms caught, represents in the dendrite a separate unit clearly separated from the remaining parts of the dendrite, is quite natural and explained by its ecological specifity (Tarwid 1939, Romaniszyn 1950 and 1958, Wülker 1961). The larvae of *Sergentia* were the almost exclusive inhabitants of the deeper, uncovered with *Fontinalis*, bottom parts of lake Jasne. At station A they were noticed only in winter and this in small numbers. During the remaining seasons of the year, *Sergentia coracina* larvae were noticed at lesser depths, mostly together with *Asellus aquaticus*. In the dendrite *Sergentia* larvae show the least difference just in relation to *Asellus*. It is worthwhile to draw our attention to the following regularity: In the particular samples, which were especially rich in the *Sergentia* larvae, not many *Asellus* have been found, and, vice versa, in samples in which *Asellus* was represented most abundantly, no larvae of *Sergentia* was found. It might be, therefore, assumed that these forms have different habitat requirements, although both were found at the same station. *Asellus aquaticus* lives on the tufts of Fontinalis, whereas *Sergentia coracina* larvae live in the mud between those tufts.

4. SUMMARY

Bottom fauna of the open water regions of ten lakes selected in Iława Lakeland was investigated. Among the forms, 24 more abundant and more frequent ones were submitted to mathematical and ecological analysis. For that purpose, the "method of dendrites" (Florek et al. 1951) was used.

It has been found, that taking into account the similarities of occurence and the relative numbers of the different bottom fauna forms, the last may be divided on eight groups.

Oligochaeta, *Tendipes f.l. plumosus* L., *Heleidae* and *Chaoborus sp.* larvae consist the part of dendrite representing forms of rather profundal character.

The most numerous group is composed by the forms, which in the investigated lakes occurre at the inner edge of the emergent plants belt, thus these forms are rather of littoral character. Among the bottom fauna forms, grouped in the second ("littoral") part of the dendrite, the larvae of *Polypedilum e.g. nubeculosum* Walk. show the greatest similarity to the profundal forms.

Remaining forms differ distinctly with their absolute and relative numbers. Their maxima of abundance were noted in the different seasons, at different lakes and stations. The ecological distinctness of these forms is confirmed by the fact that each from them builds a separate dendrite part.

Further, species and numbers analysis of the bottom fauna of particular lakes, its horizontal distribution and seasonal changes as well as the possibility of applying of these elements for classification of the lakes will be taken in consideration in the second part of this paper.

5. STRESZCZENIE

Zbadano faunę denną 10 jezior Pojezierza Iławskiego. Próby pobierano z partii śródjeziornych, do wewnętrznego skraju pasa roślin wynurzonych (do głębokości ok. 2 m).

Spośród form, wymienionych w liście zebranej fauny wybrano 24 najważniejsze pod względem frekwencji i liczebności. (Tab. II—V). Dokonano ich analizy przy pomocy „metody dendrytów" (Florek i i. 1951). Stwierdzono, że na podstawie podobieństwa występowania i względnej liczebności zbiór 24 form fauny dennej można podzielić na 8 grup.

Tendipes f.l. plumosus L., *Oligochaeta*, *Heleidae* i *Chaoborus sp.* tworzą część dendrytu, skupiającą formy raczej profundalowe.

Najliczniejszą grupę stanowią formy, które w badanych jeziorach występowały na skraju pasa roślinności wynurzonej, czyli gatunki raczej litoralowe. Spośród form, zgrupowanych w tej części dendrytu najbardziej zbliżone pod względem ekologicznym do form profundalowych były larwy *Polypedilum e.g. nubeculosum* Meig.

Pozostałe formy różniły się bardzo znacznie liczebnością bezwzględną i względną, maksimum występowania osiągały w różnym czasie, na różnych jeziorach i stanowiskach. Odrębność ekologiczna tych form znalazła potwierdzenie w fakcie, że każda z nich stanowi odrębną część dendrytu.

Analiza jakościowa i ilościowa, rozmieszczenie horyzontalne fauny w badanych jeziorach, zmiany sezonowe, jak również możliwość uwzględnienia tych elementów przy podziałach typologicznych jezior będą omawiane w następnej pracy.

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BOTTOM FAUNA AS TYPOLOGICAL INDICATOR OF LAKES. PART II. CLASSIFICATION OF LAKES IN THE IŁAWA LAKELAND

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ABSTRACT

The method of a dendrite arrangement of set was applied in investigations aiming towards the classification of lakes. It has been found that classification of lakes, based on depth and physico-chemical properties is similar to classification based on the taxonomic composition of the profundal fauna. The dependence of the faunistic conditions on depth and physico-chemical properties of the water becomes less distinct in proportion to our taking into consideration, besides the qualitative data, also seasonal changes, the horizontal distribution and the quantitative data.

CONTENTS

1. INTRODUCTION

The first part of this paper (Giziński 1967) was concerned with the ecological character of bottom fauna of ten lakes. In that paper also the description of these lakes as well as the description of a field works methods is to be found.

The aim of the paper presented now is to examine a relation, in which the classification of lakes, based on morphometric and physico-chemical properties, is to a classification based on faunistic data, and also to what a degree quantitative conditions and the distribution of bottom fauna, taken here into consideration, had influenced the modification of the lakes classification based exclusively on specific composition of the benthos.

Lakes, as generally known, are classified into three basic types, according to the nutritive substances which they contain: oligo,- meso- and eutrophic lakes. On the other hand, according to the content of humic substances, lakes are classified into humus lakes (many humic substances, brown water) and lakes of colour-less water (little humic substances). Such classification was suggested by Iversen (1929 — after Hansen, 1962). There was a time when it was thought (Nauman 1917, 1918, 1920 — after Hansen, 1962) that humic lakes are always oligotrophic in type. Later however, Juday and Birge (1932) have found that humic lakes must not at all be oligotrophic. Aberg and Rohde (1942) stated, that the terms oligo- eu- and dystrophy do not mean limited, closed units, but there may exits all possible transitions among them. Wiszniewski (1953) in his typological system of Polish lakes, considers the directions of just these transitions.

Gieysztor (1959) proved that between lakes belonging to two different types, might be placed a cotinuous series of lakes of intermediate features.

A further aim of this work was to find these intermediate stages with regard to the bottom fauna.

The metod of dendrite set arrangement (Florek et al. 1951) used in the first part of this paper, has been applied now for typological analysis. In tables II, IV, V, VI and VII, on which the drawings of the dendrite are based, an additional column has been added in which the total sum of differences between the given lake and the remainding lakes is quoted. This sum enables to arrange the lakes in a certain sequence depending on the degree of differentiation of the individual lake in proportion to the remaining lakes.

2. CLASSIFICATION OF THE LAKES BASED ON ABIOTIC FACTORS (FIG. 1, DENDRITE 1, TAB. I AND II)

In order to classify the lakes at the basis of abiotic factors, following features of the investigated basins have been considered: depth, transparency, colour, pH, total hardness, alkalinity, non-carbonate hardness, content of iron, chlorides, ammonia, nitrites and nitrates.

The results of measurements regarding the content of oxygen dissolved in water were not taken into consideration owing to following reasons: The differences of the oxygen content in the water above the bottom of the particular investigated lakes were unsignificant. Moreover, it seems that a more or less deep immersion of Ruttner's sampler at one station may cause a significant differences in the oxygen content in the sample. These differences may be greater, than the differences in the oxygen content in two different lakes in the same water level. It has been often seen that a mud at a given station emanated a strong smell of H_2S, whereas the sample of water, taken from above the bottom, shows about 80% of oxygen saturation. It seems that here the phenomenon of oxygen micro-stratification may occur (Brundin 1951).

With regard to the values of the individual abiotic features of the investigated lakes (Tab. I), following transformations have been made: The measuring results of those values, made during the four seasons of the year, were summed up and divided by four. By this method, the mean values of the given lake were obtained (Tab. I, columns "a"). To make possible a comparison of the lakes on a basis of such the different features, an estimative classification of these features has been carried out in the following way:

Table I

Physical and chemical properties of investigated lakes

	Mean for 10 lakes	Stęgwica		Gardzień		Jasne		Urowiecskie		Witoszew. Wlk.		Rucewo		Dauby		Kocioł		Tynwałdzkie		Łabędź	
		a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b
Depth, m	6,40	1,60	1	0,80	1	20	5	13	5	7	3	3	2	3,20	2	6	3	2,60	2	7	3
Visibility of Secchi disc	2,50	0,57	1	0,80	1	6	5	3	4	3,90	5	1,80	2	1,20	1	2,40	2	1,35	1	2,20	2
Reaction (pH)	7,5	6,8	2	7,4	3	6,2	1	7,5	3	7,2	2	8,0	4	8,1	4	7,7	3	8,2	4	8,2	4
Colour mg/l Pt	24	100	5	11	2	8	1	10	2	8	1	20	3	10	2	10	2	30	4	26	3
Total hardness	8,1	10,5	4	6,8	2	4,0	1	10,9	4	5,7	1	7,3	2	8,4	3	8,4	3	8,8	3	10,1	4
Non-carbonate hardness	1,3	4,7	5	2,9	4	0,6	1	3,8	5	0,9	2	0	1	0	1	0	1	0	1	0,6	1
Alkalinity mval/l	2,4	2,1	3	1,6	2	1,2	1	2,5	1	1,8	2	2,7	3	3,0	4	3,0	4	3,0	4	3,2	4
Iron mg/l Fe	0,03	0,1	5	0	1	0	1	0,01	2	0	1	0,05	4	0,04	3	0,04	3	0,05	4	0	1
Chlorides mg/l Cl	10,1	9,0	3	5,0	1	5,75	1	9,0	3	7,25	2	11,0	3	10,75	3	21,5	5	11,0	3	10,75	3
Ammonia mg/l N	0,30	0,75	4	0,87	5	0,14	2	0,18	2	0,14	2	0,44	3	0,12	2	0,03	1	0,29	3	0,07	1
Nitrites mg/l N	0,007	0,003	2	0,001	1	0,001	1	0,012	4	0,016	5	0,011	4	0,004	2	0,007	3	0,010	4	0,001	1
Nitrates mg/l N	0,23	0,41	4	0,22	3	0,15	2	0,22	3	0,05	1	0,22	3	0,10	2	0,32	4	0,25	3	0,39	4

In columns a — values of particular features
In columns b — relative values, divided into 5 classes (see also page 70—72)

Figures, showing the absolute values of different features (column a) of the particular lakes, were summed up and divided by the number of lakes (10). In this way there were obtained the mean values of the particular features for the set of ten lakes (column 1). Then, all data from columns a were divided into the following classes: ,

$$\text{class 1} \ll \text{class 2} < \text{class 3} > \text{class 4} \gg \text{class 5}$$

(mean values
or near the mean)

In columns "b" of table I the appropriate class numbers have been entered serving as the basis for calculating the differences between the particular lakes (Tab. II) to draw up the dendrite nr 1 (Fig. 1).

Table II

The "differences" between particular lakes, as concern their abiotic features

Lake	Stęgwica	Gardzień	Jasne	Urowiec	Witoszewskie	Rucewo Wlk.	Kocioł	Dauby	Tynwałdzkie	Łabędź	Total
Stęgwica	0	17	33	19	30	17	17	21	15	20	190
Gardzień		0	20	20	21	18	18	22	20	19	175
Jasne			0	20	11	24	22	24	28	21	203
Urowiec				0	17	16	18	16	18	17	161
Witoszewskie					0	19	21	21	23	22	185
Rucewo Wlk.						0	8	12	4	13	131
Dauby							0	10	6	9	129
Kocioł								0	12	9	147
Tynwałdzkie									0	13	139
Łabędź										0	140

Dendrite 1 can be in a natural way (according to the mathematical rules) divided into 5 or 6 parts. Accepted was the mathematically stronger division into the 6 following parts:

1. Lake Jasne
2. Lake Stęgwica
3. Lake Witoszewskie
4. Lake Gardzień
5. Lake Urowiec
6. Lakes Kociołek, Łabędź, Tynwałdzkie, Rucewo Wlk., Dauby. Those lakes which represented separate parts of the dendrite (1—5) are separated by distances from each other, as well as from the essential, 6 th part of the dendrite.

1. L a k e J a s n e. It differs from the other lakes by a far greater depth

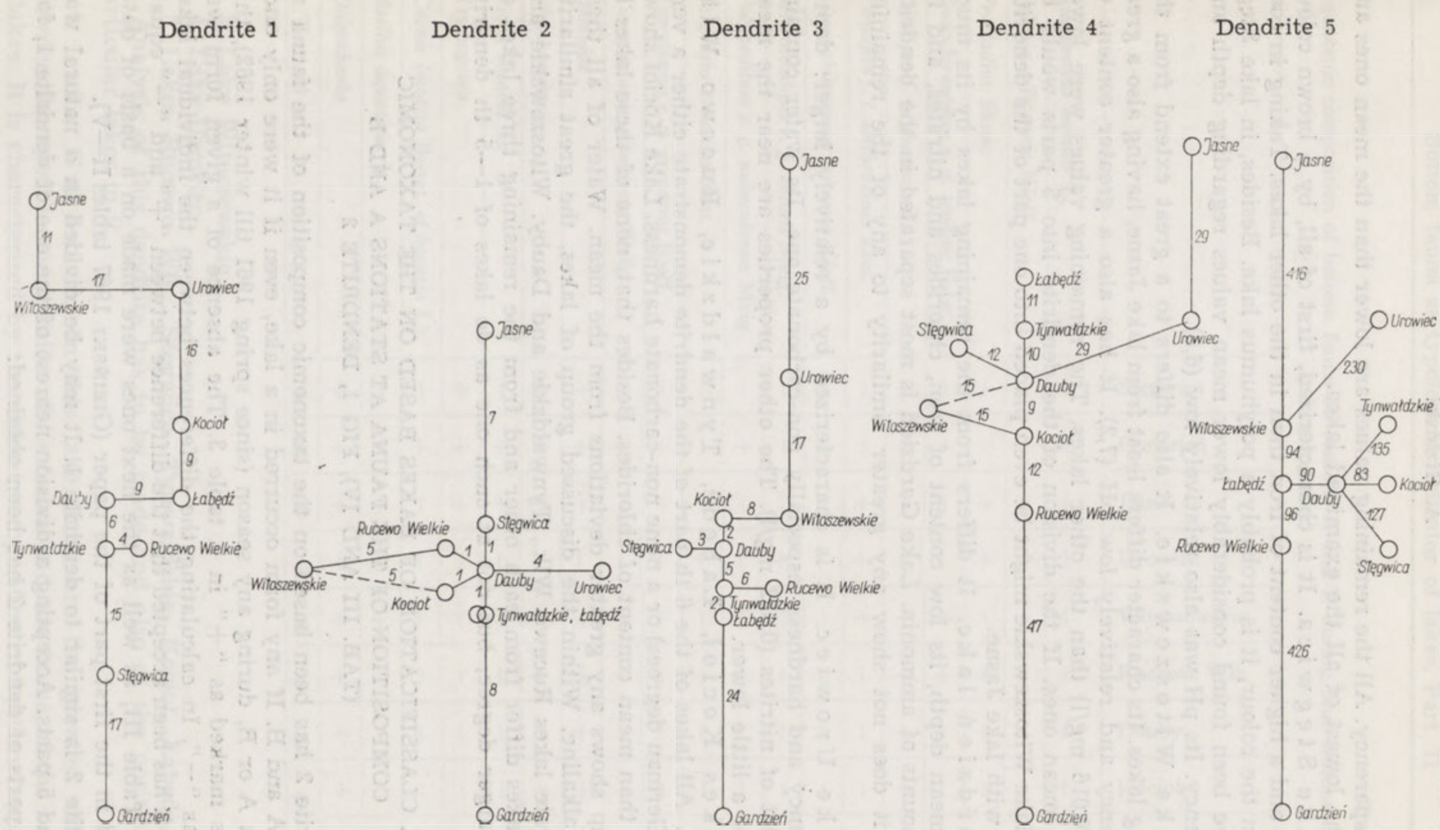

Fig. 1. Dendrites for differences between investigated in terms of abiotic features, bottom fauna taxonomic composition, its seasonal changes, its distribution and qualitative quantitative relationships (cf. Table II, IV, V, VI, VII).

and transparency. All the remaining values are lower than the mean ones and mostly the lowest of all the examined lakes.

2. Lake Stęgwica. It is characterized, first of all, by a brown colour of water and a higher content of iron than in the other lakes. Taking in consideration the colour, it is probably a polyhumus lake. Besides, in lake Stęgwica have been found considerably lower mean values regarding depth and transparency. Its pH was also relatively low (6,8).

3. Lake Witoszewskie. It also differs to a great extend from the remaining lakes. Its character differs least from lake Jasne, having also a great transparency and relatively low pH (7,2). It has also a greater content of nitrites (0,016 mg/l) than the other lakes. The remaining values were lower than the mean ones. If the division of the dendrite into 5 parts would be applied, lake Witoszewskie might be even placed into one part of the dendrite, together with lake Jasne.

4. Gardzień lake. It differs from the remaining lakes by its much smaller mean depth, its low content of iron, chlorides and nitrates, and its great amounts of ammonia. Lake Gardzień is most separated in the dendrite, because it does not show any greater similarity to any of the remaining lakes.

5. Lake Urowiec. It is characterized by a relatively larger: depth, transparency and hardness, especially non-carbonate one. Its water contains quite a lot of nitrites (0.012 mg/l). The other properties are near the mean values, or a little lower.

6. Lakes Kocioł, Łabędź, Tynwałdzkie, Rucewo Wlk., Dauby. All lakes of the 6 th part of the dendrite demonstrate either a very low (0.6 German degrees) or a none non-carbonate hardness. Lake Kocioł shows a higher than mean content of chlorides. Besides that, none of these lakes in this group shows any greater deviations from the mean. Water of all these lakes is alkaline. Within the discussed group of lakes, the great similarity demonstrate lakes Rucewo Wlk., Tynwałdzkie and Dauby. Witoszewskie and Łabędź lakes differ from each other and from the remaining three lakes at a little larger degree, but not at such one as do lakes of 1—5 th dendrite part.

3. CLASSIFICATION OF LAKES BASED ON THE TAXONOMIC COMPOSITION OF THE FAUNA AT STATIONS A AND B (TAB. III AND IV), FIG 1, DENDRITE 2

Dendrite 2 has been based on the taxonomic composition of the fauna at stations A and B. If any form occurred in a lake, even if it were only once at station A or B, during any season (since spring 1961 till winter 1962), this form was marked as "+" in a table 3. The absence of a given form was marked as "—". In calculating the differences between the individual lakes (Tab. IV) it has been accepted that the difference between "+" and "—" equals one unit. Table III, as well as the next ones were made on a basis of data, presented in the first part of the paper (Giziński 1967 tables II—V).

Dendrite 2 is similar to dendrite 1. It may be divided in a natural way into 3 and 5 parts. Accepting a division nearest of the one of dendrite 1, following 5 parts of dendrite 2 has been obtained:

1. Lake Gardzień
2. Lake Jasne

Table III

Taxonomic composition of bottom fauna on stations A and B during four seasons of the year (taken together)

	Stęgwica	Gardzień	Jasne	Urowiec	Witoszewskie	Rucewo Wlk	Dauby	Kocioł	Tynwałdzkie	Łabędź
Alabesmyia monilis L.	–	+	+	–	–	–	–	–	–	–
Pelopia vilipennis Kieff.	–	–	–	+	+	–	–	–	–	–
Procladius Skuse	+	+	+	+	–	+	+	–	+	+
Endochironomus e. g. tendens Fabr.	–	+	–	–	+	+	–	–	–	–
Tendipes f. l. plumosus L.	+	+	–	+	+	+	+	+	+	+
Tendipes f. l. anthracinus Zett.	–	–	+	+	+	–	–	–	–	–
Limnochironomus tritomus Kieff.	–	+	–	–	–	–	–	–	–	–
Microtendipes e. g. chloris Meig.	–	–	–	+	–	–	–	–	–	–
Polypedilum e. g. nubeculosum Meig.	–	+	–	–	–	–	–	–	+	+
Sergentia coracina Zett.	–	–	+	–	–	–	–	–	–	–
Tanytarsus e. g. gregarius Kieff.	–	+	–	–	+	–	–	–	–	–
Tanytarsus e. g. mancus Walk.	–	+	–	–	–	–	–	–	–	–
Heleidae	+	+	–	–	+	+	+	+	+	+
Chaoboridae	+	+	+	+	+	+	+	+	+	+
Sialis lutaria L.	–	+	+	–	–	–	–	–	–	–
Trichoptera	+	+	+	–	–	–	–	–	–	–
Caenis (*moesta* Bengt. *et horaria* L).	–	+	–	–	–	–	–	–	–	–
Asellus aquaticus L.	–	–	+	–	+	–	–	–	–	–
Oligochaeta	+	+	+	+	+	+	+	+	+	+
Total	6	14	9	7	9	6	5	4	6	6

3. Lake Witoszewskie
4. Lake Urowiec
5. Lakes Rucewo Wlk., Stęgwica, Tynwałdzkie, Kocioł, Łabędź, Dauby.

Analysis of this dendrite has to be made and also of the position of the particular lakes in it.

1. Lake Gardzień. In this lake there are the greatest differences between the specific composition of its fauna and the fauna of the remaining 9 lakes. It is characterized by the richest composition of bottom fauna at stations A and B (14 forms from among 24 studied). As in most of the examined lakes the qualitative abundance of the fauna at the analogical stations was

much smaller, this very fact effected the separation of lake Gardzień. Moreover, in connection with the small depth of this lake and the fact that its whole bottom is covered with tufts and "meadows" of submerged vegetation, most of the forms in lake Gardzień are littoral ones, which were not found in the deeper parts of other lakes. A similar, littoral character in the composition of the bottom fauna of the shallow lake Druzno was noticed by Mikulski (1955) and Klimek (1960). Lake Gardzień demonstrates relatively least differences opposite to lakes Tynwałdzkie and Łabędź.

Table IV

The "differences" between particular lakes as concern their bottom fauna taxonomic composition (for dendrite 2 — Fig. 1)

Lake	Stęgwica	Gardzień	Jasne	Urowiec	Witoszewskie	Rucewo Wlk.	Dauby	Kocioł	Tynwałdzkie	Łabędź	Total
Stęgwica	0	8	7	5	7	2	1	2	2	2	36
Gardzień		0	11	13	11	8	9	10	8	8	86
Jasne			0	8	10	9	8	9	9	9	80
Urowiec				0	6	6	4	5	5	5	57
Witoszewskie					0	5	6	5	7	7	64
Rucewo Wlk.						0	1	2	2	2	37
Dauby							0	1	1	1	32
Kocioł								0	2	2	38
Tynwałdzkie									0	0	36
Łabędź										0	36

2. Lake Jasne. It is the next lake with regard to differences in the qualitative composition of the profundal fauna. Attention must be drawn to the occurrence of such indicatory forms, as larval *Sergentia coracina* and *Tendipes f.l. anthracinus*. *Sergentia* has been noticed only in lake Jasne. The larvae of *Tendipes anthracinus* occurred sometimes also in the samples taken from lake Urowiec and once a simple larva was found in lake Witoszewskie. The main place of their occurrence is however lake Jasne. About the distinctness of lake Jasne decides also the occurrence, in its deeper parts, such forms, as *Asellus aquaticus*, larvae of *Trichoptera*, *Sialis lutaria* and *Ablabesmyia ex gr. monilis*. The remaining components of the fauna of lake Jasne (*Procladius* Skuse, *Chaoborus sp.*, *Oligochaeta*) occur in most of the other lakes, too. A characteristic is the absence on stations A and B of the larvae of *Heleidae*, like in lake Urowiec. The occurrence of *Trichoptera* larvae, at greater depth, been only noticed in lake Jasne. These larvae at stations A and B of lakes Gardzień an Stęgwica were also noticed, but both these lakes are very shallow. Lake Jasne shows the least difference in relation to lake Stęgwica.

This being most interesting that, with regard to their depth and their physico-chemical properties, just these lakes differ mostly (Tab. I and II).

3. Lake Witoszewskie. In the discused dendrite this lake differs evidently from the remaining ones. Its bottom fauna is relatively rich (9 forms). It has to be pointed out that, in the profundal of Witoszewskie lake there were found such forms as *Tendipes anthracinus*, *Tanytarsus e.g. gregarius*, *Endochironomus e.g. tendens*, *Asellus aquaticus*, and *Pelopia vilipennis*. Although the two first forms were found at stations A or B only sporadic, even by accident, they have to be considered in the qualitative setting. In the second dendrite lake Witoszewskie demonstrates the greatest similarity towards lakes Stęgwica and Rucewo Wlk. And here again, as has been pointed out in the characteristics of lake Jasne, it should be stressed that, with regard to its physico-chemical properties, lake Witoszewskie differed most, just in relation to the lake Stęgwica (Tab. III). As concerns the lake Jasne, however, which is similar with regard to its physico-chemical properties, it shows a clear difference within the discussed dendrite.

4. Lake Urowiec. Its difference, in relation to the remaining lakes, is caused by the presence of the larvae of *Pelopia vilipennis* and *Microtendipes e.g. chloris* at its deeper parts, and also by the absence of the larvae of *Heleidae* at these bottom parts. Also the larvae of *Tendipes f.l. anthracinus*, as mentioned, were found, outside lake Urowiec, only in the lakes Jasne and Witoszewskie. The remaining forms, occurring in the profundal of lake Urowiec (*Tendipes f.l. plumosus*, *Procladius sp.*, *Chaoborus sp.*, *Oligochaeta*), were noticed in almost all other lakes. Urowiec lake demonstrated its least difference towards lake Dauby, and no much more towards lakes Stęgwica, Tynwałdzkie and Łabędź. From among the quoted lakes only lake Stęgwica differed greatly from Urowiec lake with regard to the physico-chemical properties of its water.

5. Lakes Dauby, Stęgwica, Tynwałdzkie, Łabędź, Kocioł and Rucewo. All these lakes of this part of dendrite 2 are characterized by the occurrence, in their profundal, of *Tendipes f.l. plumosus* larvae, *Chaoborus sp.*, *Heleidae* and *Oligochaeta*. Also the larvae of *Procladius* Skuse were noticed in all (except lake Kocioł) the lakes placed in the discussed dendrite part. About the differences between the lakes of the fifth part of the dendrite, has decided the presence (lakes Tynwałdzkie and Łabędź), or the absence (remaining three lakes) of the larvae of *Polypedilum e.g. nubeculosum*. Lake Tynwałdzkie and Łabędź have an identical qualitative composition of their profundal fauna, and their distance in the dendrite equals nought.

After comparing dendrite 1 with dendrite 2, following conclusion may be drawn:

Despite the general likeness of both dendrites, there is a clear and essential difference consisting of the fact that lake Stęgwica, which in the first dendrite represented a separate part, came in the second dendrite into the compact group of lakes (fifth part of the dendrite 2). It may be, therefore, be concluded that differences in the physico-chemical properties of the water in the particular lakes must not necessarily cause differences in the qualitative compound of their bottom fauna.

Secondly, the degree of the differentiation of the physico-chemical properties of the water is not equal to the differentiation of the specific compound of its fauna. It is true, that both dendrites, 1 and 2, except Stęgwica lake, are divided into the same parts, but the mutual similarities and differences between the particular lakes, in both dendrites, are not identical, sometimes even, as e.g. with regard to lake Stęgwica, Jasne, Witoszewskie, just opposite. However, in nine out of the ten investigated lakes there has been found a more or less clear connection between the abiotic properties and the compound of the bottom fauna. Thus, the existence of this connection should be accepted as a rule, whereas any deviations from this rule — as an exception, which may take place with regard to polyhumus lakes.

4. CLASSIFICATION OF LAKES, BASED ON THE TAXONOMIC COMPOSITION OF BOTTOM FAUNA, DURING THE FOUR SEASONS OF THE YEAR. (TAB. V, FIG. 1 — DENDRITE)

Dendrite 3 has been drawn up similarly to the previous one, with the exception that into consideration have been taken also seasonal differences in the composition of the bottom fauna in the investigated lakes.

In drawing this, and the consecutive dendrites, the author was compelled to make a certain simplification. As had been already mentioned (in the

Table V

The "differences" between particular lakes as concern their bottom fauna taxonomic composition and its seasonal changes (for dendrite 3 — Fig. 1)

Lake	Stęgwica	Gardzień	Jasne	Urowiec	Witoszewskie	Rucewo Wlk.	Dauby	Kocioł	Tynwałdzkie	Łabędź	Total
Stęgwica	0	30	30	20	12	12	3	5	6	8	126
Gardzień		0	37	34	33	29	28	30	25	24	270
Jasne			0	25	29	33	31	29	34	31	279
Urowiec				0	17	25	18	18	20	17	197
Witoszewskie					0	15	10	8	12	12	147
Rucewo Wlk.						0	9	7	6	7	130
Dauby							0	2	5	8	111
Kocioł								0	5	7	108
Tynwałdzkie									0	2	112
Łabędź										0	113

previous paper), the author was unable to collect autumn samples from lake Rucewo Wlk. The absence of the data from the autumn would make it impossible to place lake Rucewo in that dendrite arrangement which considers the seasonal differences, or else, the drawing up the dendrites of all investigated lakes had to be made without considering the autumn results. To avoid this, it has been hypothetically accepted that the faunistic differences between lake Rucewo Wlk. and the remaining lakes were in the autumn the same as they were in winter. It may be assumed that a possible mistake will not affect fundamentally the position of lake Rucewo Wlk. in the dendrite, because in those lakes, which are in their character like Rucewo Wlk., there has been found a clear similarity in the occurrence of the bottom profundal fauna in the autumn of 1961 and the winter of 1962.

Dendrite 3 is similar to dendrite 2. It can be divided into 4, 5, 7 and 8 parts. If we accept a 5 — part division, dendrite 3 will split in a identical way, like dendrite 2.:

1. Lake Jasne
2. Lake Gardzień
3. Lake Urowiec
4. Lake Witoszewskie
5. Lakes Rucewo Wlk., Stęgwica, Łabędź, Tynwałdzkie, Dauby, Kocioł. The general similarity of dendrites 2 and 3 suggests the conclusion that the seasonal changes in the taxonomic composition of the bottom fauna in the investigated lakes run generally on almost the similar way.

However, despite the similarity between dendrites 2 and 3, there can be seen certain differences which illustrate the distinctness of the course in the seasonal changes which take place in the composition of fauna inhabiting the particular lakes. Here are the more important of these differences: Lake Jasne demostrated in dendrite 2 its greatest similarity in relation to lake Stęgwica, whereas in dendrite 3 it is connected with lake Urowiec by the smallest distance. The closer connection between lake Jasne and Urowiec have to be explained by the fact, that the forms, which decided upon the difference between the specific compositions of these lakes, have been mostly noticed only in one season of the year. So, for example, the larvae of *Microtendipes ex gr. chloris* were noticed in the profundal of lake Urowiec only once, in the autumn, whereas, during the other seasons it has not been noticed in any of these two lakes. Similarly, *Sialis lutaria* larvae were noticed in lake Jasne only in summer, whereas in the remaining season of the year they has been noticed in neither of these lakes. The "distancing" of lake Jasne from lake Stęgwica was caused by the fact, that the forms, which have been common for these lakes (*Procladius* Skuse, *Oligochaeta*), used to be caught in both lakes during different seasons of the year. For the same reasons, lake Urowiec is "distancing", in the third dendrite, from lake Dauby and "approaching" to lake Witoszewskie.

The remaining lakes, in both dendrites, demonstrate a similar differentiation in relation to each other, because the seasonal changes in the taxonomic composition of these lakes (except lake Gardzień) are unsignificant and more or less similar.

5. CLASSIFICATION OF LAKES BASED ON THE DIFFERENCES BETWEEN THE TAXONOMIC COMPOSITION, SEASONAL CHANGES, AND DIFFERENCES IN THE DISTRIBUTION OF BOTTOM FAUNA AT STATIONS A AND B. (TAB. VI, FIG. 1, DENDRITE 4)

The succesive, fourth dendrite, has been drawn up like the third one with the difference that the composition of bottom fauna was compared separatly for stations A and B. This resulted in an increase of the differences between particular lakes (Tab. VI.). Dendrite 4 does not differ by almost anything from dendrite 3. Thus it may be divided into 5 analogical parts:

1. Lake Gardzień
2. Lake Jasne
3. Lake Urowiec
4. Lake Witoszewskie

Table VI

The "differences" between particular lakes, taking into account their bottom fauna taxonomic composition, its seasonal changes and distribution (for dendrite 4)

Lake	Stęgwica	Gardzień	Jasne	Urowiec	Witoszewskie	Rucewo Wlk.	Dauby	Kocioł	Tynwałdzkie	Łabędź	Total
Stęgwica	0	47	33	30	25	22	12	16	15	16	216
Gardzień		0	48	47	52	47	52	53	48	50	444
Jasne			0	29	38	44	38	39	44	41	354
Urowiec				0	30	39	29	32	40	36	312
Witoszewskie					0	27	15	15	24	25	251
Rucewo Wlk.						0	21	12	17	19	248
Dauby							0	9	10	13	199
Kocioł								0	19	16	211
Tynwałdzkie									0	11	228
Łabędź										0	227

5. Lakes Rucewo Wlk., Tynwałdzkie, Łabędź, Stęgwica, Kocioł, Dauby. Similarities between dendrite 3 and 4 allows us to make the conclusion that the distribution of the particular species (forms) in the investigated lakes is also similar. As a matter of fact, it can be seen, that forms which are rather characteristic for the littoral, if they were noticed in the profundal, then almost exclusively at stations B, nearer the shore. Forms, however, peculiar for the profundal occurred mostly at both stations (A and B). An exception is lake Gardzień, where no regularities in the distribution of the particular fauna forms depending on the distance of shore, were found.

6. CLASSIFICATION OF LAKES BASED ON THE QUALITATIVE AND QUANTITATIVE RELATIONS OF FAUNA (TAB. VII. FIG. 1, DENDRITE 5)

In drawing up dendrite 5, considered were also the numbers of the particular forms of bottom fauna, besides the criterions accepted for dendrites 2—4. Dendrite 5 differs considerably from dendrite 4 with regard to the situation within them of the particular lakes, as well as with regard to its division into the parts. In can be divided into 3, 4, and 6 parts. Accepted has been the division into 6 parts, as closest to the foregoing ones. The dendrite is then divided as follows:

1. Lake Gardzień
2. Lake Jasne
3. Lake Urowiec
4. Lake Tynwałdzkie
5. Lake Stęgwica
6. Lakes Kocioł, Rucewo Wlk., Witoszewskie, Łabędź, Dauby. As may be seen, there exist essential differences in relation to the preceding dendrite. The most important difference is that lakes Stęgwica and Tynwałdzkie singled out of the compact group of lakes (fifth part of dendrite 4) into separate parts of the dendrite, whereas lake Witoszewskie is found to be included in a quite compact group of lakes which consists the sixth part of dendrite 5.

Table VII

The "differences" between particular lakes, taking into account their bottom fauna qualitative and quantitative relations (for dendrite 5)

Lakes	Stęgwica	Gardzień	Jasne	Urowiec	Witoszewskie	Rucewo Wlk.	Dauby	Kocioł	Tynwałdzkie	Łabędź	Total
Stęgwica	0	514	485	315	169	210	127	150	224	156	2350
Gardzień		0	744	619	475	426	497	530	574	465	4844
Jasne			0	558	416	481	450	481	571	428	4614
Urowiec				0	230	251	266	289	367	260	3155
Witoszewskie					0	139	100	131	205	94	1949
Rucewo Wlk.						0	140	132	207	96	2082
Dauby							0	83	135	90	1887
Kocioł								0	170	139	2105
Tynwałdzkie									0	187	2640
Łabędź										0	1915

These changes can be explained by an analysis of the quantitative composition of the fauna in the particular lakes. Table VIII may facilitate this analysis. In talking over the succesive parts of dendrite 5, we can trace the quantitative relations of the bottom fauna in the investigated lakes, and also state up to which degree the taking into consideration the quantitative relations influenced the change in the classification of these lakes.

1. Lake Gardzień. It differs from the remaining lakes at a still higher degree than in the preceding dendrite arrangements, because it is characterized not only by the different specific composition but also by quantitative ralations at stations A and B. Those forms which in the other lakes consist, sometimes,

almost 100% of the fauna of the deeper parts, occurred in lake Gardzień in very small numbers:

Tendipes f.l. plumosus	— 20 specimen	= 7.5%	of fauna at st. A and B
Chaoborus sp.	— 2 „	= 0.7%	„ „ „
Heleidae	— 3 specimen	= 1.1%	of fauna at st. A and B
Oligochaeta	— 2 specimen	= 0.7%	of fauna at st. A and B

These four forms consist all together 10.1% of the sum of specimen caught at stations A and B (from spring 1961 till winter 1962). At relatively great numbers occured the larvae of *Procladius* *Skuse* (71 specimen = 26.7%). The remaining fauna at stations A and B of lake Gardzień consisted of forms peculiar for the littoral.

2. Lake Jasne. It also differs gratly from the other lakes. Forms which were common with other lakes have been in lake Jasne found only sporadic. Hardly 6 specimen were caught all together of: *Chaoborus sp.*, *Oligochaeta* and *Procladius* Skuse which represent 2% of the fauna caught at stations A and B.

The larvae of *Sergentia coracina*, the only profundal form of lake Jasne were also caught in numbers not very great. At stations A and B, during all four considered seasons, all together 26 *S. coracina* larvae were caught, which represent 8.7% of the sum of bottom fauna specimen from these stations. Almost 90% of the fauna in the deeper parts of lake Jasne consist of littoral forms, mostly *Asellus aquaticus*. This is understandable considering the fact that great parts of lake Jasne bottom are covered with *Fontinalis antipyretica* Hedw.

3. Lake Urowiec. This lake demonstrates a very specific arrangement of its quantitative relations:

Tendipes f.l. plumosus	— 1 specimen	= 0.3%	of fauna at st. A and B
„ *anthracinus*	— 19 „	= 4.9%	„ „ „ „
Chaoborus sp.	— 325 „	= 84.2%	„ „ „ „
Oligochaeta	— 23 „	= 6.0%	„ „ „ „
Procladius Skuse	— 2 „	= 0.5%	„ „ „ „

Although the number of the larvae of *Chaoborus* and *Oligochata* show a certain similarity in relation to the quatitative conditions in such lakes as Dauby and Kocioł, the seasonal aspect of the occurrence of these forms in lake Urowiec id different. The *Choborus sp.* larvae were caught at lake Urowiec mostly in small numbers. Only in the autumn they appeared at station A in unusually great numbers (291 specimen). The appearance of these larves in the other lakes is more uniform. For this reason, lake Urowiec differs greatly from the other lakes and represents a separate part of the dendrite.

4. Lake Tynwałdzkie. More essential differences between dendrites 4 and 5 refer, to a great degree, to the situation of just this lake. The transfer of Tynwałdzkie lake from a compact group of lakes (dendrite 4) into a separate part of dendrite 5 has been caused mainly by its quantitative richness of profundal fauna. A total of 801 specimen was collected at stations A and B (Tab. VIII). The numbers of the particular forms of the bottom fauna are as follows:

Tendipes f.l. plumosus	— 334 specimen	= 41.7%	of total fauna (st. A and B)
Chaoborus sp.	— 318 „	= 39.7%	„ „ „
Heleidae	— 11 „	= 1.4%	„ „ „

Oligochaeta	— 117	„	= 14.6%		„	„	„
Procladius Skuse	— 20	„	= 2.5%		„	„	„
Total:	— 800	„	= 99.9%		„	„	„

About the distinctness and the dendrite- separation of lake Tynwałdzkie have decided not only the quantitative abundance in general, but also the richness of the larvae of Tendipes f.l. plumosus found in no other of all of the investigated lakes.

Table VIII

Numbers of bottom fauna components at stations A and B in lakes investigated

Lake	Spring			Summer			Autumn			Winter			Total, A	Total, B	Total, A+ +B
	A	B	Sum	A	B	Sum	A	B	Sum	A	B	Sum			
Stęgwica	3	118	121	60	44	104	132	109	241	95	43	138	290	314	604
Gardzień	38	26	64	19	8	27	46	40	86	76	13	89	179	87	266
Jasne	0	150	150	0	94	94	1	21	22	7	25	32	8	290	298
Urowiec	0	31	31	10	5	15	291	21	312	23	5	28	324	62	386
Witoszewskie	12	0	12	8	3	11	12	11	23	44	22	66	76	36	112
Rucewo Wlk.	12	19	31	25	10	35	?	?	?	60	21	81	97	50	147
Dauby	22	57	79	16	27	43	95	75	170	76	53	129	209	212	421
Kocioł	117	71	188	23	26	49	109	110	219	70	45	115	319	252	571
Tynwałdzkie	90	110	200	31	17	48	145	152	297	130	126	256	396	405	801
Łabędź	42	26	68	8	6	14	28	20	48	7	31	38	85	83	168
T o t a	336	608	944	200	240	440	859	559	1418	588	384	972	1983	1791	3774

5. Lake Stęgwica. The qualitative composition of the bottom fauna in this lake is very close to the qualitative composition of the fauna in the lakes consisting the 6 th part of the dendrite. The quantitative relations of the individual groups of bottom fauna in lake Stęgwica are, however, entirely different:

Tendipes f.l. plumosus	— 3	specimen	= 0.5%	of total fauna (st. A and B)			
Chaoborus sp.	— 537	„	= 88.0%		„	„	„
Heleidae	— 9	„	= 1.5%		„	„	„
Oligochaeta	— 6	„	= 1.0%		„	„	„
Procladius Skuse	— 48	„	= 8.0%		„	„	„
Total:	— 603	„	= 99.0%		„	„	„

Special attention deserves the evident domination of *Chaoborus sp.* during all seasons of the year. Such a great number of these larvae was found only in lake Urowiec but there, as already mentioned, *Chaoborus sp.* larvae were caught in such numbers only in the autumn. Besides, from the lakes of 6-th part of dendrite, lake Stęgwica differs above all by its very small numerosity of *Tendipes f.l. plumosus* larvae. In this case, therefore, the diversity of lake Stęgwica is decided by the reverse phenomenon as related to lake Tynwałdzkie. The quantitative relations of the bottom fauna in lake Stęgwica requires a special classification from among the set of investigated lakes, as an separate unit.

6. Lakes Kocioł, Rucewo Wlk., Witoszewskie, Łabędź and Dauby. A special explanation needs the fact of classifyiny lake Witoszewskie to this group of lakes. As we know from the previous dendrites, this lake is characterized by a different, more rich composition of its profundal fauna. Those forms, however, which have decided about such a distinctness, were caught in lake Witoszewskie rather sporadic, often by accident. From among *Tanytarsus e.g. gregarius* and *Tendipes f.l. anthracinus* only one specimen of each were caught, *Endochironomus e.g. tendens* — 2 specimen, *Asellus aquaticus* — 5. Such small numbers of forms, which in the general fauna of other investigated lakes are represented by rather great numbers, could not decide about the excluding of this lake into a separate group. With regard to its bottom fauna, lake Witoszewskie is similar to lake Łabędź. Both lakes are characterized by a poor fauna with regard to its numbers (Witoszewskie — 112, Łabędź — 168 specimen). The particular forms of bottom fauna in both lakes have a close relation in numbers:

	Lake Witoszewskie			Lake Łabędź		
Tendipes f.l. plumosus	— 34	specimen	= 30.4%	35	specimen	= 20.8%
Chaoborus sp.	— 26	„	= 23.2%	81	„	= 48.2%
Oligochaeta	— 21	„	= 18.7%	35	„	= 20.8%
Heleidae	— 1	„	= 0.9%	2	„	= 1.2%
Procladius Skuse	— —	„	—	11	„	= 6.5%
Total:	— 82	„	= 73.2%	164	„	= 97.5%

About the difference between these two lakes have decided mainly the differences in the numbers of larvae of *Chaoborus sp.* and the absence of larvae of *Procladius* Skuse in lake Witoszewskie.

The greatest similarity, in the 6th part of the dendrite, is shown by the lakes Kocioł and Dauby. They are relatively rich in fauna (571 and 421 specimen) and are characterized by very similar quantitative relations of their main components of the bottom fauna at stations A and B:

	Lake Kocioł			Lake Dauby		
Tendipes f.l. plumosus	— 73	specimen	= 12.8%	85	specimen	= 20.2%
Chaoborus sp.	— 450	„	= 78.8%	310	„	= 73.6%
Oligochaeta	— 39	„	= 6.8%	20	„	= 4.7%
Heleidae	— 9	„	= 1.6%	4	„	= 0.9%
Total:	— 571	„	= 100.0%	419	„	= 99.4%

As can be seen, in both lakes the grouping of forms qualifying for the first part of the fauna dendrite (see Giziński, 1967, fig. 2), consists of almost 100% of profundal fauna. It seems that these specimen do form in both lakes an association, but in order to confirm this assumption it would be necessary to carry out further investigations.

Lake Rucewo Wlk. It does not differ conspicuously from the other lakes. 95.3% of the total fanua consists of the same four groups of animals as in the lakes discussed above:

Tendipes f.l. plumosus	— 42	specimen	= 28.6%
Chaoborus sp.	— 10	„	= 6.8%
Oligochaeta	— 83	„	= 56.5%
Heleidae	— 5	„	= 3.4%
Total*:	— 140	„	= 95.3%

In lake Rucewo Wlk. there were found relatively many Oligochaeta but very few larvae of *Chaoborus*. The latter may be partly explained through lack of data from the Autumn, that season being of the greatest quantitative development of these forms.

The analysis of the particular dendrites, and a comparison between the positions of the particular lakes in the succesive dendrite arrangements, allows to draw the following conclusions:

The taxonomic composition of the investigated lakes remains in a strict connection with their depth and the physico-chemical properties of water. It does not refer only to the polyhumus lake Stęgwica. When at the classification of lakes, besides the quantitative composition of their fauna, the seasonal changes and horizontal distribution of the bottom fauna is also taken in consideration, the similarity of the succesive dendrites decreases a little. In all the lakes, the seasonal changes in the composition of the bottom fauna, as well as its distribution are similar.

The quantitative conditions of the bottom fauna, even in the group of lakes of similar taxonomic composition, are very different and require another division. This division is different from that which has been done previously, without taking into consideration the numerosity of the particular compounds of the bottom fauna. The suggestion of Patalas (1954), therefore refering to the necessity of considering in case of "planktonic" classification of lakes, not only the very fact of finding any indicatory form but also its numerosity, is correct also with regard to a classification based on bottom fauna investigations.

7. THE POSITION OF THE INVESTIGATED LAKES IN THE MOST FREQUENTLY APPLIED TYPOLOGICAL SYSTEMS

Lake Gardzień, after the system of Stangenberg (1936), may be classified as a pond — lake. Within the system of Wiszniewski (1953), it would be an eutrophic lake with features of polymixis. It would be here impossible to apply the typology of Thienemann (1922, 1925), Lundbeck (1926), or Decksbach (1929), because the systems of these authors deal with the composition of bottom fauna in the profundal. In lake Gardzień, however, there is no profundal, because it is shallow and having its bottom covered with rooted vegetation. Among Polish lakes, similar faunistic conditions shows lake Druzno(Mikulski 1955, Klimek 1960).

Lake Jasne does not "fit" into Wiszniewski's system, because of its depth, smaller than 24 m, it should be reckoned among eutrophic lakes, whereas the other properties of lake Jasne are characteristic for mesotrophic lakes. An exact location of lake Jasne in any of the typological faunistic systems, proves also to be quite difficult. Most closely it would cor-

* Quantitative relations given without data of the autumn.

respond to the group of lakes "U — I" (*Sergentia- Stictochironomus See*) or "U — II" (*Sergentia- Bathophilus — Plumosus See*) after Decksbach (l.c.). The absence of *Stictochironomus* larvae, however, makes the possibility of location of lake Jasne into any of these types, also rather questionable.

Taking into consideration the physico-chemical properties of its water, its great depth (in comparison with the other lakes of that area), and the presence of *Sergentia* larvae, Jasne lake can be surely classified as mesotrophic lake, showing a tendency towards dystrophy.

Such direction in the evolutional changes of the lake has been foreseen in this system by Wiszniewski (1953).

Lake Urowiec proves also difficult to be placed into Wiszniewski's system. As the maximum depth of Urowiec is over 30 m, it should be classified among, at least, b-mesotrophic lakes, but this is in no way confirmed by its faunistic conditions. After the system of Thienemann, Lundbeck, Decksbach and Brundin (1958), lake Urowiec could be placed among lakes moderately eutrophic (*Chironomus anthracinus* lakes), because the larvae of *Tendipes f.l. plumosus* was caught in this lake only sporadic, and, in addition, in the littoral zone.

Lake Tynwałdzkie. In accordance with above mentioned typological systems this lake, as well as the remainig lakes of the 6th part of dendrite 5, should be placed among lakes decidedly eutrophic, "*Plumosus-lakes*". Most of the investigated lakes could be included into this, so broadly understood type, but lake Tynwałdzkie distinguishes itself by its quantitative aboundance of fauna, especially of the larvae of *Tendipes f.l. plumosus*. For this reason a classification into subgroups, according to the domination of profundal fauna forms, has been accepted. To the subgroup of eutrophic lakes of the "*Plumosus*" type, which are characterized by faunistic conditions similar to those one of lake Tynwałdzkie, proposition is presented to give the name: "*Polyplumosus — Chaoborus lakes*".

Lake Stęgwica. The physico-chemical properties of the water, which are characteristic for polyhumus, alloiotrophic lakes, allow to place Stęgwica in Wiszniewski's system (alloiotrophic lakes). If regard its faunistical conditions, lake Stęgwica may be named a "*Chaoborus- oligoplumosus lakes*".

All the remaining lakes, like lake Tynwałdzkie, are decidedly eutrophic, "*Plumosus*" lakes. With the difference of lake Tynwałdzkie, and adhering to the accepted classification into subgroups, they should be denominated as follows:

Lakes Witoszewskie and Łabędź — "*Oligoplumosus — Chaoborus lakes*"

Lakes Kocioł and Dauby — "*Chaoborus- mesoplumosus lakes*"

Lake Rucewo Wlk. has features of those lakes which Valle (1927) defined as "*Tubifex-See*" or "*Tubifex — Corethra -See*". It should be mentioned that, besides similar faunistic conditions, lake Rucewo, as Valle's *Tubifex--lakes*, is situated among morainic clay grounds.

The lakes of the 6th part of the dendrite and lake Tynwałdzkie may serve as an example that even in a group of lakes, which are closely related with regard to their physico-chemical properties, there may be detected various kinds of their bottom fauna character. These varieties are probably the result of several factors acting in complexes, and being often peculiar for one, defined lake. Refering to Gieysztor's (1959) theory of a continuous series of lakes it has to be assumed that a diagram of such an interrupted succesion, based on bottom fauna, would not produce a straight line, but a "step-like" one, illustrating the jump-like character of the faunistic differences between the particular lakes.

8. SUMMARY

The method of a dendrite arrangement of set (Florek et al. 1951) was applied in investigations aiming towards the classification of lakes.

It has been found that classification of lakes, based on depths and physico-chemical properties is similar to classification based on the taxonomic composition of the profundal fauna. This rule does not apply to the polyhumus, alloiotrophic lake Stęgwica, because the qualitative composition of its fauna is almost indentical with that of oligohumus lakes of a similar degree of eutrophization.

The dependence of the faunistic conditions on depth and physico-chemical properties of the water becomes less distinct in proportion to our taking into consideration, besides the qualitative composition itself, also seasonal changes, the character of the horizontal distribution, and, especially, the quantitative data. As correct has to be considered the suggestion of Patalas (1954), refering to the necessity of considering during typological investigations regarding plankton, not only the qualitative conditions but also the numerosity of the individual forms in an analogic studies on bottom fauna.

At investigations, to which a great number of various lakes would be subjected, it is always possible to put them into "continuous series" (as Gieysztor, l. cit. suggests). It seems, however, that in connection with the great specificity in the environmental conditions of the individual lakes, especially with regard to the bottom biotopes, the differences between the particular lakes will always demonstrate a "jump-like" character.

In order to consider the quantitative varieties in the profundal fauna of eutrophic, "*Plumosus*" lakes it is proposed to introduce such terms that would define the quantitative conditions of a given lake (e.g. "*Polyplumosus — Chaoborus lake*").

9. STRESZCZENIE

Przedstawiono próbę klasyfikacji jezior przy pomocy metody dendrytowego porządkowania zbioru (Florek i i. 1951). Przy dokonywaniu podziałów klasyfikacyjnych uwzględniono różne kryteria (dendryty 1—5, Fig 1). Przeprowadzono analizę i porównanie kolejnych podziałów.

Stwierdzono podobieństwo klasyfikacji jezior, dokonanej na podstawie głębokości i właściwości fizyko-chemicznych wody do klasyfikacji, opartej na składzie jakościowym fauny profundalowej. Reguła ta nie dotyczy polyhumusowego, alloiotroficznego jeziora Stęgwica, w którym skład jakościowy fauny dennej jest taki sam, jak w jeziorach oligohumusowych o podobnym stopniu eutrofizacji.

W miarę uwzględniania oprócz samego składu jakościowego także zmian sezonowych, charakteru rozmieszczenia horyzontalnego, a zwłaszcza danych ilościowych — zależność stosunków faunistycznych od głębokości i właściwości fizyko-chemicznych wody jest coraz mniej wyraźna. Dowodzi to, iż twierdzenie Patalasa (1954) dotyczące konieczności uwzględniania przy typologicznych badaniach planktonowych nie tylko stosunków jakościowych, lecz także liczebności poszczególnych form, należy uznać za słuszne w odniesieniu do analogicznych badań nad fauną denną.

Przy badaniach dużej liczby jezior zawsze można je ułożyć w "ciągłą serię" (w zrozumieniu Gieysztora, 1959). Jednakże wydaje się, że w związku ze znaczną specyficznością warunków środowiskowych w poszczególnych jeziorach, zwłaszcza w odniesieniu do biotopów dennych, różnice między poszczególnymi jeziorami będą wykazywały charakter skokowy.

Dla uwzględnienia różnic ilościowych w składzie fauny profundalowej jezior eutroficznych, typu "*Plumosus*", proponuje się wprowadzenie terminologii, która by określała charakter stosunków ilościowych fauny dennej danego jeziora (na przykład jeziora "*Polyplumosus — Chaoborus*").

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A. SIKOROWA

OCCURRENCE OF *CHAOBORUS ALPINUS* PEUS (*DIPTERA, CULICIDAE*), A NEW SPECIES IN POLAND

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ABSTRACT

Attention is paid to the conditions necessary to determine the species *Chaoborus alpinus* Peus 1938, belonging to the genus *Chaoborus* Licht., for the first time found in the area of Poland. A fact is described of a change in numbers of mandibular bristles, characteristic of the larva of the genus *Chaoborus*, which are thought to be a stable feature of the individual species of this genus.

The present paper deals with some features found in taxonomy keys, which are characteristic of two species of the genus Chaoborus Licht., i.e. *Chaoborus flavicans* Meig. and *Chaoborus alpinus* Peus. In the material collected, the hydrobiologists find mainly the larval stage, considerably rarely the pupae, mainly on account of a short, only several-day lasting period of the pupal stage. This is why during the determination of the species of *Chaoborinae* one uses first of all the keys to determine their larvae.

When distinguishing the larvae of *Ch. flavicans* Meig. from those of *Ch. alpinus* Peus (other species are easily distinguishable mainly on their mandibular teeth) both PEUS (1938) and HIRVENOJA (1961) mention, as a characteristic feature, first of all the number of the bristles on mandible, which constitute the so-called catch-basket. The number of these bristles is thought by these authors to be stable, ad different in various species. BERG (1937) was the first to state, when analysing the material gathered from Danish lakes that considerable deviations exist from the number of 15 mandibular bristles in the larvae of *Ch. flavicans* Meig. mentioned by PEUS (1934). In the lakes Esrom and Grobso, the number of the bristles was 10—11, 11—12, 12—13 and 13—14. Analysing the genital sclerite of males (according to MARTINI, 1931) BERG and PETERSEN (1956) stated that the larvae of *Chaoborus* Licht. from Danish lakes belong to the species *Ch. flavicans* Meig., and also ascertained that the feature was little stable, thus also questionable.

Similar difficulties were met with during the identification of the larvae of *Chaoborus* Licht., gathered by the present author in Poland, mainly as concerns larvae of the group "flavicans". These larvae, determined by means of the key of PEUS (1934) and PROKEŠOVA (1959), might have been determined only as *Ch. flavicans*. However, in the light of the work by PEUS (1938), and of the key of HIRVENOJA (1961), as well as on the basis of the taxonomic features observed in the material collected. I must have recognized these determinations for dubious. For this reason, the mandibular bristles of a part of the larvae, so far included in the group "flavicans", underwent, after preservation, a detailed counting. Another part of the larvae was reared in aquariums screened with a net to catch imago stage. The larvae were gathered in various seasons. The number of mandibular bristles, characterizing the larvae of several Polish water basins, is considerably more varying than those quoted by Peus (1934, 1938), Berg (1937), Montshadskii (1936), Berg, Petersen (1956), Hirvenoja (1961), Ökland (1964) and others (Table I).

Table I

Number of mandibular bristles in catch-basket of the larvae of the II, III and IV instars and number of the examined male adults of *Ch. alpinus* Peus

Name of basin	Number of mandibular bristles			Numer of the individuals examined	
	instar				
	II	III	IV	larvae	male imagos
Lake Kortowskie	5	7; 8; 9;	10; 11; 12;	37	25
Lake Legińskie			10; 11; 12;	11	14
Lake Wondoł					3
Lake Lutynówka					2
Water basin changing into a swamp	5;	7; 8; 9; 10	9; 10; 11; 12; 13; 14; 15; 16;	69	44
	Sum of the individuals examined			117	88

A varying number of these bristles in the subsequent larval stages is, beside their general unstable amounts, a source of these differences. Younger larvae are characterized by a considerably lower amount of the mandibular bristles: beginning with 4 bristles in the first instar (in this stage larvae do not possess adequately developed taxonomic features and, under conditions of the present-day state of knowledge, are indeterminable) and ending with 16 bristles in the fourth instar (Fig. 1, and Table I). The number of the larvae examined by the present author is not too high (particularly as concerns those collected from lakes) and, during further observations, can increase. Nevertheless, the number of the mandibular bristles of the larvae that belong to the group "flavicans" gathered in Poland, exceeds those presented by Peus (1934, 1938) and others for both species of this group.

Male adults reared from the population "flavicans" that occur in the water basins listed in Table I, in all cases possessed genital sclerites typical, according to Peus (1938), of the species *Ch. alpinus* Peus (Fig. 2). Female adults of these two species do not differ from each other (Peus, 1938). Genital sclerite of *Ch. alpinus* Peus differs from that of *Ch. flavicans* Meig. in having a transparent wing-like crest situated at the upper margin (Fig. 2a). For the present author this was a basis to determine the larvae *Chaoborus* of the group "flavicans" from the Lake Kortowskie, Lake Legińskie, Lake Wondoł, Lake Lutynówka, and from a water basin changing into a swamp, as *Chaoborus alpinus* Peus.

Lack of taxonomic keys in entomologic literature, which could help in determining *Culicidae* in all their developmental stages, is highly disadvantageous. Still worse is the situation concerning the sub-family *Chaoborinae*. The keys available at present are only fragmentary and incomplete and, as

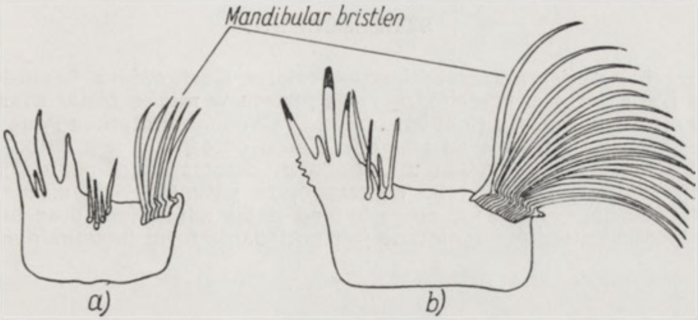

Fig. 1. Mandibles of *Chaoborus alpinus* Peus
a — mandible in the second instar; b — mandible of the fourth instar (immediately before transformation into a pupal stage);

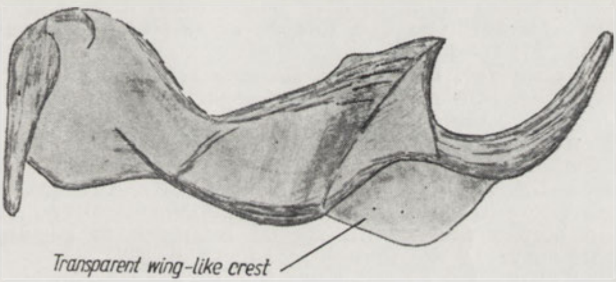

Fig. 2. Genital sclerite of imago of *Chaoborus alpinus* Peus from the Lake Kortowskie

concerns some features characteristic of the individual species, they frequently are contradictory. Furthermore, some characteristic features are, as presented above, highly varying, therefore not very reliable in determination of species.

As far as the larvae of the group "flavicans" are concerned, a proper determination of species in the present state of knowledge of taxonomic features of larval stages, is possible on the basis of male imaginal stage, only.

SUMMARY

In the Lakes Kortowskie, Legińskie, Wondoł, and Lutynówka, as well as in a water basin changing into a swamp (Mazury Lake District) the species *Chaoborus alpinus* Peus 1938 belonging to the genus *Chaoborus* Licht. was for the first time found in the area of Poland.

Attention is paid in the present paper to the variable features characteristic of the species of the group "flavicans" that belong to the genus *Chaoborus* Licht., both

in the representatives of the individual populations and in the individual larval stages. It was demonstrated that the species *Ch. alpinus* and *Ch. flavicans* cannot, when in larval stage, be distinguished from each other and that male adults are necessary to determine the species considered.

STRESZCZENIE

W jeziorach Pojezierza Mazurskiego — Jeziorze Kortowskim, Legińskim, Wondoł, Lutynówka i w zbiorniku przechodzącym z jeziora w młakę został znaleziony nowy dla Polski gatunek z rodzaju *Chaoborus* Licht.: *Chaoborus alpinus* Peus 1938.

W pracy zwrócono uwagę na zmienność cech odróżniających gatunki *Chaoborus* Licht. z grupy "flavicans" zarówno u osobników poszczególnych populacji jak i w poszczególnych stadiach larwalnych. Wykazano, że gatunki — *Ch. alpinus* i *Ch. flavicans* w stadium larwalnym nie mogą być od siebie odróżnione oraz że do oznaczania wymienionych gatunków konieczne jest posiadanie form imaginalnych osobników męskich.

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H. Klimowicz

ROTIFERS OF ASTATIC WATERS. PART II. ROTIFERS OF SMALL WATER BODIES FROM THE MIKOŁAJKI REGION

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ABSTRACT

Between April 20, 1956 and September 9, 1958 rotifers fauna was surveyed in 16 astatic water bodies in the region of Mikołajki, Mazury Lake District. Samples were taken from every pool once or twice a month. Sporadic observations were performed till 1963. The investigated water bodies may be divided into following two groups: 1. Better supplied with rotifers fauna, less muddy, lying in open spaces of fields and meadows ones, 2. With lesser developed rotifers fauna, and bottom covered by a thick layer of mud, leaves and twigs, surrounded by trees and bushes. A luxurious macrophyte vegetation, lasting from spring till the end of August increases the amount of rotifers species. From the beginning of September to the time when the pool freezes, the number of species gradually diminishes. All intermittent water bodies are completely devoid of oxygen in late winter, which phenomenon is often accompanied by a total lack of rotifers. Only *Rotaria rotatoria* is able to resist to a lack of oxygen for a very long time.

CONTENTS

1. INTRODUCTION

In papers concerning mainly the sytematics of rotifers based on materials collected simultaneously from numerous small water bodies, the authors hardly ever take into consideration the yearly cycle of sampling. Investigations of rotifers in yearly cycles in a larger amount of water bodies of that type

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concerned mostly fishponds, as was the case with Kulamowicz (1956) or Hillbricht-Ilkowska (1963). Only very few authors, like Pejler (1957) or Pawłowski (1958) studied rotifers in full yearly cycles from a range of astatic water bodies, not stocked with fry. The task of the present publication is:

1. The cognition of periodical occurrence of particular species of rotifers in various astatic water bodies

2. The isolation of some environmental factors inducing the decrease or increase of number of rotifer species.

2. AREA AND METHOD OF INVESTIGATION

Sampling was performed in 16 water bodies, lying within a radius of 12 km. from the Hydrobiological Station of the Polish Academy of Sciences in Mikołajki, Masurian Lakeland (see map). All these water bodies are found in a similar surface relief formation, namely among small hills. Some of the

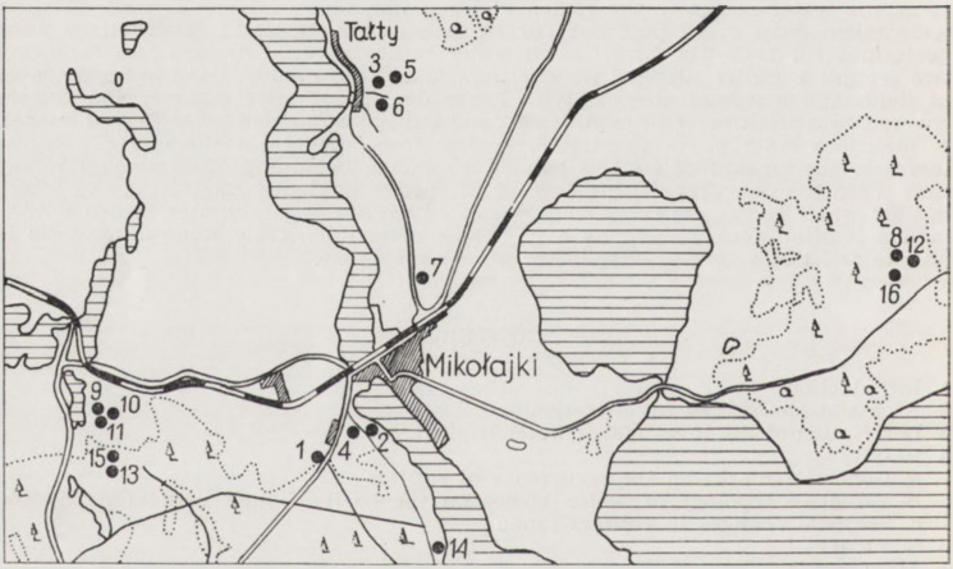

Fig. 1. Distribution of the small water bodies and ponds in the investigated area
1 — Chirocephalusowy; 2 — Świerkowy; 3 — Turzycowy; 4 — Huczkowy; 5 — Gospodarski; 6 — Trójkątny; 7 — Stały; 8 — Osi; 9 — Osemkowy; 10 — Krzaczkowy; 11 — Olszynkowy; 12 — Cyrkowy; 13 — Szczawiowy; 14 — Romantyczny; 15 — Leśny; 16 — Komarowy; HS — Hydrobiological Station

water bodies lie in the forest, some among fallow ground and meadows with trees, the remaining one in open areas, surrounded by lad under crop. The soil in the neighbourhood of the water bodies is loamy-arenaceous. The loamy-substratum of the water bodies isolate the contained water from the influence of groundwater. Ground waters might have played here an insignificant role, difficult to notice. The level of water in these pools depends mainly on precipitation and intensity of evaporation. This dependence of the water balance upon atmospherical conditions is of decisive value for the astatic character of these pools. The water level is subjected to frequent fluctuations even to complete disappearance of water. Only two among the water bodies (Stały and Osi) represent natural ponds. They never subside entirely, but may lose as much as a third of their water during the hot summer months. Among the 14 remaining water bodies — 6 vanish entirely once in a few years, 8 — once or several times in the course of the year. In winter time, the greatest part of the water freezes, considering their insignificant depth (Table I) and the fact that the ice-crust reaches a thickness of 35 cm.

Table I

Morphology of the water bodies surveyed in 1956

No.	Name of water body	Max. lenght in m.	Max. width in m.	Max. depth in m.	Max. area in sc. m.	Max. volume in cu m.	Dry per-idos in se-ason	Dry days in se-ason
1	Chirocephalusowy	20,0	15,0	1,25	217,0	18,99	3	99
2	Świerkowy	22,5	7,5	1,08	96,6	7,81	—	—
3	Turzycowy	45,0	22,0	1,45	965,0	60,25	—	—
4	Huczkowy	52,0	48,0	1,00	700,0	57,39	—	—
5	Gospodarski	110,0	50,0	0,70	600,0	18,20	—	—
6	Trójkątny	30,0	14,0	0,60	216,0	17,07	1	10
7	Stały	55,0	28,0	2,00	1101,0	96,90	—	—
8	Osi	56,0	26,0	1,80	1208,0	146,89	—	—
9	Osemkowy	38,0	11,0	0,72	242,0	18,99	1	3
10	Krzaczkowy	14,0	6,0	0,78	29,4	8,19	—	—
11	Olszynkowy	24,0	9,0	0,27	138,0	14,50	1	50
12	Cyrkowy	29,5	16,5	0,85	308,0	30,81	—	—
13	Szczawiowy	13,5	4,0	0,60	22,0	15,40	1	5
14	Romantyczny	34,0	11,0	0,62	176,0	12,97	2	50
15	Leśny	28,5	12,0	0,60	184,0	14,82	1	3
16	Komarowy	44,0	9,0	0,94	77,0	6,43	3	70

During the warm season the water bodies were sufficiently oxygenated (6 to 9 mg/l in the superficial water-layers), whereas in winter (with the exception of Stały) oxygen disappeared entirely from beneath the ice. In summer time, the oscillations of temperature attained 15°C in shallow near--shore places. In winter, the temperature of water under the ice fell to 0.5—3.0°C (Klimowicz 1959). The water bodies selected for investigations were those most morphologically and hydrologically differentiated that is with water through flow, water outflow (drainage) stagnant ones and of greatly differentiated periods of duration (Table I).

Materials were collected from May 1956 to September 1958. A total of 460 samples were collected, among them 177 from under the ice and 13 in the spring, when the central part of the pool was still frozen. In order to check the extent and duration of water subsidence in the pools, sporadical observations were performed till 1963. Qualitative samples was done sporadically also till 1963. The samples were collected by means of a net of bolting sieve, mesh No. 25. The whole surface of the pools was easily accessible, owing to their size. Each qualitative sample contained materials from about a score of drives of the net, dragged over the water plants and the clear water, starting from the middle of the pool and towards the shore. Water from under the ice was collected with a quart and sieved. In each water body, two air-holes were made in the ice, one at the centre, the other nearer to the shore.

On the day of the sampling, each sample was superficially investigated in the laboratory, in order to determine the easily not dying individuals. On the following days the samples alive were investigated in detail. According the indications of Wulfert (1939), the samples not completely elaborated were poured into Petri dishes and kept in conditions of humidity and temperature approximating the conditions in the pool.

3. DESCRIPTION OF THE INVESTIGATED WATER BODIES

Chirocephalusowy. A pool lying in a shallow depression surrounded by fields, a few scores of meters from the road Mikołajki-Ukta. It is extensive but shallow, with only a small pit in its middle. After the thaw in spring 1957, the pool was very small, lying at a distance of about 200 m. from the road and 100 m. from the forest. At the same time in 1958 the water surface reached from the forest to the road. This is a type of ephemeral water body, it dries out in early May, and fills again during long lasting autumnal precipitations. Its bottom is not muddy but covered with meadow-plants, mostly *Polygonum hydropiper*, *Gliceria fluitans*, *Carex stricta*, *Agropyren repens*, *Cirsium arvense*.

Świerkowy. It is situated at the top of the slope steeply descending to the Mikołajki lake-shore, and distant from the lake as well as from the forest by about 300 m. The pool is always entirely insolated. A score of meters from the pool, fir- and fruit trees are growing. In summer 1956 the pool did not dry out, but it subsided entirely in the summer of 1957. Its bottom is muddy, covered with plants, like *Carex stricta*, *C. vesicaria*, *Glyceria fluitans*, *Lemna minor*, *Polygonum amphibium*, *Comarum palustre* and *Alisma plantago*.

Turzycowy. This water body lies in between tilled fields, at a distance of 500 m. from Tałty village. Its surface hardly changed in the course of two successive years, because of poor drainage area and steep shores. This water body subsides entirely once in a few years. The bottom is covered with mud and plants detritus. Its surface presents tussocks of *Carex stricta*. In the warm season, the water mirror is almost entirely smothered by them, with the exception of a narrow band near the shore, of 30 to 100 cm, and a few free spots near the middle of the pool.

Huczkowy. This water body lies amidst tilled fields and fallow land about 80 m. from the road Mikołajki-Wierzba. On the east shore grow spreading poplars and willow shrubs. The extensive surface induces important water-level fluctuations. In two successive years after thaw of snow great differences appeared in extent and depth. This pool subsides only seldom, on very hot summers. The bottom is muddy, covered with rotting plant detritus, and the water surface is thickly grown with water and mud vegetation. Noted: *Sparganium ramosum*, *Carex stricta*, *Comarum palustre* and *Lysimachia thyrsiflora*.

Gospodarski. This pool lies about 200 m beyond Tałty village, with a distinct outflow. One shore is contiguous to arable land, the other to meadows, used since a long time as pastures. The water excess flows through a ditch in direction of the Trójkątny pool, so that the highest water level was similar in both successive years. This water body subsides entirely every few years. Its bottom is muddy, overgrown with water and mud vegetation. In one part *Carex hudsonii*, *Comarum palustre*, *Polygonum amphibium* and *Typha latifolia* may be found, growing high above water-level, in the other grow mud-plants: *Equisetum limosum*, *Galium palustre*, *Iris pseudoacorus*.

Trójkątny. Surrounded by tilled fields, about 500 m. from Tałty village. It lies in a small triangular concavity, surrounded by a narrow belt of meadow, further extend tilled fields. It is a through-flow water body fed by a shallow stream running along the depression — a distinctly astatic pool, subsiding in warm weather, as a result of drying out of the stream. Maximal water levels were kept even by through-flows. The bottom is formed of deposited sandy-muddy material. After drying out the bottom is covered with lavish meadow vegetation with dominance of *Carex vesicaria*, *Equisetum limesum* and *Comarum palustre*.

Stały. Surrounded by fields, lies about 80 m. from the road Mikołajki-Tałty. Second in size to Osi among studied pools, and described as eutrophic natural pond. Most eustatic of all, does not dry out, yet a great part of its water evaporates in summer. With steep shores and a rather small basin. In some sections of the shore, rare bulrushes are growing, forming a band of about 4 m. and surround an underwater meadow of *Elodea canadensis*. The plants are mostly *Phragmites communis* and *Equisetum limosum*. On some parts of the shore grow *Alisma plantago aquatica* and *Poligonum amphibium*.

Osi. This is the largest water body, a natural but dystrophic pond. Lies in a clearing of the forest district Osa, never dries out. The basin is relatively large, the bottom covered with forest litter, over grown with shrubs and high grass. The bottom is covered with great amount of rotting brenches and leaves. During the exceptionally poor precipitations of the summer of 1963, the pool was transformed into a muddy puddle 8 m. long, 2 m. broad and 20 cm. deep at the utmost. On the surface of this pool there is always a thick layer of *Lemna minor* in the warm season. A scant vegetation appears here merely in the shore zone.

Ósemkowy. This pool lies near Zelwągi village, on fallow land in the vicinity of alders and bushes, with the througs-flow. The stream crossing it starts on peat-bog meadows overgrown with bush and alders. After the thaw and pouring rains the water level in the pool did not present any fluctuation. The bottom is slightly muddy and *Carex vesicaria* and *Alisma plantago aquatica* grow on it; the water is often brown-tinted.

Krzaczkowy. Also near Zelwągi village, in a meadow overgrown with alder- and other bushes. The meadow is surrounded on three sides by fields on hills. This water body has two distinct parts-one formed of a shady peat-pool and the second presenting an insolated meadow depression, which only fills with water at high water level. The maximum water level remains even, as the excess of water flows to the Osemkowy pond. During summer heat the pools subsides entirely every few years. The shady part of the bottom is very muddy. The occurring here vegetation is composed of *Carex vesicaria*, *Glyceria fluitans*, *Lythrum salicaria*, *Alisma plantago-aquatica*, *Poligonum amphibium*, *Lysimachia vulgaris* and numerous others.

Olszynkowy. It lies near Zelwągi village, surrounded by high hills covered with tilled fields. The east shore is overgrown with alders and bushes. The pool is shallow, often subsiding completely, the bottom is covered with branches and leaves. Freezes to the bottom on very cold winters. Mainly overgrown with *Carex vesicaria*, *Comarum palustre*, *Glyceria fluitans*.

Cyrkowy. A pool lying in a thick forest, in the Osa forestry, surrounded by high hills, all day long in the shade of coniferous and deciduous trees. Water level fluctuations are relatively insignificant in spite of an extensive drainage area. It is probably the only one among investigated water bodies of which the water balance is dependent on ground water. It subsides once in a few years. Its features are those of a natural pond. The bottom is covered with a thick layer of mud and branch and leafy detritus. There is a small islet in the center, where among plants dominates *Calla palustris*.

Szczawiowy. Situated in a mixed wood among hills beyond Zelwągi village, shaded by trees growing on the shore. This pool subsides entirely in summer. The maximum water levels during two consecutive springs differed strongly. In 1958, after the thawing of ice, it presented, similarly as Chirocephalusowy a twofold larger surface as in the preceding year. The bottom is covered with a thin layer of mud and rotting leaves and branches. Poor vegetation in the middle of the pool only, a few clumps of *Carex vesicaria* and *C. elongata*.

Romantyczny. Situated in a depression not far from Mikołajki lake. Surrounded by fallow land, but next to the pool there grow quite a lot of alders shading it. The pool subsides several times in the course of the year. The water is distinctly brownish. Thick layer of mud and alder leaves on the bottom. After subsidance of water the bottom, dries out entirely. Vegetation: *Carex hudsonii*, *C. elongata*, *Iris pseudoacorus*.

Leśny. It lies in a thick, mixed wood, between hills beyond Zelwągi village, subsides frequently in summer time. The bottom is covered with mud and not decayed leaves. Very poor vegetation, mostly: *Glyceria fluitans*, *Lysimachia thyrsiflora*, *Juncus conglomeratus*, *Alnus glutinosa*, *Salix aurita*.

Komarowy. Situated in a valley in a mixed wood of the Osa forestry always in the shade. Bottom not very muddy, covered by leaves and branches of surrounding trees. Poor vegetation, mainly on the shore: *Juncus conglomeratus*, *Lysimachia vulgaris*, *Lemna minor*, *Bidens cernuus*, *Salix cinerea* and *Epilobium montanum*.

4. RESULTS

a) GENERAL REMARKS ON THE OCCURRENCE OF ROTIFERA

Table II. presents all rotifers found in the particular pools. Rotifers in this table are not classified in a systematic order, as only the frequency of occurrence was taken into consideration in the area of investigated water bodies. The first place in succession is given to most often encountered species. At the end of the list are found those species which only sporadically occur in the examined area.

Table II

The frequency of rotifers species occurrence in investigated samples

No.	Species or form	Situation in the field	In open area on fields under crop							Surrounded by trees in woods or on meadows									Total
		Pool permanence	Small drying up pools						Permanent ponds		Small drying up pools								
		Hydrological type of the pool	Ephemeral	Closed intermittent	Closed semi-permanent		Drained semi-permanent	Through-flow intermittent	Permanent ponds		Through-flow intermittent	Drained semi-permanent	Drained intermittent	Closed semi-permanent	Closed intermittent			Ephemeral	
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
		Pool	"Chirocegha-lusowy"	"Świerkowy"	"Turzycowy"	"Huczykowy"	"Gospodar-ski"	"Trójkątny"	"Stały"	"Osi"	"Ósemkowy"	"Krzacz-kowy"	"Olszyn-kowy"	"Cyrkowy"	"Szczawio-wy"	"Leśny"	"Romanty-czny"	"Komarowy"	Total
1	Rotaria rotatoria (Pallas 1766)		16	24	26	23	23	20	27	24	23	26	22	26	24	20	21	22	367
2	Lepadella ovalis (Müller 1786)		4	20	13	17	17	15	9	17	18	14	5	10	19	19	3	5	205
3	Lepadella patella (Müller 1786)		6	11	14	18	14	15	5	16	13	10	6	21	15	16	4	11	195
4	Testudinella patina (Hermann 1863)		3	18	25	21	23	18	1	18	8	16	10	13	3		3	5	185
5	Lecane luna (Müller 1776)		2	6	17	9	23	5	1	16	6	22		25	24	2	6	8	172
6	Rotaria tardigrada (Ehrenberg 1832)		1	19	15	7	19	2	6	10	11	15	16	6	18	3	6		154
7	Polyarthra vulgaris (Carlin 1943)		1	21	23	8	14	18	15	20				9	7				136
8	Synchaeta pectinata (Ehrenberg 1832)		8	19	16	7	11	11	15	6	3	1		4	11	8		9	129
9	Platyias quadricornis (Ehrenberg 1832)			1	17	15	21	6	5	14	2	14	4	6	18				123
10	Colurella bicuspidata (Ehrenberg 1832)		6	7	10	13	11	10	5	11	7	14	8	7	9			2	120

11	Mytilina crassipes (Lucks 1912)		1	6	11	15	17	6	2	26	1	13		8	9		2	1	118
12	Euchlanis dilatata Ehrenberg 1832		1	4	13	6	14	12	10	10	9	2	8	8	8		4	6	115
13	Keratella testudo (Ehrenberg 1832)		4	20	10	7	5	6	8	10	8	6	3	6	7			14	114
14	Trichocerca tenuior (Gosse 1886)		4	10	14	8	4	5	10	10	6			10	11	3		5	100
15	Keratella ticinensis (Callerio 1920)		1	8	26	3	10	5	1	6	3	4			6	14		9	97
16	Mytilina mucronata (Müller 1773)		3	10	15	13	7	10	2	12	4	5		6	4		1	4	96
17	Euchlanis incisa (Carlin 1939)			11	12	10	5	7	1	8	3	10	8	13	4			3	95
18	Lopchocharis salpina (Ehrenberg 1834)		4	4	12	9	12	8	3	57	11	7	8	2			2	7	94
19	Philodina citrina (Ehrenberg 1832)		2	10	5	8	5	7	8	1	4	3	6	1	17	8		4	89
20	Enteroplea lacustris (Ehrenberg 1830)		3		3	10	17	4	1	4			12	13	14	4	3		88
21	Rotaria gracilicauda (Bory de St. Vincent 1826)			15	2	19		3	5	12	15						11	1	83
22	Trichocerca rattus (O.F.Müller 1776)		3	3	13	5	11	7	5	6	1	12	7	4	4			2	83
23	Monostyla closterocerca (Schmarda 1859)		1	1	5	6	5	5	9	11	7	2		8	5	7	4	3	79
24	Dissotrocha aculeata (Ehrenberg 1832)			8	3	8	—	1			6	5		12	6	26	1		76
25	Epiphanes senta (Müller 1771)		5	3	4	6	7	12	1	3	9	1	6		6	3	1	6	73
26	Monostyla bulla (Gosse 1851)		1	3	8	3	6		12	51		3		3	7	3			54
27	Mytilina trigona (Gosse 1851)			10		14	9	2			2	12		1					50
28	Synchaeta tremula (Müller 1786)		1	1	10	9	9	4	5		4	1			2			2	48
29	Anuraeopsis fissa (Gosse 1851)			7	1	2	1		8	15	5			1	3			3	46
30	Keratella valga (Ehrenberg 1834)		2	1				1				2		8	10	14		6	44
31	Notommata pachyura (Gosse 1886)				7		3	3			1	4		13	13				44
32	Mytilina ventralis (Ehrenberg 1832)			3			3	4	8	12	1	1		8	1		1		42
33	Lepadella rhomboides (Gosse 1886)		1	1		13	2	1	5		1	15		2	1				42
34	Brachionus angularis (Gosse 1851)		1				1	2	32	1	1	1			1				40
35	Pleurotrocha petromyzon (Ehrenberg 1830)		1	8	1	5		7	1	6	3		2	2	1			1	38

36	Rotaria nepunia (Ehrenberg 1832)			14	4	1		1	7			9						1	37
37	Trichotria tetractis (Ehrenberg 1830)		3		3	1	2	2	10		2			10	1	3			37
38	Monostyla lunaris (Ehrenberg 1832)			1	5	4	4	5			2	1		1	4	1	4	4	36
39	Postclausa hyptopus (Ehrenberg 1838)		3	2	11	3	3	3			1	3			6				35
40	Dicranophorus caudatus (Ehrenberg 1834)		1	6		18	2	2	4			2							35
41	Keratella quadrata (Müller 1786)		1	1		1		3	12		4	4			3		1	3	33
42	Polyarthra remata (Skorikov 1896)			5	3	1	1		4	1	6	5			7				33
43	Mytilina ventralis brevispina (Ehrenberg 1832)			5	7	3	1	6							10				32
44	Dipleuchlanis propatula (Gosse 1886)			2	8	4	8	2		1	1	2	3						31
45	Monostyla cornuta (Müller 1786)			3	6	4	4	5			1	4	3						30
46	Notommata copeus (Ehrenberg 1834)				3				4	4				2	16	2			30
47	Cephalodella gibba (Ehrenberg 1832)		3	6	4	4			2	4		4		1·				1	29
48	Trichocerca bicristata (Gosse 1887)		2			5			5						16		1		29
49	Eudactylota eudactylota (Gosse 1886)				7	7	6			3				5					28
50	Platyias patulus (Müller 1786)			1	6	6	2	9			1	1							26
51	Polyarthra dolichoptera (Idelson 1925)		1	1		5			15									4	26
52	Itura aurita (Ehrenberg 1830)		1	2	2	6			4	1	1					1	2	4	24
53	Euchlanis deflexa (Gosse 1851)			4	4	1		12										2	23
54	Brachionus urceus (Linne 1758)		2				1		12								5	1	21
55	Keratella cochlearis (Gosse 1851)		1			1	1	1	13						1	1		1	20
56	Filinia maior (Colditz 1914)							1	13	6									20
57	Brachionus quadridentatus (Hermann)		2						17									1	20
58	Cephalodella catellina (Müller 1786)		5	1				4			4		2	1					17
59	Cephalodella gracilis (Ehrenberg 1832)							2		1					3		3	5	14
60	Synchaeta oblonga (Ehrenberg 1832)			1	3	2	1	4	1		1								13

61	Epiphanes brachionus (Ehrenberg)		3	8	6	1	6	4			6	2		3			2		41
62	Proales decipiens (Ehrenberg 1832)				1	1	1							3	3	1	1		11
63	Macrotrachela quadricornifera (Milne 1886		6		1							1					2		10
64	Trichocerca stylata (Gosse 1851)								11										11
65	Testudinella elliptica (Ehrenberg 1834)		1	5		2					1								9
66	Euchlanis triquetra (Ehrenberg 1838)					1	2		5										8
67	Conochilus hippocrepis (Schrank 1803)				2									6					8
68	Cyrtonia tuba (Ehrenberg 1834)														6	2			8
69	Collotheca mutabilis (Hudson 1885)								8										8
70	Hexartha mira (Hudson 1871)			1	1					1	1				3				7
71	Dissotrocha macrostyla (Ehrenberg 1838)														2		5		7
72	Collotheca ornata cornuta (Dobie 1849)													2	5				7
73	Lophocharis oxysternon (Gosse) 1851											4	3						7
74	Polyarthra minor (Voigt 1904)																	7	7
75	Eothinia elongata (Ehrenberg 1832)		1		2						1					1		1	6
76	Notommata collaris (Ehrenberg 1832)							1			1					3	1		6
77	Ptygura pilula (Cubitt 1872)														1	5			6
78	Adineta vaga (Davis 1873)		1					2							1			1	5
79	Notommata tripus (Ehrenberg 1838)			1										1	2	1			5
80	Testudinella reflexa (Gosse 1887)							1			2	2							5
81	Monommata orbis (Müller 1776)				2					1					2				5
82	Notholca squamula (Müller 1786)							1			1		3						5
83	Euchlanis lyra (Hudson 1886)												3		1			1	5
84	Brachionus calyciflorus (Pallas 1766)			2					3										5

85	Cephalodella auriculata (Müller 1773)					1								2	1				4
86	Philodina acuticornis (Murray 1902)							2								2			4
87	Rotaria elongata (Weber 1888)							1	3										4
88	Notommata cyrtopus (Gosse 1886)												3					1	4
89	Filinia limnetica (Zacharias 1893)								4										4
90	Monostyla hamata (Stokes 1896)							4											4
91	Lepadella scuminata (Ehrenberg 1834)				1		1								1				3
92	Dicranophorus forcipatus (Müller 1773)			1		1		1											3
93	Lecane intrasinuata (Olofsson 1917)				1									1			1		3
94	Cephalodella forficata (Ehrenberg 1832)			1		2													3
95	Rhinoglena frontalis (Ehrenberg 1853)								3										3
96	Trichocerca elongata (Gosse 1887)													3					3
97	Trichocerca pocillum (Müller 1776)								3										3
98	Cephalodella exiqua (Gosse 1886)														3				3
99	Keratella cochlearis tecta (Gosse 1851)								3										3
100	Scaridium longicaudum (Müller 1786)				1		1												2
101	Philodina roseola (Ehrenberg 1832)								1							1			2
102	Habrotrocha bidens (Gosse 1851)									1								1	2
103	Macrotrachela musculosa (Milne 1886)										1					1			2
104	Mytilina bisulcata (Lucks 1912)				1	1													2
105	Polyarthra major (Burckhardt 1900)				2														2
106	Cephalodella forficula (Ehrenberg 1831)								2										2
107	Brachionus rubens (Ehrenberg 1838)						1												1
108	Philodina flaviceps (Bryce 1906)														2				2

109	Philodina megalotrocha (Ehrenberg 1832)							1										1
110	Adineta gracilis (Janson 1893)									1								1
111	Cephalodella hyalina (Myers 1924)								1									1
112	Collotheca coronetta (Cubitt 1869)																1	1
113	Keratella cochlearis macracantha (Lauterborn 1898)							1										1
114	Habrotrocha elegans (Milne 1886)					1												1
115	Lecane flexilis (Gosse 1886)														1			1
116	Lecane signifera ploensis (Voigt 1902)			1														1
117	Lepadella triptera (Ehrenberg 1832)							1										1
118	Macrotrachela habita (Bryce 1894)														1			1
119	Macrotrachela papillosa (Thompson 1892)									1								1
120	Rotaria citrina (Ehrenberg 1838)			1														1
121	Rotaria exoculis (Koning 1947)			1														1
122	Rotaria socialis (Kellicott 1888)			1														1
123	Trichocerca iernis (Cosse 1887)			1														1
	Amount of samples	20	29	31	30	32	31	32	31	28	30	25	31	31	31	21	27	
	Amount of occurring species	44	54	62	58	52	58	60	41	51	44	23	44	56	32	26	43	

The upper part of Table II indicates the character of the water body and its appartenance to particular groups. The numerals in columns indicate how many times a representant of a given species has been found in all the samples taken from that water body. The column of numerals on the right side of the table establishes how many times the given species was found in all the water bodies jointly. The numerals in the lower horizontal section indicate, how many species were found in each particular water body, as well as the total amount of samples taken during the performed investigations.

The fauna mentioned in the tables originates from a total of 460 samples. The highest number of samples taken from one water body did not exceed 32, the lowest reached 20. The least number of samples originated from ephemeral pools, i.e. those disappearing most often. The Chirocephalusowy pool yielded only 20 samples, Komarowy — 27. From the frequently drying out Romantyczny 21 samples were taken, from Olszynkowy — 25 (Tab. II).

The number of species in the particular water bodies oscillated between 23 in the Olszynkowy and 62 in Turzycowy. When analyzing tb. II, it is possible to establish what species are characteristic for all pools (as e.g. *Rotaria rotatoria, Lapadella ovalis*). Sporadically occurring species are represented by *Adineta gracilis, Brachionus rubens, Cephalodella hyalina, Collotheca coronetta, Habrotrocha elegans, Keratelle cochlearis macrocantha, Lecane flexilis, L. signifera ploenensis, Lepadella triptera, Macrotrochella habita, M. papilosa, Philodina megalotrocha, Rotaria citrina, R. exoculis, R. socialis* and *Trichocerca iernis*. The above species occurred only once and in merely one of the pools. Some species occur in a pool frequently and numerously, like *Keratella testudo* in the Świerkowy pool, in other pools it occurred only incidentally. *Brachionus angularis* and *Keratella cochlearis* was frequent in the Stały pool and incidental in Osi. *Keratella valga* was most frequent in forest pools, as in Komarowy, Cyrkowy and Szczawiowy, and sporadically in others. Doner (1964) mentions that because of sporadical appearance of some rotifers, it is difficult to establish their cyclic yearly occurrence. In the pools mentioned above, the occurrence of species was variable. Two or three samplings in one and the same place gave various results in species assortment. Numerously represented species in one sample were absent from the next sample taken in the same place after a month it is only exceptional to establish the same species in one place on successive summer months. Even when the general number of species increases, at optimal developmental periods, there is not always continuity of particular species. No analogy of rotifers species could be established in samples taken in successive years from the same pools at the same seasons. A general analysis of fauna of analogous warm or cold successive seasons mostly does not present similar species. Eurytopic species, however, present some continuity in their occurrence during seasons optimal for their development.

A relatively most frequently repeated in fauna analogous successive years could be observed in the following pools: Osi, Szczawiowy and Cyrkowy, which (Szczawiowy excepted) may be considered the most static. The fauna of successive samples taken from these pools presents many species, common to all of them. Their total number in particular seasons oscillated, however Osi and Cyrkowy had the best preserved continuity of species occurrence. This could be connected with their greater depth and thus lesser fluctuations of water level. Larger water bodies are as environment less sensitive to atmospheric changes. In frequently drying out water bodies, like Romantyczny and Olszynkowy, there was a lack of species peculiar to those pools, which suggests that in unfavourable conditions only eurytopic species may occur, like *Rotaria rotatoria*, *Euchlanis dilatata* or *Keratella testudo*. Kulamowicz (1956) when studying the fauna of carp-ponds established, that an astatic environment does not permit to isolate constantly characteristic species for particular pools. Hillbricht (1961), studying the rotifers fauna in aquaria has observed that the irregular variability of their medium modulates their fauna, by connecting particular species into various combinations and quantitative structures, in dependence on the actual state of the environment. The fact that the majority of species does not occur in all water bodies at the time of most favourable conditions may be explained by the high astatism of pools and strong interspecies competition. It is well known from the studies of Edmondson (1960), Gilbert (1963) Amren (1964a) that rotifers are short lived. The problem remains, however, if in the investigated water-bodies, between one sampling and the next, whole adult generations could perish, leaving only dormant eggs.

The investigated water-bodies are mostly entirely over-grown with vegetation, owing to their small surface and depth. Stały and Osi presented an exception, as macrophytes did not appear on their central surface. The shores of all the pools were covered with vascular plants. It goes without question that the heterogeneity of vegetation increases the amount of microhabitats for rotifers. This phenomenon is most striking in larger water-bodies, like, for instance, lake littorals. Klimowicz (1964) observed the greatest heterogeneity of rotifers species in lake-shore zones, where vegetation is most differentiated. In the 16 investigated pools it could be established that the seasonal (spring-autumn) development of vegetation increases the amount of species. A sporadic case was that of Trójkątny, where in 1956 no increase in the amount of species could be observed from spring to autumn. In periodically drying out pools, in the investigated area, the heterogeneity of vegetation is probably of secondary importance. The essential role is played here by the luxuriancy of vegetation, regardless of their differentiation.

b) TYPOLOGY OF WATER-BODIES ON THE BASIS OF ROTIFERS OCCURRENCE

It could be established that the differentiation in rotifers fauna is not necessarily connected with the character of the water-body. The occurrence of particular species is very often accidental. Generally speaking, the faunistic differentiation is connected with the permanence of the pool, the amount of water flowing through it and some broadly taken physical and chemical environmental features of water and basin. Even in closely adherent pools a fauna of varied composition and amount of species may occur. Such characteristics are presented by the closely neighbouring Osi and Komarowy, or Leśny and Szczawiowy. The greatest number of common species are found, however, in pools, lying in the same basin or even region.

All the water-bodies investigated here could be divided into two groups, according to the species occurring in them. It should be stressed, however, that each particular pool constitutes a specific individuality with a distinct composition of rotifers. No common features characterizing a larger group of pools could be established. A group of seven pools have a larger number of species (Nos 1—7 in Table II). These water-bodies are situated in open spaces, on fields and meadows. The amount of species increase as a rule in particular pools along with their size, but only if other parameters like e.g. amount of mud on the bottom are similar. This is in agreement with the thesis of Edmondson (1944) that out of each two pools with similar water volume that one has more species of which the surface is larger. Depth of pools, however, is not a decisive condition of particular species occurrence. In the frequently drying out Chirocephalusowy, as well as in the never subsiding Stały we find *Brachianus quadridentatus*, a species characteristic of eutrophic lake littorals as well as large ponds and rivers. The Chirocephalusowy presented also the species *Brachinus urceus*, *B. angularis*, *Cephalodelle gibba*, *Polyarthra delichoptera* and *Trichotria tetractis*, met with in the investigated area only in never drying out or the largest pools. An important amount of 58 species was found in the through-flow, not very large Trójkątny. The brook flowing through that pool could have carried a heterogenous fauna from other water-bodies, during seasonal thaws or precipitations in the first place from Gospodarski, wherefrom it started. However, not all the species found in Gospodarski occurred also in Trójkątny. Pawłowski (1958) exemplifies it on a river, of which the rotifers content is not merely a sum of the fauna of segments, lying above the place of sampling.

The remaining water-bodies (Nos 8—16, Tab. II) are situated in woods or at least surrounded by trees and bushes. Their bottom is mostly covered with a thick layer of mud, leaves and branches, the water mostly of brownish hew, the basins more differentiated than in the preceding group, Rotifers species did not increase here proportionally to the size of pools. Ósemkowy had more species as compared with others, because of its through-flow character. It is mentioned in Pawłowski (1958) that a deep through-flow water-body, in the vicinity of a river had a poor fauna, in every respect. In Ósemkowy the frequency of occurrence of particular species during the yearly cycle was relatively small. This could indicate that the incidentally observed here individuals originate from other water-bodies. The brook which crossed it had its beginning in the region of Krzaczkowy. The fauna of these two pools, however, had only few species in common. Szczawiowy, in this same group, presents as many as 56 species, which may be connected with the small amount of leaves and twigs lying on its bottom. In the largest of the investigated pools, the very muddy Osi, only 41 species could be found, and only Olszynkowy presented a lesser number than Osi — i.e. — 23, Romantyczny 26 — and Leśny — 32. The last three pools were of the frequently subsiding kind. In these pools, with comparatively little water, the number of species is dependent on water level. Varga (1954) says of such pools that because of their ephemeral character, the developmental rotifers cycles have the most interesting course. The small, ephemeral pool Komarowy, had, on the other hand, an unexpectedly large amount of species — 43. The numerically smaller amount of species in forest pools than in open-area water bodies may be related to their very muddy bottoms. Pejler (1962a) considers that numerous kinds of rotifers avoid a loose sediment, and only morphologically adapted species, with a strongly developed basis, as *Euchlanis triquera* and *Lepadella triptera* may accomodate themselves of a loose sediment. Sometimes, however, bottom mud increases the heterogeneity of species. This happens in water-bodies situated on exceptionally poor, mountainous substrata, as established by Pejler (1957)

c) SASONAL CHANGES OF ROTIFERS FAUNA

The first signs of spring could be noticed in the investigated water-bodies already in February—March. Thaw-water stood up to 50 cm. high on the ice of the investigated pools. This water, however, did not reveal any rotifers, but in the water samples taken from beneath the ice characteristic species for these pools in late winter could be found, like: *Rotaria rotatoria, Mytilina trigona, M. crassipes, Dissotrocha aculeata, Rotaria tardigrada, R. gracilicauda, R. neptunia, Testudinella patina, Platyias quadricornis* and *Lecane luna*. In the insolated, iceless shore-zone the water warms up rapidly, and the blowing winds compensate entirely oxygen deficiency (oxygen content 5—7 mg/l). In forest water bodies, surrounded by trees like Leśny and Cyrkowy, such changes take place one or two weeks later. In February and March, and even in April, when ice still swims in the central part of the pool, the rotifers faune is scarce in every respect. At this time, numerous mosquito larvae are present, which perish when the water freezes again. Samples taken then from beneath the ice present an increased number of rotifers species; this could be explained by the fact that the destruction of plant microplankton, protozoa and bacteria increased the food basis of the rotifers. The following species are then noted: *Keratella testudo, Synchaeta pectinata, Mytilina mucronata, Enteroplea lacustris, Polyarthra vulgaris, Lophocharis salpina, Lepadella ovalis, Philodina citrina.*

April is the beginning of actual spring-time, when the ice finally subsides. Most samples indicate an increase of species. Additional not very numerous species appear, like *Euchlanis incisa, Monostyla cornuta, M. lunaris, Trichocerca rattus, T. tenuior, Notommata pachyura, Postclausa hyptopus, Trichotria tetractis, Dipleuchlanis propatula, Colurella biscupidata*. Scarce individuals represent their species in the still partly frozen shore-zone. It is only in May, when the ice has thawn entirely and the shores of the pools are producing a thin green vegetation (though no green macrophytes are visible in the pools yet) that the amount of individuals of the few occurring here species increases strongly. We find then *Keratella testudo, Keratella ticinensis, Synchaeta pectinata, Polyarthra dolichoptera, Epiphanes senta, Keratella quadrata*. The lack of macrophytes in water early in spring provides a monotonous environment with few microhabitats. The number of individuals increases suddenly and strongly with the exit of mosquitoes. It was also established here as in the investigations of KULAMOWICZ (1956) and PEJLER (1962), that when the samples contained many plankton crustaceans the amount of rotifera species distinctly diminished. WESENBERG-LUND (1930) observed a violent increase of *Epiphanes* senta individuals in frequently drying out pools immediately after ice thaw, and ascribes this to the rapid development of amictic females. AMREN (1964) mentions that the high productivity of the first generation of *Keratella quadrata* and *Polyarthra dolichoptera* is the result of rich food and metabolic substance supply of dormant eggs. But most certainly it is the freezing of the pool down to the very bottom which is the decisive factor, reducing the number of species in early spring. Such water bodies as Olszynkowy, Leśny and Romantyczny had less numerous species after ice thaw. In the spring of 1956, after a hard winter, much less species were found in pools not exceeding 1 m. maximal depth than in analogous periods of the year after milder winters.

By the end of May, macrophytes are already luxuriously developed in water. In such an environment, which is stronger differentiated, there appear gradually important amounts of individuals of previously not observed rotifers species, as *Polyarthra remata*, *Monostyla bula*, *Anuraeopsis fissa*, *Pleurotrocha petromyzon*, *Euchlanis deflexa*, *Platyias patulus*, *Conochilus hippocrepis*, *Eudactylota eudactylota*, *Monostyla closterocerca*, *Cephalodella gracilis*. The increase in number of species lasts till the end of August. In periodical water-bodies there is usually a drop in number of species before the drying out of the pool. The same happens in water bodies which present a reduced amount of water as a result of long lasting heat and drought. After heavy precipitation, in the then formed pools, the following species make their appearance: *Rotaria rotatoria*, *R. tardigrada*, *R. gracilicauda*, *Monostyla lunaris*, *M. closterocerca*, *Keratella testudo*, *Euchlanis dilatata*, *Enteroplea lacustris*, *Epiphanes senta*, *Trichocerca rattus*, presenting initially, however, very few individuals. Even in permanent water bodies, never completely drying out but losing temporarily the majority of their water volume, the amount of species increase after a rise of water level. After a fall of temperature, or very strong winds, species appeared which were never noted previously at the same period. Such a striking example could be seen on June 8, 1957, after a drop of temperature, when *Mytilina trigona* individuals appeared, typical for the winter period. The same species was found on August 22, 1957, in Swierkowy. In the investigated water bodies, *Epiphanes brachionus* was symptomatic for spring fauna, but a few individuals could be found in summer, after a strong drop of temperature. After strong winds appeared representatives of the species *Epiphanes senta*, *Rotaria rotatoria*, *Mytilina mucronata*, *Brachionus calyciflorus*, which could hardly be noticed at the time preceding the windy period in the investigated pools. Klimowicz (1962) when studying the rotifera fauna in artificial reservoirs at the Botanical Garden established, that a periodical addition of a larger portion of water produced a slight increase in number of species. In the same reservoirs a strong increase in amount of species could be observed after the bottom had been weeded and fresh water added.

It is, as rule, at the end of summer that the largest number of rotifers species appear, similarly as in a shallow lake littoral (Klimowicz 1964). At that period the macrophytes in water are best developed and the environment most differentiated. A decisive role in the increase of microhabitats is played here not so much by macrophytes as by the periphyton overgrowing it (Duflakcff 1925, 1928), Pawłowski (1958), Doner (1964). Since beginning of September, the number of species diminished in the samples, up to the time of freezing of the water body. Pejler (1962) observed a peak of rotifers occurrence in July and a regression starting in September. In the autumn. inspite of a general reduction of species, an important amount of some of them which were not noted in the spring or summer, appeared, such as *Cyrtonia tuba*, *Ptygura pilula*, *Cephalodella forficata*, *C. auriculata*, *Notommata collaris*, *N. tripus*, *Collotheca ornata cornuta* and *Testudinella reflexa*. According to Jakubski (1915) the spring species occur in larger concentrations, while the autumn ones are more numerous, but in less concentrated populations.

In November of 1956, the water bodies were already ice covered, while in 1957 only in December. After the water was frozen, the amount of species increased as a rule. Pejler (1957) explains this phenomenon by the increase of the food basis, as a result of phytoplankton decay. Hillbricht (1961) who bred rotifers in aquariums, established that after supplying the water body with macrophytes, their decay brought about a distinct increase of number and species of rotifers. In early winter the fauna composition of rotifera under the ice is greatly differentiated in the reservoirs. Later, when the pool was less deep and more muddy, like in the shore lake littoral (Klimowicz 1964) the number of species diminished accordingly. In connection with intensive processes of oxygen reduction under the ice, in January already an almost total oxygen deficit could be observed. The only exception was the deeper and less muddy Stały pond.

The drop of species number in late winter was ascribed by Pejler (1962) to oxygen deficit an excess of CO_2 and H_2S and also to the low water temperature and lack of appropriate food. That is why in late winter the majority of shallow water bodies have a similar assortment of species, as environmental conditions are then similar. The rotifers fauna at this time of year has the largest per cent of common species, with the exception of Stały pond. At the begining of winter an important amount of species sporadically occurring in the investigated area could be noted. Part of these species, in concordance with the publications of Wiszniewski (1954) and Pawłowski (1958) had been noted by the earlier authors merely in the warm seasons of the year. These were *Eothina elongata*, *Testudinella reflexa*, *Adineta vaga*, *Cephalodella fortificata*, *Eudactylota eudactylota* and *Dissotrocha macrostyla*. During cool periods these authors noted among these species the following ones: *Lecane intrasinuata*, *Cephalodella forficula* and *C. hyalina*. In later winter no individuals of these species were noted any more in the pools. These species were encountered on two successive winters only in a few water bodies. At the end of winter in almost every sample only *Rotaria rotatoria* occurs. It was only in exceptionally unfavourable conditions of late winter, during a very long period of oxygen deficit as in Komarowy and Osi, that on specimens of *Rotaria rotatoria* were found any more in active state, but motionless, and recovering from this state after a few hours stay in the laboratory. *Rotaria rotatoria* was represented in winter under the ice by a much more numerous amount of individuals than during the warm season. A mass population of *Rotaria rotatoria* was found in the water bodies Leśny, Szczawiowy, Olszynkowy, Romantyczny during periods when there were no other rotifers any more. During late winter and total oxygen deficit it is often possible to find exceedingly well preserved rotifers lorica which were still alive some weeks before. In fixed samples of this kind lorica may be treated as fixed specimens. In order to investigate accurately the rotifers fauna in small pools, the samples taken from under the ice should be studied in a live state.

5. SUMMARY

Between April 20, 1956 and September 9, 1958 rotifers fauna was surveyed in 16 astatic water bodies in the region of Mikołajki, Mazury Lake District. Samples were taken from every pool once or twice a month. Sporadic observations were performed till 1963. The amount of species and their composition in each particular water body is mostly dependent upon the degree of durability of the pool and upon its basin. The investigated water bodies may be divided into following two groups:

1. Better supplied with rotifers fauna, less muddy, lying in open spaces of fields and meadows ones,
2. With lesser developed rotifers fauna, and bottom covered by a thick layer of mud, leaves and twigs, surrounded by trees and bushes.

In water bodies situated in open areas, the number of species increases along with the dimensions of the pool, whereas in water bodies surrounded by trees and

bushes the number of species diminishes in connection with increasing mud, leaves and twigs deposits. Throughflow water bodies contain a richer rotifers fauna than undrained ones, dimensions and situation being similar.

A luxurious macrophyte vegetation, lasting from spring till the end of August increases the amount of rotifers species. The differentiation of macrophyte species in the investigated water bodies does not actually affect the number of rotifers species.

The majority of encountered species shows cyclic changes connected with the seasons, but a certain part of them occurs at unprevisible periods.

In the spring, after total thaw of the ice but before the appearance of macrophytes in the water, a mass development of a few species takes place. After the emergence of macrophytes in water, the amount of rotifers species increases and this process lasts till the end of August. From the beginning of September to the time when the pool freezes, he number of species gradually diminishes. On the first days of appearance of the ice crust, the number of species mostly increases, but diminishes later under the ice, till spring-time.

All intermittent water bodies are completely devoid of oxygen in late winter, which phenomenon is often accompanied by a total lack of rotifers. Only *Rotaria rotatoria* is able to resist to a lack of oxygen for a very long time.

Water bodies, which freeze to the very bottom in winter, have a smaller amount of species in the spring than those which are not filled with ice to the bottom. After a frosty winter, less rotifers species are encountered in the spring than after a mild winter, when the water bodies were covered with only a thin the crust. A few days after heavy downpours, the amount of species increases distinctly.

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STRESZCZENIE

W okresie od 20 IV 1956 r. do 9 IX 1958 r. obserwowano faunę wrotków z 16 astatycznych zbiorników w okolicach Mikołajek na Pojezierzu Mazurskim. Próby pobierano 1—2 razy w ciągu każdego miesiąca, stwierdzono 123 gatunki. Ilość gatunków i ich skład w poszczególnych zbiornikach jest głównie uzależniony od stopnia trwałości zbiornika i otaczającej go zlewni. W zbiornikach położonych na otwartych terenach liczba gatunków wrotków wzrasta wraz z wymiarami zbiornika, natomiast w zbiornikach otoczonych drzewami i krzewami liczba gatunków wrotków maleje przy wzroście ilości mułu, liści i gałęzi zalegających dno.

Bujny rozwój makrofitów od wiosny do końca sierpnia pociąga za sobą zwiększenie się ilości gatunków wrotków. Zróżnicowanie gatunkowe makrofitów w badanych zbiornikach nie wywiera natomiast istotnego wpływu na ilość gatunków wrotków. Od początku września do zamarznięcia wody liczba gatunków stopniowo maleje. W pierwszych dniach po pojawieniu się lodu liczba gatunków wrotków przeważnie wzrasta, a po tym pod lodem, aż do wiosny maleje. We wszystkich zbiornikach okresowo wysychających stwierdzono w zimie zupełny brak tlenu, czemu niekiedy towarzyszy zupełny brak wrotków. Brak tlenu najdłużej znosi *Rotaria rotatoria*. Zbiorniki przemarzające do dna w zimie, wczesną wiosną mają mniejszą ilość gatunków wrotków niż zbiorniki nie przemarzające do dna. W kilka dni po ulewnych deszczach liczba gatunków wrotków wyraźnie zwiększała się w astatycznych zbiornikach.

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