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ANALYSIS OF AGGLOMERATION TENDENCIES OF ZOOPLANKTON IN THE VISTULA LAGOON AS A FUNCTION OF TIME

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Abstract

The performed analysis of agglomeration tendencies of zo oplankton in the Vistula Lagoon has indicated that the formation of the zooplankton in part icular seasons of the year depended on climatic and environmental conditions.

1. INTRODUCTION

Complex studies on the zooplankton of Vistula Lagoon, carried out in 1974 - 1978, resulted in a number of papers on the species composition [1, 2, 5], dynamics of the numbers of planktonic organisms, analysis of zooplankton taxon grouping in Vistula Lagoon in a spatial system [6], and assesment of zooplankton grouping trends in this water body [6].

In this paper a detailed analysis of the grouping trends is presented in a time system, basing on the numbers of zooplankton organisms during 3-year studies. Zooplankton groupings are related more to the phenology of particular species than to the seasonal pattern. Such objectiveness of the analyses was possible due to the applied method of numerical calculations. The method was derived from Wrocław taxonomy and consisted of dendrite construction with the use of properly defined distances [9, 10, 11, 12].

2. MATERIALS AND METHODS

Materials for the present work were collected in the periods: March – November 1975, May – November 1977, February – November 1978.

Zooplankton samples were collected at monthly intervals from the same nine stations each year. The stations were selected taking into account hydrological character of Vistula Lagoon. Totally 512 samples were collected and analysed (Table 1).

Data on physical and chemical factors presented in Tables 6, 7 and 8 were taken from works by Różańska and Więcławski [13, 14, 15].

Zooplankton samples were collected with a 5 - 1 Ruttner sampler, from 0 m, 1 m, 2 m and 3 m, depending on station depth. Samples were filtered through Apstein

Table 1. Dates of sampling and number of samples collected

1975		1977		1978		
Date	Number of samples	Date	Number of samples	Date	Number of samples	Together
				27/28 II	11	11
18 III	2			16/18 III	9	11
2/23 IV	21			27/28 IV	19	40
20/21 V	15	2/3 V	27	31 V	24	66
29/20 VI	17	2/3 VI	26	3 VI	22	65
16/17 VII	21	1/2 VII	24	21 VII	26	71
12/13 VIII	21	10/11 VIII	30	18 VIII	27	78
16/17 IX	9	8/9 IX	26	14 IX	15	50
16/17 X	17	5/6 X	29	31 X	18	64
11/12 XI	21	8/11 XI	21	27 XI	14	56
Together	144		183		185	512

net no 25, fixed with Utermöl's solution and preserved in 4% for malin. In the laboratory each sample was brought up to 50 ml in order to standardize the calculations. Each time 3 cm^3 of the sample were analysed. Number of particular species or taxons was expressed as number of individuals per 1 m^3 of water.

Calculations of basic statistical parameters, viz. mean numbers and coefficients of similarity, were made with an electronic computer "Odra-1204". The results on the number of zooplankton taxons were analysed according to the definition of similarity and distance [11].

The degree of similarity was expressed using the equation of Marczewski and Steinhaus [10]:

$$S = \frac{w}{a+b-w},$$

where:

S – similarity between the two compared elements or features,

w – number of common elements,

$a+b$ – summed up value of compared elements or features.

Arrangement of months and taxons was determined by linear ordering of the branched dendrites (Figs. 1 - 11, Tables 2 - 8). Numerosity of coded taxonomic units analysed for the grouping trends was expressed as average numerical value of individuals of the given taxon in the given month. It is presented in Tables 6, 7 and 8, together with selected abiotic factors. Fields formed after presentation of the groupings reflect inter-relations between particular sets. The tables present also groups of months and taxons. The sets of elements which could have been distinguished only at lower or higher coefficients of similarity than the optimal one remained outside the groupings. According to Chojnacki [7, 8] a grouping is biologically feasible only if it contains as many elements of the set as possible, even if the coefficient of similarity is not very high.

Only taxonomic units at the level genus – species were taken into account. This was it was necessary to omit naupli forms of *Copepoda* which embraced an undefined number of species.

Due to changeable environmental conditions, the analysis of grouping trends in the zooplankton in a time system was made for each year separately.

3. RESULTS

Grouping trends of 34 taxons of *Rotatoria* and 19 taxons of *Crustacea* were analysed on the basis of zooplankton numbers. The following taxonomic units were identified in the materials (numerical codes in parentheses):

Rotatoria: *Ascomorpha ecaudis* Perty (1), *Ascomorpha saltans* Bartsch (34), *Asplanchna priodonta* Gosse (2), *Brachionus angularis* Gosse (3), *Brachionus calyciflorus* Pallas (4), *Brachionus calyciflorus amphiceros* Ehrenberg (5), *Brachionus diversicornis* (Daday) (6), *Brachionus quadridentatus* Herman (7), *Brachionus urceolaris* Müller (8), *Brachionus rubens* Ehrenberg (9), *Cephalodella* sp. (33), *Euchlanis dilatata* Ehrenberg (10), *Filinia longiseta* (Ehrenberg) (11), *Kellicottia longispina* (Kellicott) (16), *Keratella cochlearis* (12), *Keratella cochlearis tecta* (Gosse) (13), *Keratella cruciformis* (Thompson) (14), *Keratella quadrata* (Müller) (15), *Lecane luna* (Müller) (17), *Notholca acuminata* (Ehrenberg) (18), *Notholca squamula* (Müller) (19), *Notholca striata* (Müller) (20), *Pedalia fennica* (Levander) (22), *Polyarthra dolichoptera* Idelson (21), *Polyarthra vulgaris* Carlin (23), *Proales* sp. (24), *Synchaeta* sp. (26), *Synchaeta litoralis* Rousselet (27), *Synchaeta monopus* Plate (29), *Synchaeta oblonga* Ehrenberg (36), *Synchaeta pectinata* Ehrenberg (28), *Synchaeta stylata* Wierzejski (38), *Trichocerca pusilla* (Lanterborn) (31), *Trichocera* sp. (32).

Crustacea: *Bosmina coregoni maritima* (Müller) (41), *Bosmina longirostris* (Müller) (42), *Chydorus sphaericus* (Müller) (43), *Diaphanosoma brachyurum* (Lievin) (45), *Evadne nordmanni* Loven (46), *Leptodora kindti* (Focke) (47), *Pleuroxus uncinatus* Baird (48), *Podon polyphemoides* (Leuckart) (49), *Sida cristalina* (Müller) (50), *Simocephalus vetulus* (Müller) (51), *Acartia bifilosa* (Giesbrecht) (74), *Acartia longiremis* Lilljeborg (61), *Acartia tonsa* (Dana) (63), *Centrophages hamatus* (Lilljeborg) (76), *Cyclops* sp. (69), *Eurytemora* sp. (65), *Mesocyclops leuckarti* (Claus) (67), *Pseudocalanus elongatus* Boeck (77), *Temora longicornis* (Müller) (73).

The results are given in synthetic tables presenting number of zooplankton taxons in Vistula Lagoon (Tables 6, 7, 8). In a time system, L_1 - L_3, J_1 - J_3 and Z_3 denote groupings of particular months. Groupings resulting from the similarity of zooplankton numbers are denoted as a_2 - a_7, b_3 - b_5, c_4 - c_{10}.

3.1. GROUPING OF MONTHS RESULTING FROM SIMILARITIES IN ZOOPLANKTON NUMBERS

Groupings of particular months were obtained in an objective way, basing on the criterium of natural division of the dendrite, comparing the calculated quotients of respective distances. Similarities (S) of zooplankton numbers in particular months, month distances (r) arranged in a decreasing order, and quotients (d) of adjacent distances for particular years amounted to:

– in 1975 min (max S) = 10.06%

r	d
89.94	
81.48	1.104
77.05	1.057
74.59	1.033
73.48	**1.015**
66.87	1.099
64.31	**1.040**
50.77	1.267

The dendrite of months breaks down to 8 groupings, at the similarity S = 49.23%, although it is also possible to make a weaker division into 6 groupings (S = 33.13%). Division of the dendrite into groupings is presented in Table 2 and Fig. 1.

– in 1977 min (max S) = 12.94%

r	d
87.06	
72.94	1.193
67.20	**1.085**
60.00	1.120
59.79	**1.003**
59.09	1.012

Table 2. Scheme of groupings of particular months during 3-year studies in Vistula Lagoon

<table>
<tr><th>Coefficient of similarity [%]</th><th>Number of groupings</th><th colspan="10">Months</th></tr>
<tr><td></td><td>1975</td><td colspan="10"></td></tr>
<tr><td></td><td></td><td></td><td>III</td><td>XI</td><td>X</td><td>IX</td><td>VIII</td><td>VII</td><td>VI</td><td>V</td><td>IV</td></tr>
<tr><td>33,13</td><td>6</td><td></td><td>–</td><td>–</td><td colspan="2">———</td><td colspan="3">———</td><td>–</td><td>–</td></tr>
<tr><td>49,23</td><td>8</td><td></td><td>–</td><td>–</td><td colspan="2">———</td><td>–</td><td>–</td><td>–</td><td>–</td><td>–</td></tr>
<tr><td></td><td>1977</td><td colspan="10"></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td>V</td><td>VII</td><td>VI</td><td>VIII</td><td>IX</td><td>X</td><td>XI</td></tr>
<tr><td>40,00</td><td>4</td><td></td><td></td><td></td><td>–</td><td colspan="2">———</td><td>–</td><td colspan="3">———</td></tr>
<tr><td>40,91</td><td>6</td><td></td><td></td><td></td><td>–</td><td>–</td><td>–</td><td>–</td><td colspan="2">———</td><td>–</td></tr>
<tr><td></td><td>1978</td><td colspan="10"></td></tr>
<tr><td></td><td></td><td>II</td><td>III</td><td>IV</td><td>IX</td><td>VII</td><td>VIII</td><td>VI</td><td>V</td><td>X</td><td>XI</td></tr>
<tr><td>26,97</td><td>3</td><td colspan="3">———</td><td colspan="5">———</td><td colspan="2">———</td></tr>
<tr><td>33,75</td><td>4</td><td colspan="2">———</td><td>–</td><td colspan="5">———</td><td colspan="2">———</td></tr>
<tr><td>42,11</td><td>7</td><td>–</td><td>–</td><td>–</td><td>–</td><td colspan="3">———</td><td>–</td><td colspan="2">———</td></tr>
<tr><td>58,74</td><td>9</td><td>–</td><td>–</td><td>–</td><td>–</td><td colspan="2">———</td><td>–</td><td>–</td><td>–</td><td>–</td></tr>
</table>

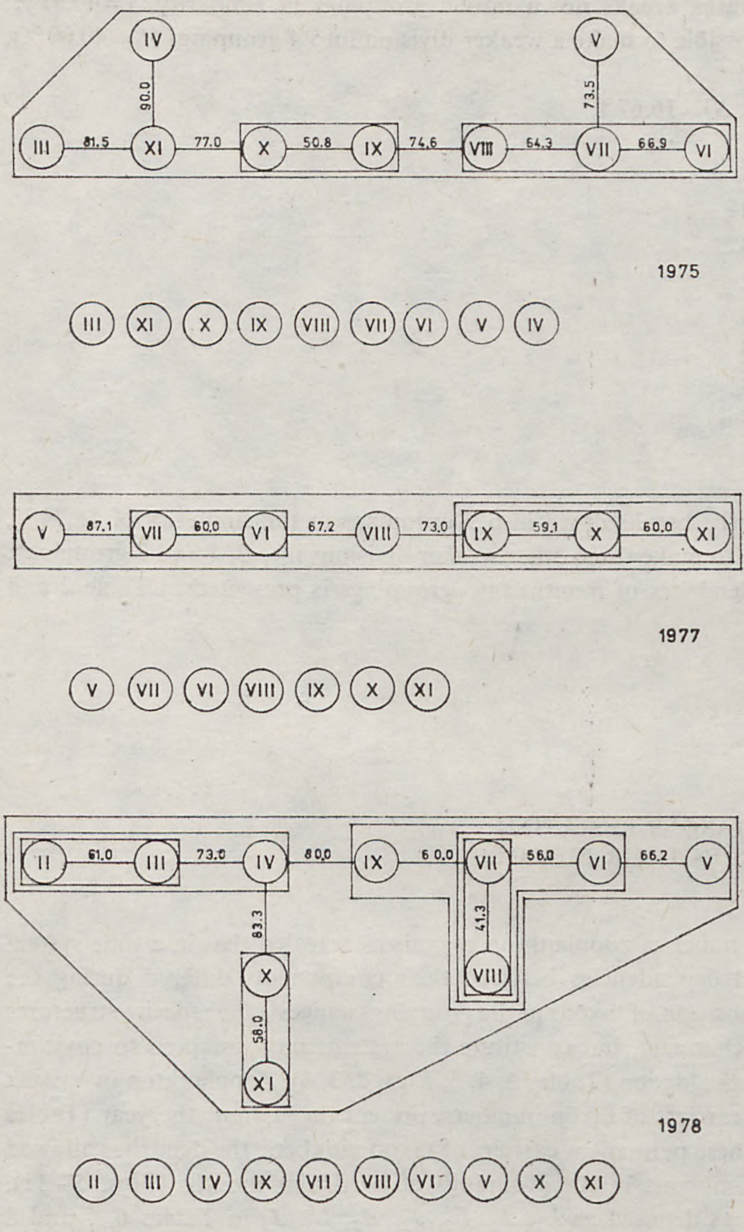

Fig. 1. Dendrites and month grouping on the background of zooplankton numbers in Vistula Lagoon.

The dendrite of months breaks down into 6 groupings at similarity $S=40.91\%$, although it is also possible to make a weaker division into 4 groupings ($S=40.00\%$).

— in 1978 min (max S)$=16.67\%$

r	d
83.33	
79.82	**1.044**
73.03	**1.093**
66.25	1.102
60.92	1.088
60.00	**1.015**
57.89	1.038
55.95	**1.035**
41.26	1.356

The dendrite of months breaks down into 9 groupings at the similarity of 58.74%, but it is also possible to make three other weaker divisions into 3, 4 and 7 groupings.

Division of the dendrites of months into groupings is presented in Table 2 and Fig. 1.

3.2. GROUPING OF TAXONS RESULTING FROM SIMILARITIES IN THEIR NUMBERS

Analysis of the number of zooplankton organisms revealed that in a time system taxon groupings and dependencies between their components differed during the 3-year studies. Composition of taxons in the groupings suggests that species structures are not of a chance character, but constitute the systems most adapted to environmental conditions in the lagoon (Tables 3, 4, 5, Figs. 2, 3, 4). Zooplankton in Vistula Lagoon is based on carriers of taxon numbers, present throughout the year (Tables 6, 7, 8). Apart from these permanent carriers of taxon numbers, the dendrites allowed for distinguishing dominants in the groupings of particular months (Figs. 5 - 11). Since month groupings denoted as L_1, J_1, L_2, J_2, Z_3, L_3, J_3 in Tables 6, 7 and 8 have been distinguished on the basis of objective criteria, they do not correspond to year seasons, the latter being connected with species phenology. Hence, inter-relations between particular species are analysed with respect to their simultaneous occurrence which results from a variety of ecological factors rather than from the seasonal pattern.

In the distinguished concentrations L_1, J_1, L_2, J_2, Z_3, L_3 and J_3 cenologic distances (r) of taxons and quotients (d) of the distances between adjacent sections arranged in a diminishing order amounted to:

Table 3. Scheme of taxon groupings in the zooplankton of Vistula Lagoon in 1975

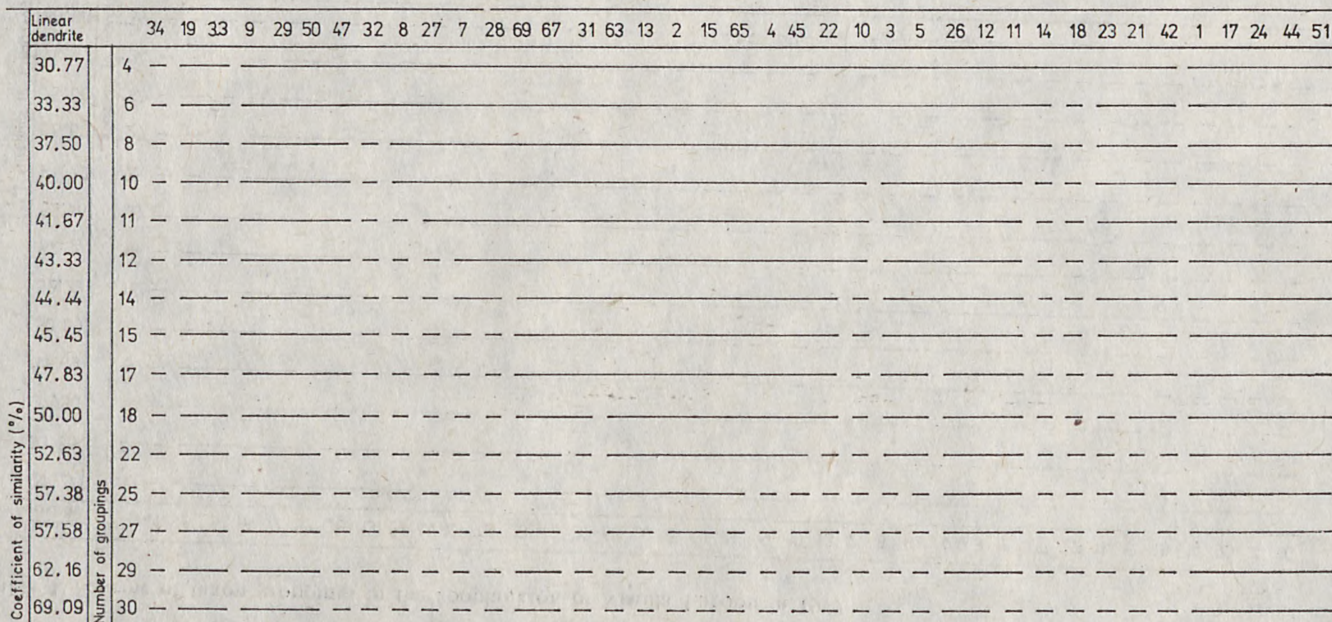

Table 4. Scheme of taxon groupings in the zooplankton of Vistula Lagoon in 1977

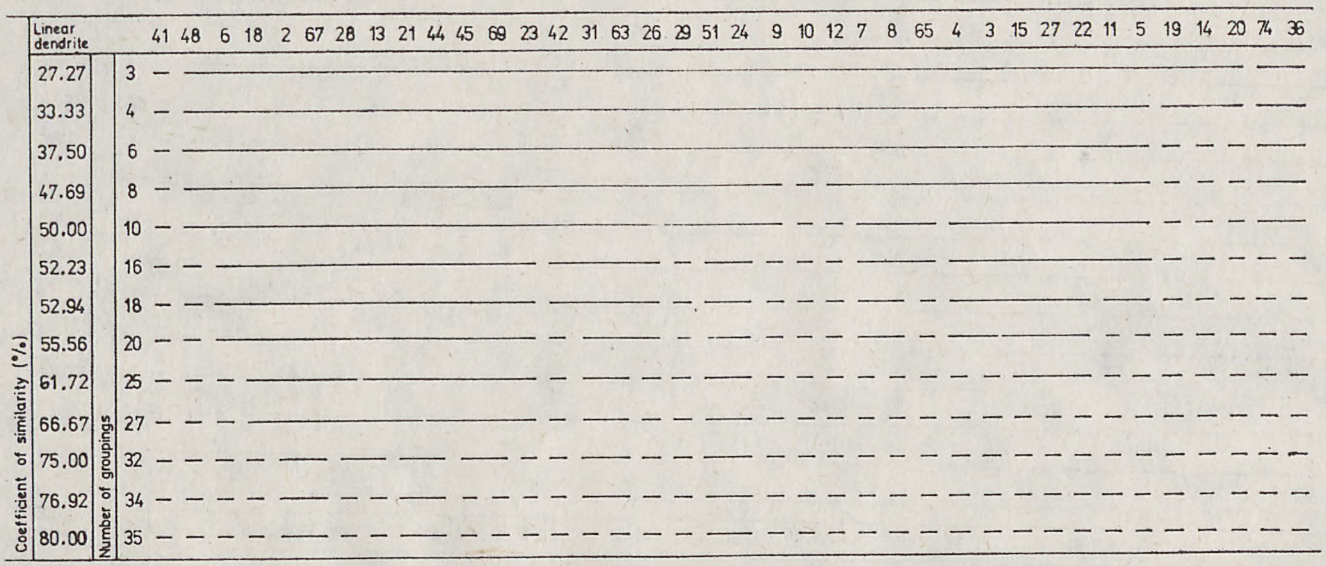

Table 5. Scheme of taxon groupings in the zooplankton of Vistula Lagoon in 1978

Linear dendrite: 16 67 69 22 11 26 12 3 5 10 65 15 63 7 13 45 31 2 23 4 42 41 19 8 50 14 46 74 28 27 18 49 61 24 20 77 32 38 73 76 34 48 51 9 21

Coefficient of similarity (%)	Number of groupings
35.71	7
40.00	8
44.44	12
50.00	14
50.91	24
53.33	26
55.56	28
56.30	30
57.14	32
58.82	33
62.50	36
66.67	38
82.35	41

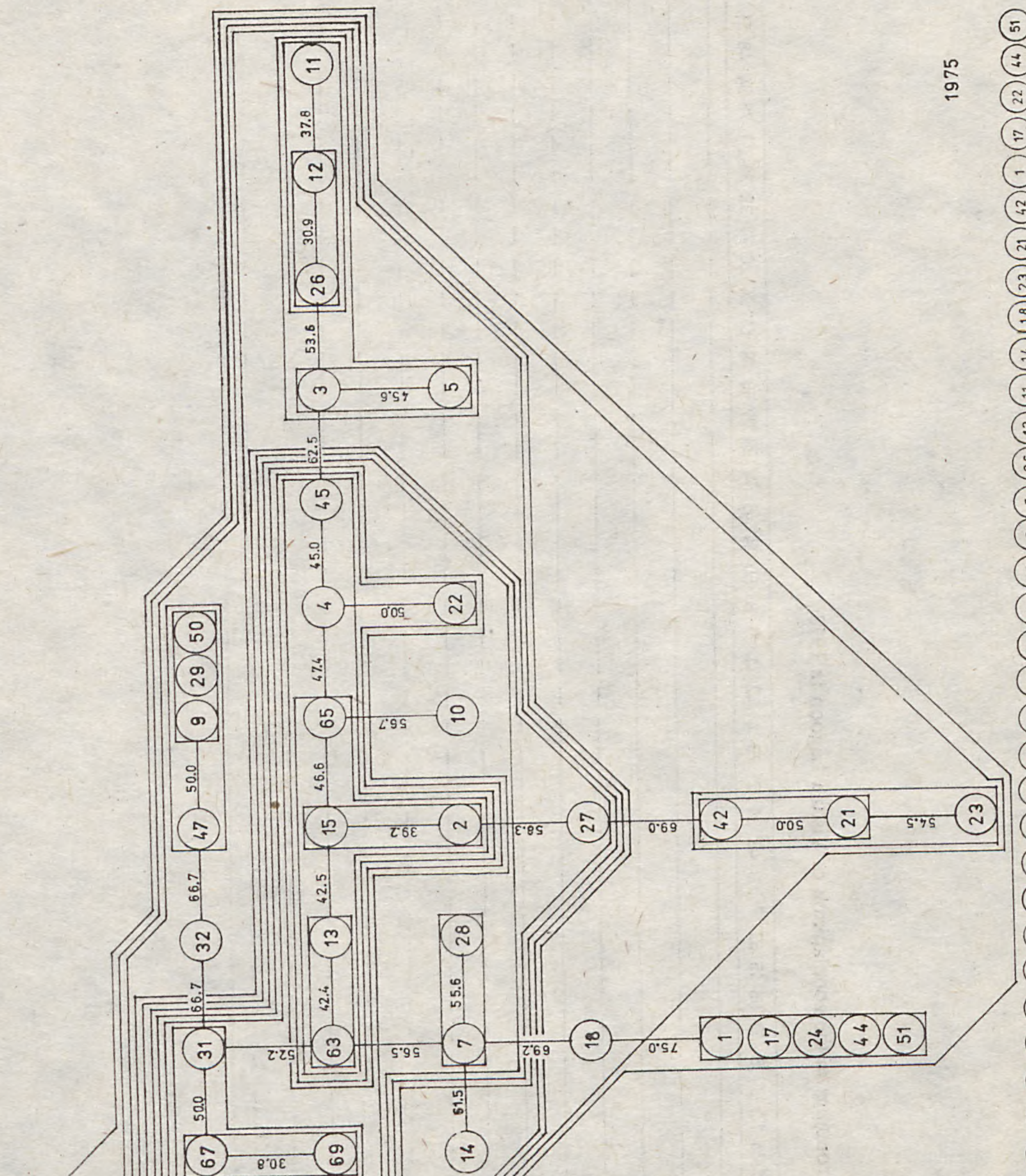

Fig. 2. Dendrite and taxon groupings of the zooplankton in Vistula Lagoon in 1975 – time system.

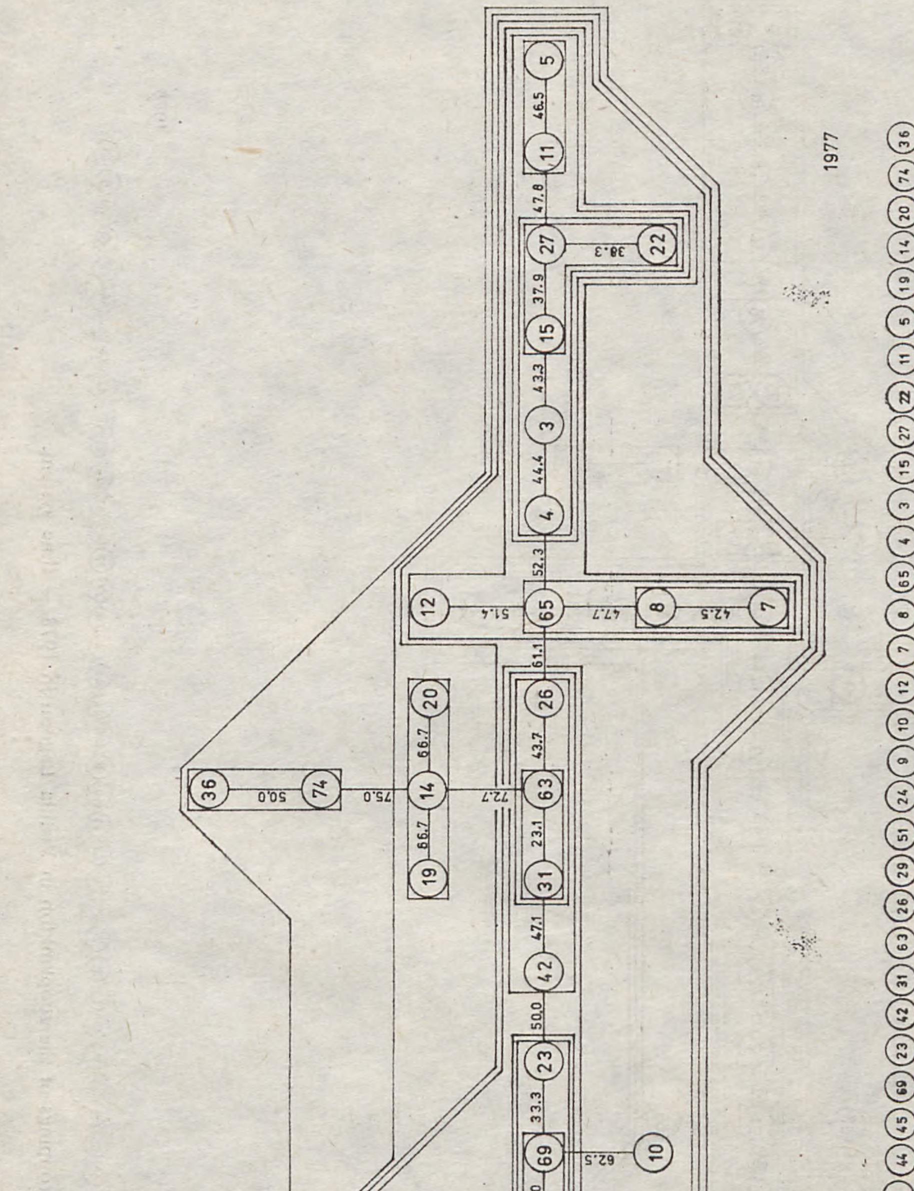

Fig. 3. Dendrite and taxon groupings of the zooplankton in Vistula Lagoon in 1977 – time system.

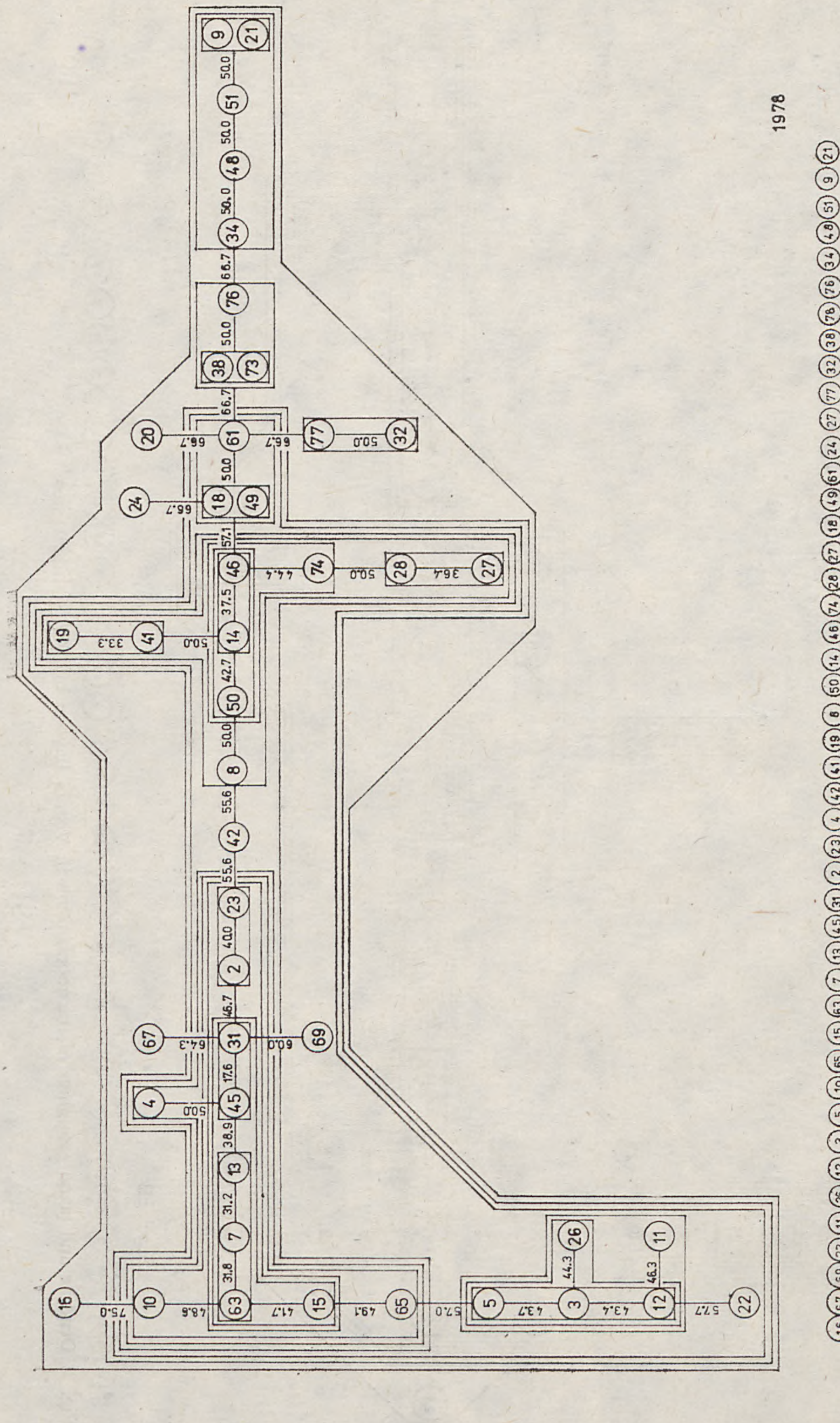

Fig. 4. Dendrite and taxon groupings of the zooplankton in Vistula Lagoon in 1978 – time system.

Table 6. Zooplankton numbers in Vistula Lagoon in particular months of 1975, according to linear arrangement of the dendrites (in thousand indiv.$\cdot m^{-3}$)

Temperature [°C]	2,5	5,2	8,3	15,8	23,0	22,3	18,2	16,7	7,2
Salinity [‰]	2,85	3,90	3,23	3,28	2,89	2,37	2,69	2,08	2,47
Nitrates [mg $N\text{-}NO_3 \cdot dm^{-3}$]	2,10	0,65	0,71	1,17	1,05	1,22	0,51	0,28	0,50
Free phosphates [mg $PO_4 \cdot dm^{-3}$]	0,100	0,191	0,287	0,194	0,173	0,237	0,254	0,182	0,097
Oxydability [mg $O_2 \cdot dm^{-3}$]	34,0	19,6	19,4	20,4	27,7	23,5	43,4	22,6	17,1

				J_1		L_1				
	Taxon[S] \ Months	III	XI	X	IX	VIII	VII	VI	V	IV
	34						10			
	19									7
a_2	33						15			
	9					3	10			
a_3	29									13
	50					7				
	47					5		7		
	32							11		
	8					16		10		
	27		99	27		37				43
	7			10		27	7	19		
	28									32
	69					45	8			8
	67					30	13	13	15	8
	31			7	13	28	16			
	63		26	31	65	44	27	14		
a_4	13		8	16	24	72	21	25	17	13
	2						13	80	113	37
	15	7	18	23	10	12	15	112	105	17
	65		83	89	47	104	41	80	271	92
	4								20	69
	45				14	116	17	10	17	
	22	3	8	9				6		119
	10		10			10	145	12		
	3			8	10	74	542	35	178	37
	5			17		24	286	17	653	
a_5	26	43	45	10	15		43	50	24	1179
	12		12	199	331	879	524	269	158	13
	11			54		305	565	1139	64	17
	14			10			8	12	7	
	18									10
	23			13		7	40	23	107	14
a_6	21								82	
	42			7		23	10	151	38	
	1						3			13
	17						10			
a_7	24					7				
	44					7				
	51					5	7			

Table 7. Zooplankton numbers in Vistula Lagoon in particular months of 1977, according to linear arrangement of the dendrites (in thousand indiv.$\cdot m^{-3}$)

Temperature [°C]	11,3	20,9	12,7	20,5	16,8	9,4	7,6
Salinity [$^0/_{00}$]	2,02	2,00	1,73	2,59	2,85	2,93	3,15
Nitrates [mg N-$NO_3 \cdot dm^{-3}$]	3,36	1,31	0,85	0,52	0,77	1,06	0,43
Free phosphates [mg $PO_4 \cdot dm^{-3}$]	0,124	0,243	0,190	0,201	0,303	0,189	0,186
Oxydability [mg $O_2 \cdot dm^{-3}$]	21,5	21,1	21,3	28,6	35,0	24,7	28,7

			L_2			J_2		
	Taxons \ Months	V	VI	VII	VIII	IX	X	XI
	41		3	3	4		3	
	48				10	3		
	6		14	23	16			
	18	6		5				
	2		8	9	10	5	8	7
	67		6	17	7	7	7	
	28	6		33				
	13		9		3		5	
	21			11				
	44			5		7		
b_3	45		13	4	6	8		
	69	22		5		12	7	7
	23	23	22	6	11		7	21
	42		18	12	47	10	8	
	31		15		4	5	7	
	63		36		28	38	23	24
	26	5	30	12	11	48	11	16
	29		5	13	8			
	51		3		7			
	24					5		
	9	7	3					
	10		34	10	10	33		
	12	8	36	30	178	68	42	10
	7		62		9			
	8	15	50			4		
	65	69	16	160	48	67	57	75
	4	98	42					38
b_4	3	8	221	163	175	26	10	
	15	386	182	18	18	10	10	21
	27	334	58	47	10	8	30	18
	22	486					6	22
	11	13	546	234	15	45	17	35
	5		327	202	45	6		
	19	7						
	14	3	6				3	7
	20	4						
b_5	74						3	7
	36		5					

Table 8. Zooplankton numbers in Vistula Lagoon in particular months of 1978, according to linear arrangement of the dendrites (in thousand indiv.$\cdot m^{-3}$)

Temperature [°C]	0,9	2,8	7,3	13,8	16,9	19,1	20,3	19,2	7,9	5,7
Salinity [‰]	3,93	2,92	2,72	3,59	2,90	2,97	3,37	2,99	3,03	3,30
Nitrates [mg $N\text{-}NO_3 \cdot dm^{-3}$]	1,47	1,67	0,26	0,31	0,24	0,28	0,22	0,26	0,53	0,52
Free phosph. [mg $PO_4 \cdot dm^{-3}$]	0,245	0,113	0,000	0,094	0,147	0,167	0,179	0,121	0,163	0,120
Oxydability [mg $O_2 \cdot dm^{-3}$]	30,9	17,1	26,3	30,7	19,5	25,6	29,0	22,6	28,3	39,4

		Z_3			L_3					J_3	
	Taxons	II	III	IV	IX	VII	VIII	VI	V	X	XI
	16							26			
	67					7	26	3	7		
	69			12			28				
	22		21	124						14	
	11			18	39	179	217	394	519	7	
	26	653	269	119	34	89		69	7	13	14
c_4	12			12	196	282	272	203	15	14	12
	3			14	47	168	231	42	17		
	5				110	102	71	132			
	10	10		7		29	63	14			
	65	8	15	95	76	30	114	26	199	157	77
	15	6	39	101	28	17	13	65	16	9	6
	63				31	47	107	37	7		
	7					12	28	21	10		
c_5	3		3	13	20	9	18	8	3	7	3
	45		10				19		13		
	23				13	8	21				
	2			17	20		8	13	3		
	23	6	9	18	34			7			
	4		10	28		69	12	30		8	
	42				19	7	10	7	11		
c_7	41							7	7		
	19			3	10		7				
	8			8	30			11	8		
	50				15		7	7	3		
	14			6	7	13		15			
c_8	46	17	12	8							
	74	29	18	17	3					8	
c_9	28		32				10				
	27			54		7					10
c_{10}	18			7					7		
	49	13	3						4		
	61	7									11
	24			3			7				
	20			7							
	77			3							
	32							7	8		
c_3	38								5		
	73	7	3	3	3						
	76	10	3	4							
	34					3			7		
	48						7				
	51						7		7		
c_6	9			7							
	21			7							

– in 1975

L_1 concentration min (max S) = 30.00%

r	d	r	d	r	d
70.00		49.77	**1.004**	34.12	1.063
66.85	1.047	48.93	1.017	33.33	1.023
64.29	1.039	48.78	1.003	33.09	1.007
63.64	**1.010**	45.45	1.073	30.51	1.084
62.54	**1.017**	45.00	1.010	30.19	**1.010**
57.94	1.087	44.73	**1.006**	29.10	**1.037**
55.14	1.042	39.53	1.131	24.19	1.202
53.85	**1.023**	38.89	1.016	23.08	1.048
50.94	1.057	37.00	1.051	23.08	1.000
50.00	1.018	36.29	**1.019**		

The dendrite of taxons breaks down into 27 groupings, although 10 more divisions are possible into 5, 6, 9, 12, 14, 16, 19, 21, 24 and 26 groupings. The dendrite of taxons in the L_1 concentration, their linear arrangement, and all possible groupings are presented in Fig. 5.

J_1 concentration min (max S) = 25.66%

r	d	r	d	r	d
74.34		38.10	1.172	23.08	**1.019**
58.33	1.274	37.84	**1.006**	22.22	**1.038**
50.00	1.166	37.50	**1.009**	20.00	1.111
49.35	**1.013**	37.04	**1.012**	19.05	**1.049**
44.68	**1.104**	23.53	1.574	10.00	1.905

The dendrite of taxons breaks down into 15 groupings, but 7 other divisions are possible into 5, 6, 8, 9, 10, 12 and 13 groupings. The dendrite of taxons in the J_1 concentration, their linear arrangement and all possible groupings are presented in Fig. 6.

– in 1977

L_2 concentration min (max S) = 33.19%

r	d	r	d	r	d
66.81		37.14	1.018	26.09	1.050
54.55	1.224	36.59	**1.015**	25.00	**1.043**
54.17	**1.007**	33.33	1.097	21.74	1.149
52.17	1.038	33.33	1.000	20.00	1.087
51.06	1.022	33.33	**1.000**	19.35	**1.033**
50.00	**1.021**	32.18	1.035	16.67	1.160
47.92	**1.043**	31.58	**1.018**	16.00	**1.041**
40.00	1.198	29.41	1.073	14.29	1.119
39.29	**1.018**	28.57	**1.029**	13.04	1.095
37.84	1.038	27.41	**1.042**		

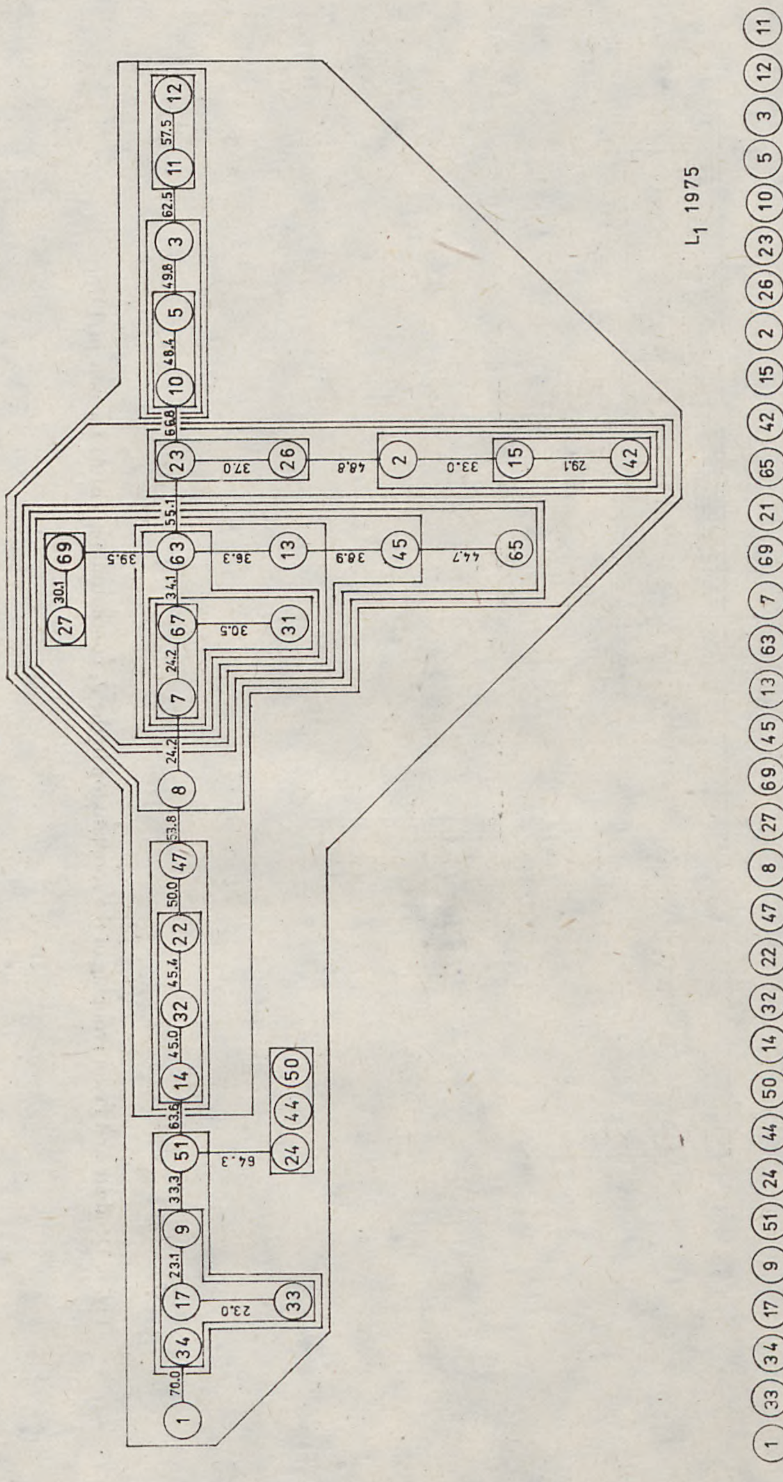

Fig. 5. Dendrite and taxon grouping of the zooplankton in the L_1 concentration; Vistula Lagoon in 1975.

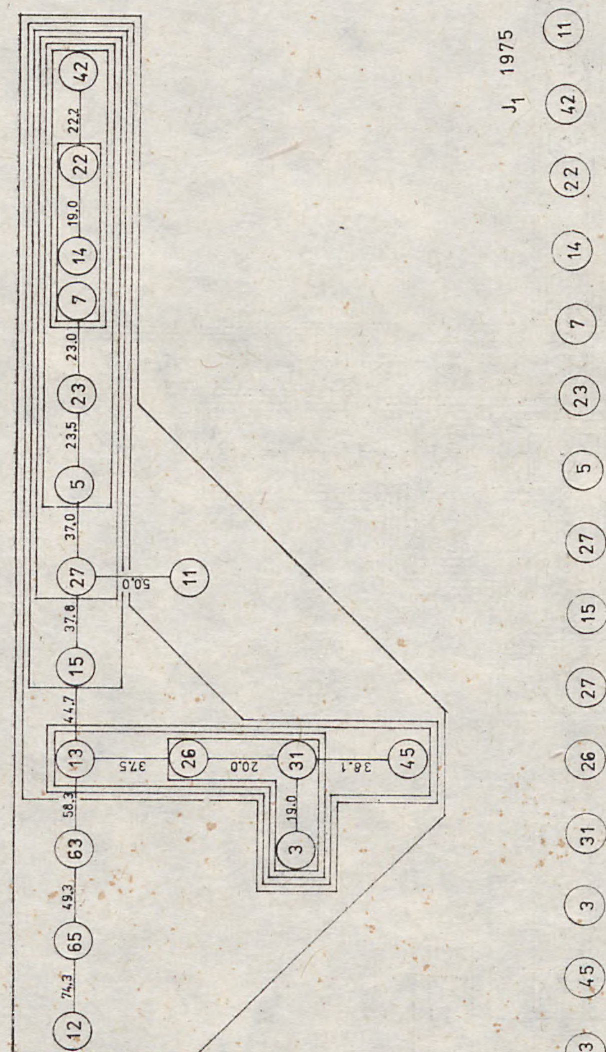

Fig. 6. Dendrite and taxon grouping of the zooplankton in the J_1 concentration; Vistula Lagoon in 1975.

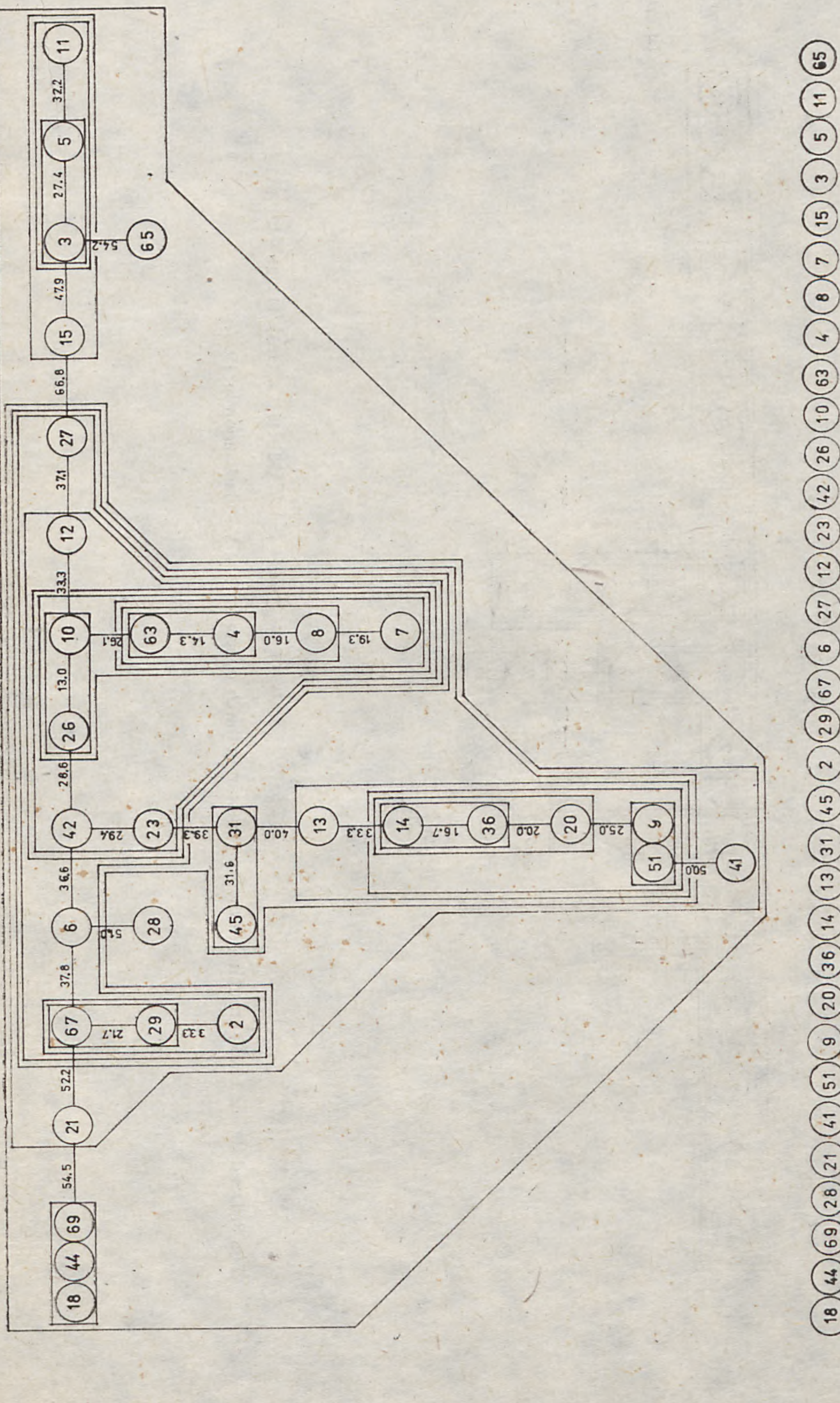

Fig. 7. Dendrite and taxon grouping of the zooplankton in the L_2 concentration; Vistula Lagoon 1977

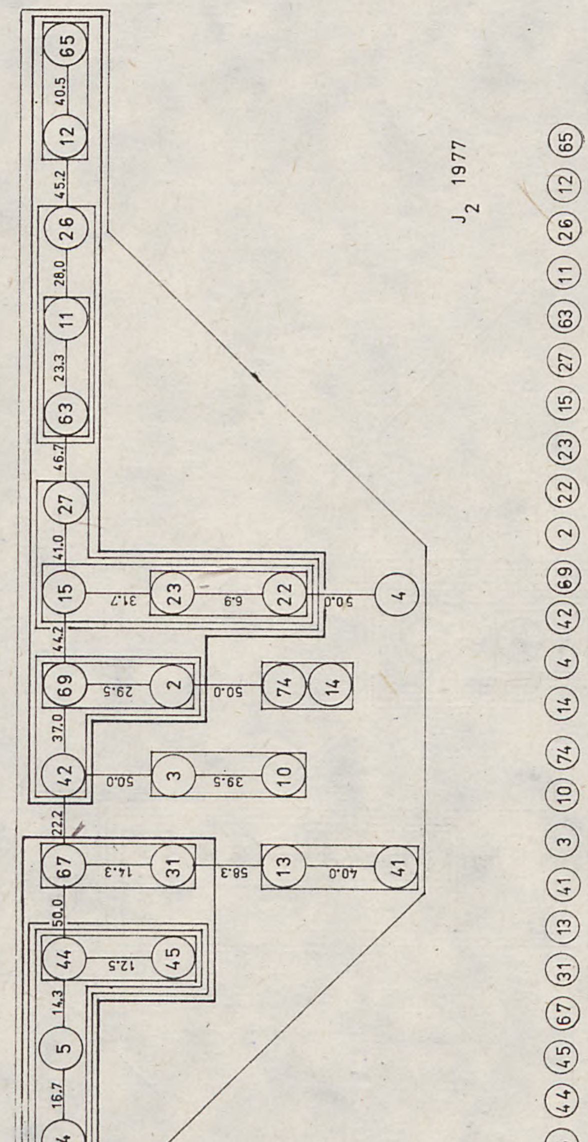

Fig. 8. Dendrite and taxon grouping of the zooplankton in the J_2 concentration; Vistula Lagoon in 1977.

The dendrite of taxons breaks down into 28 groupings, but 11 other divisions are possible into 4, 7, 8, 10, 13, 15, 18, 20, 21, 23 and 26 groupings. The dendrite of taxons in the L_2 concentration, their linear arrangement and all possible groupings are presented in Fig. 7.

J_2 concentration min (max S) = 41.67%

r	*d*	*r*	*d*	*r*	*d*
58.33		40.50	**1.011**	22.22	**1.048**
50.00	1.166	40.00	1.012	20.00	**1.111**
50.00	1.000	39.53	**1.011**	16.67	1.199
50.00	1.000	37.04	**1.067**	14.29	1.166
50.00	**1.000**	31.71	1.168	14.29	**1.000**
46.74	1.069	29.63	1.070	12.50	**1.143**
45.24	1.033	28.00	**1.058**	6.90	1.811
44.19	**1.023**	25.00	1.120		
40.98	**1.078**	23.30	1.072		

The dendrite of taxons breaks down into 25 groupings, but 9 other divisions can be made into 6, 9, 11, 13, 14, 17, 20, 21 and 24 groupings. The dendrite of taxons in the J_2 concentration, their linear arrangement and all possible groupings are presented in Fig. 8.

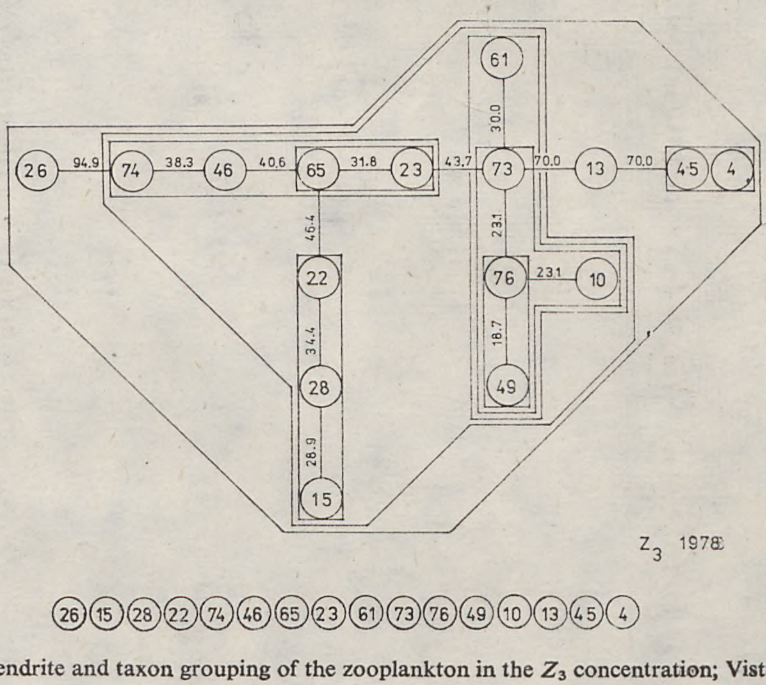

Fig. 9. Dendrite and taxon grouping of the zooplankton in the Z_3 concentration; Vistula Lagoon in 1978.

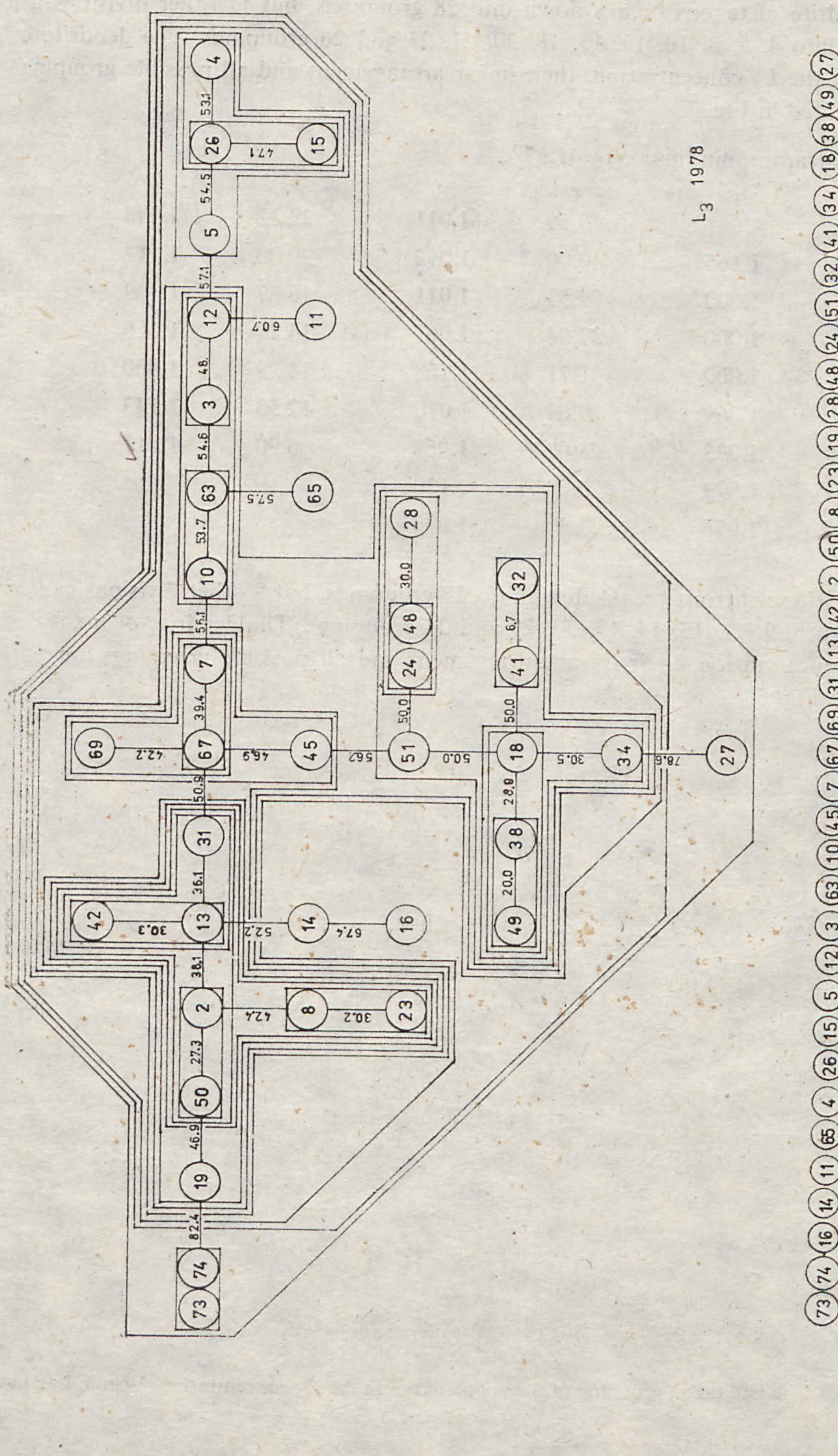

Fig. 10. Dendrite and taxon grouping of the zooplankton in the L_3 concentration; Vistula Lagoon in 1978.

– in 1978

Z_3 concentration min(max S)=5.10%

r	*d*	*r*	*d*	*r*	*d*
94.90		40.63	1.076	28.89	**1.038**
70.00	1.355	38.30	**1.060**	23.08	1.251
70.00	**1.000**	34.38	1.114	23.08	**1.000**
46.43	1.507	31.82	1.080	18.75	1.230
43.75	1.061	30.00	1.060		

The dendrite of taxons breaks down into 14 groupings, but 4 other divisions are possible into 4, 6, 8 and 12 groupings. The dendrite of taxons in the Z_3 concentration, their linear arrangement and all possible groupings are presented in Fig. 9.

L_3 concentration min(max S)=17.65%

r	*d*	*r*	*d*	*r*	*d*
82.35		53.08	**1.011**	38.10	**1.035**
78.57	**1.048**	50.88	1.043	36.07	**1.056**
67.39	1.165	50.00	1.017	3.030	1.190
65.22	**1.033**	50.00	1.000	30.19	**1.003**
60.73	1.073	50.00	**1.000**	30.00	1.006
57.51	1.055	48.14	1.038	30.00	**1.000**
57.13	**1.006**	47.06	1.022	28.57	1.050
56.25	1.015	46.94	1.002	27.27	**1.047**
56.10	**1.002**	46.88	**1.001**	20.00	**1.363**
54.65	1.026	42.37	1.106	6.67	2.998
54.50	**1.002**	42.22	**1.003**		
53.71	1.014	39.44	1.070		

The dendrite of taxons breaks down into 34 groupings, but 14 other divisions can be made into 3, 5, 8, 10, 12, 14, 18, 22, 24, 26, 27, 29, 31 and 33 groupings. The dendrite of taxons in the L_3 concentration, their linear arrangement and all possible groupings are presented in Fig. 10.

J_3 concentration min(max S)=11.54%

r	*d*	*r*	*d*	*r*	*d*
88.46		42.31	**1.012**	12.50	2.400
57.69	1.533	33.33	1.269	10.71	**1.167**
42.86	1.346	30.00	**1.111**	9.09	1.178

The dendrite of taxons breaks down into 9 groupings, but 2 other divisions are possible into 5 and 7 groupings. The dendrite of taxons in the J_3 concentration, their linear arrangement and all possible groupings are presented in Fig. 11.

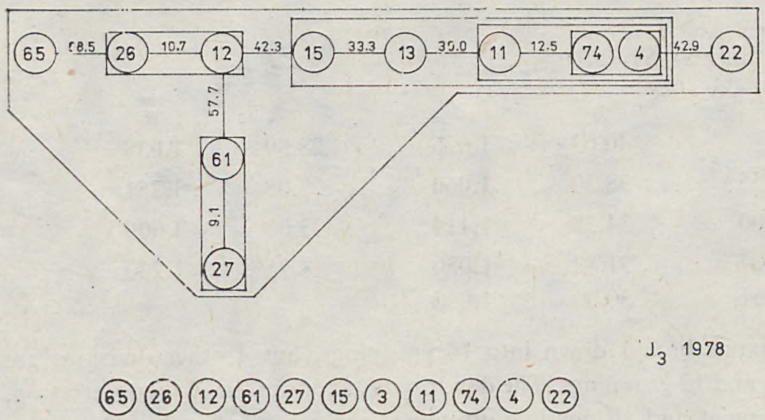

Fig. 11. Dendrite and taxon grouping of the zooplankton in the J_3 concentration; Vistula Lagoon in 1978.

4. DISCUSSION

Annual grouping trends in the zooplankton, as based on number of taxons, differed during the three years of studies, and depended most of all on water temperature and salinity. These differences were reflected in varying number of the dominants and their components in particular groupings.

It should be noted that in all three years of studies, even as the lowest coefficient of similarity, no grouping was formed in spring months (Table 2). Spring months (April, May) either formed separate groupings, or – at low coefficient of similarity (26.97%) – April belonged to winter grouping, as in 1978 (Fig. 1). This points to changeable environmental conditions in spring, as also to significant variety in the number and intensity of changes taking place in species structure of the zooplankton.

In 1975 six groupings of taxon numbers were distinguished in the dendrite of months (Fig. 1), at the similarity of 33.13%. The strongest concentration of June, July and August was denoted as L_1 (Tables 6, 2, Fig. 1). Characteristic environmental factors common for this concentration were the highest average temperature of water in 1975, ranging from 18.2 to 23.0°C, similar salinity (2.37 - 2.89°/oo), and the highest levels of organic matter (23.5 - 43.4 mg $O_2 \cdot dm^{-3}$). Next strong concentration was denoted as J_1. It comprised September and October, which were characterized by almost the same salinity (3.23 - 3.28°/oo). The remaining months formed separate groupings and were characterized by different values of the environmental factors (Tables 2, 6, Fig. 1).

In 1977 two concentrations (L_2 and J_2) of taxon numbers were obtained from a branched dendrite (Fig. 1), at similarity of 40.00% (Tables 2, 7, Fig. 1). The following months remained outside the groupings: May, with the predominance of *Pedalia fennica* (22), and August, with the predominance of the rotifers *Keratella cochlearis* (12) and *Brachionus angularis* (3) (Table 7).

The L_2 concentration was the strongest one as regards the numbers and abundancy of taxons. Environmental factors similar for this concentration were water salinity (1.73°/$_{oo}$) and organic matter (21.1 - 21.3 mg $O_2 \cdot dm^{-3}$). The J_2 concentration embraced September, October and November which were characterized by different hydrobiological conditions. The highest water salinity for these three months was noted in 1977 when the average values ranged between 2.85 and 3.15°/$_{oo}$ (Tables 2, 7, Fig. 1).

In 1978 four groupings of taxon numbers were obtained from the dendrite of months, at similarity of 33.75% (Tables 2, 8, Fig. 1). The strongest, L_3 concentration was composed of 5 months: May, June, July, August and September, at average water temperature of 13.8 - 20.3°C, and water salinity of 2.90 - 3.59°/$_{oo}$. With respect to the coefficients of similarity, the other strong concentration, denoted as Z_3, was composed of February and March, and corresponded to winter period. The third concentration, distinguished from a branched dendrite, was denoted as J_3. It was composed of October and November, the two months being characterized by similar values of some environmental factors, such as salinity (3.03 - 3.30°/$_{oo}$), temperature of water (5.7 - 7.9°C), and nitrate content (0.52 and 0.53 mg N-$NO_3 \cdot dm^{-3}$) (Tables 2, 8, Fig. 1).

Taxon groupings in the concentrations corresponding to summer period in particular years were denoted as L_1, L_2 and L_3. Their dendrites are presented in Figs. 5, 7 and 10.

As regards the numbers, a rotifer *Filinia longiseta* (11) predominated the grouping in the L_1 concentration. Its abundancy reached 1139000 indiv.$\cdot m^{-3}$. Other components of this grouping were: *Keratella cochlearis* (12) – 879000 indiv.$\cdot m^{-3}$, *Brachionus angularis* (3) – 542000$\cdot m^{-3}$, *Brachionus calyciflorus amphiceros* (5) – 286000$\cdot m^{-3}$ and *Euchlanis dilatata* (10) – 145000 indiv.$\cdot m^{-3}$ (Fig. 5, Table 6).

The next grouping was composed of 19 taxons. Hence, it contained a large number of species, but their numerosity was rather low. The grouping was predominated by *Bosmina longirostris* (42) with the highest numbers, amounting to 151000 indiv.$\cdot m^{-3}$. Other numerous components of this grouping were *Diaphanosoma brachyurum* (45), at the level of 116000 indiv.$\cdot m^{-3}$, *Keratella quadrata* (15) – 112000 indiv.$\cdot m^{-3}$, *Eurytemora* sp. (65) with copepodits – 104000$\cdot m^{-3}$, and *Acartia tonsa* (63) – 44000 indiv.$\cdot m^{-3}$. The remaining species occurred with different abundancy but they were always less numerous than the dominating species and main components of the zooplankton.

The other two groupings embraced sporadic or rare species, which occurred in low numbers. They were most frequent in the L_1 concentration. Mention should be made of species occurring together at a similar level of 7000 indiv.$\cdot m^{-3}$: *Proales* sp. (24), *Chydorus sphaericus* (44), *Sida cristalina* (50), as also of taxons which occurred at levels varying from 3 to 15000 indiv.$\cdot m^{-3}$: *Brachionus rubens* (9), *Lecane luna* (17), *Cephalodela* sp. (33), *Ascomorpha saltans* (34), *Simocephalus vetulus* (51) (Fig. 5).

In the L_2 concentration four groupings were distinguished from a branched dendrite, at similarity of species numbers at the level of 47.83% (Fig. 7). In this concentration a grouping of 4 species was the strongest one. It was predominated by *Filinia longiseta* (11), occurring at the level of 546000 indiv.$\cdot$m^{-3}. Other components of this grouping were *Brachionus calyciflorus amphiceros* (5) – 327000 indiv.$\cdot$m^{-3}, *Brachionus angularis* (3) – 221000$\cdot$m^{-3} and *Keratella quadrata* (15) – 182000$\cdot$m^{-3}.

The grouping with the highest number of species was composed of 25 taxons of varying abundancy. As regards the numbers, *Synchaeta litoralis* (27) was the dominating species (58000 indiv.$\cdot$m^{-3}). The other components were: a few species of *Brachionus*, such as *Brachionus quadridentatus* (7), *Brachionus urceolaris* (8), *Brachionus diversicornis* (6), and *Keratella cochlearis* (12). The latter species was most numerous in August (175000 indiv.$\cdot$m^{-3}). The grouping comprised also *Bosmina longirostris* (42), *Diaphanosoma brachyurum* (45), *Acartia tonsa* (63), *Mesocyclops leuckarti* (67). Next grouping was composed of three species, occurring at the level of 9 - 22000 indiv.$\cdot$m^{-3}: *Cyclops* sp. (69), *Chydorus sphaericus* (44) and *Notholca acuminata* (18). *Eurytemora* sp. (65) remained outside the grouping. Its abundancy reached 16000 indiv.$\cdot$m^{-3}, being the highest in the L_2 concentration in 1977. Maximal numbers of this genus occurred one month later compared with 1975 and 1978, probably due to low temperature of water (Tables 6, 7, 8).

The L_3 concentration, characterized by the highest abundancy and number of taxons, was composed of three groupings, at similarity of the numbers amounting to 32.61% for 39 taxons. In 1978 the strongest grouping, characteristic for the L concentrations in the previous years, was the most numerous grouping of 36 taxons, with *Filinia longiseta* (11) as the dominanting species (519000 indiv.$\cdot$m^{-3}). Other components of the grouping were: *Keratella cochlearis* (12) – 281000 indiv.$\cdot$m^{-3}, *Brachionus angularis* (3) – 231000$\cdot$m^{-3}, *Eurytemora* sp. (65) with copepodits – 199000 indiv.$\cdot$m^{-3}, *Brachionus calyciflorus amphiceros* (5) – 132000$\cdot$m^{-3}, *Acartia tonsa* (63) – 107000$\cdot$m^{-3}. This grouping embraced also less numerous *Cladocera* species (Table 8, Fig. 10). *Synchaeta litoralis* (27) occuring at the level of 7000 indiv.$\cdot$m^{-3}, *Acartia bifilosa* (74) and *Temora longicornis* (73) (3000 indiv.$\cdot$m^{-3} each) remained outside the grouping.

Taxon groupings in the concentrations corresponding to autumn period were denoted as J_1, J_2 and J_3. Their dendrites are presented in Figs 6, 8 and 11.

The J_1 concentration, with similarity of species numerosity at the level of 55.32%, formed five groupings (Fig. 6). The largest grouping of 13 taxons (with the lowest abundancy) embraced the zooplankton species which usually disappear in autumn, together with the taxons which appeared again but at low numbers (for instance, *Synchaeta* genus). Four species of different abundancy remained outside the groupings: *Keratella cochlearis* (12) – 331000 indiv.$\cdot$m^{-3}, *Eurytemora* sp. (65) – 89000$\cdot$m^{-3}, *Acartia tonsa* (63) – 65000$\cdot$m^{-3} and *Filinia longiseta* (11) – 54000$\cdot$m^{-3}. These species formed separate groupings (Table 6, Fig. 6).

The J_2 concentration, corresponding to species structure in autumn, formed six groupings in the dendrite of taxon numbers, at similarity of 53.26% (Fig. 8). Grouping with *Eurytemora* sp. (65) as the dominant (75000 indiv.$\cdot$m^{-3}) was characterized by the highest numbers. Other components of this grouping were *Keratella cochlearis* (12) – 68000 indiv.$\cdot$m^{-3}, *Synchaeta* sp. (26) – 48000$\cdot$m^{-3}, *Filinia longiseta* (11)

– 45000·m^{-3}, *Acartia tonsa* (63) – 38000·m^{-3}, *Synchaeta litoralis* (27) – 3000·m^{-3}, *Pedalia fennica* (22) – 22000·m^{-3}, *Keratella quadrata* (15) – 21000·m^{-3}, *Polyarthra vulgaris* (23) – 21000·m^{-3}, *Cyclops* sp. (69) – 12000·m^{-3} and *Bosmina longirostris* (42) – 10000·m^{-3}.

The other grouping was composed of 8 taxons, with *Mesocyclops leuckarti* (67) as the dominant (8000 indiv.·m^{-3}, and the other components characterized by low numbers. Three groupings of thic concentration embraced unstable species which were characterized by similar requirements as regards the salinity of water, viz. *Keratella cruciformis* (14), *Acartia bifilosa* (74), *Bosmina coregoni maritima* (41), or else species occuring at similar numbers, viz. *Euchlanis dilatata* (10), *Brachionus angularis* (3), *Keratella cochlearis tecta* (13). *Brachionus calyciflorus* (4) appeared in the J_2 concentration only in November (at the level of 38000 indiv.·m^{-3}) and, thus, remained outside the groupings.

Five groupins were distinguished in the dendrite of taxon numbers of the J_3 concentration, at similarity of the elements reaching 66.67% (Fig. 11). Two taxons remained outside the groupings. In Vistula Lagoon autumn period was always characterized by the presence of *Eurytemora* sp. (65), which occurred at maximal numbers (157000 indiv.·m^{-3}) in the J_3 concentration, and *Pedalia fennica* (22), which occurred at the level of 14000 indiv.·m^{-3}. Two groupings were composed of species occurring at similar numbers. These were *Synchaeta* sp. (26), *Keratella cochlearis* (12) – both at the level of 14000 indiv.·m^{-3}, and *Acartia longiremis* (61) and *Synchaeta litoralis* (27) – 11 and 1000 indiv.·m^{-3} respectively. Grouping of taxons characterized by the lowest numbers (7 – 9000 indiv.·m^{-3}) embraced *Keratella quadrata* (4), *Filinia longiseta* (11) and *Keratella cochlearis tecta* (13) (Table 8, Fig. 11).

Considerable numerosity of the Z_3 concentration (which corresponded to winter period) was determined by the numbers of *Synchaeta* sp. (26) – 653000 indiv.·m^{-3}. In this period *Synchaeta* genus was mainly represented by *Synchaeta baltica*, but untypical species also occurred, so that the species were not identified. The Z_3 concentration was composed of four groupings, resulting from the similarity of taxon numbers of 53.57%. Two taxons formed individual groupings: *Synchaeta* sp. (26) – due to its considerable abundancy, and *Keratella cochlearis tecta* (13) – due to low abundancy.

As regards the number of taxons, the largest grouping was predominated by *Keratella quadrata* (15) – 39000 indiv.·m^{-3}. Its components were: *Synchaeta pectinata* (28) – 32000·m^{-3}, *Pedalia fennica* (22) – 21000·m^{-3}, *Evadne nordmanni* (46) – 17000·m^{-3}, *Acartia longiremis* (61) – 7000·m^{-3}. Two species of the same abundancy of 10000 indiv.·m^{-3}, viz. *Brachionus calyciflorus* (4) and *Diaphanosoma brachyurum* (45) formed a separate grouping (Table 8, Fig. 9).

In analysing grouping trends of the zooplankton attention should be drawn to the fact that during the three years of studies no groupings were formed which would correspond to spring period. Such groupings were represented by single months: May in 1975, April and May in 1977, and April in 1978. It is most probable that water temperature in spring (ranging between 7.2 and 11.3°C) and the salinity (2.47 – 2.72‰) are of essential significance for the zooplankton development in the lagoon.

Hence, climatic conditions in Vistula Lagoon do not allow for objective distinguishing of the spring period.

In the zooplankton groupings corresponding to summer period (denoted as *L*) *Filinia longiseta* was the predominating species. Its numbers varied in particular years. These groupings were usually composed of species occurring in considerable numbers, such as: *Keratella cochlearis*, *Brachionus angularis*, *Brachionus calyciflorus amphiceros*. Groupings characterized by a high number of taxons but low abundancy of the organisms were also formed in summer. *L* concentrations embraced also groupings of sporadic species, occuring at low numbers.

Most stable concentrations were those denoted by *J*, which embraced groupings corresponding to autumn period. These groupings were composed of a few taxons only, occuring at low numbers. They embraced species disappearing in autumn, as well as cold-water species of the *Synchaeta* genus. Autumn groupings of the zooplankton were predominated by *Copepoda*.

The Z_3 concentration, which corresponded to winter period, was analysed only once, so no comparisons could be made. Its abundancy was determined most of all by organisms belonging to the *Synchaeta* genus. Due to considerable abundancy and predominance in the Z_3 concentration, this genus did not form groupings with other taxons. Consequently, the largest grouping as regards the number of taxons (but not the abundancy of individuals) was that predominated by *Keratella quadrata*.

Analysis of grouping trends in the zooplankton of Vistula Lagoon showed that taxon groupings differed in particular years of studies, reflecting phenology of the zooplankton organisms. The differences consisted of varying abundancy of the organisms in particular groupings, different number of taxons, and varying abundancy of the dominants in particular seasons.

5. CONCLUSIONS

The following conclusions can be drawn from the studies:

1. Analysis of grouping trends in the zooplankton showed that climatic and environmental conditions did not allow for objective distinguishing of spring period in Vistula Lagoon.

2. Zooplankton groupings corresponding to summer period were characterized by high number of taxons and the highest abundancy of organisms in the concentrations, with the predominance of *Filinia longiseta* (Ehrenberg).

3. Autumn groupings were the most stable ones. They were characterized by the predominance of *Copepoda* over other zooplankton components, low number of taxons, and low abundancy of organisms in the groupings.

4. In winter number of organisms in the grouping was determined by the abundancy of *Synchaeta* species. This grouping was characterized by the lowest number of taxons.

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