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DYNAMICS OF THE VISTULA LAGOON ZOOPLANKTON NUMBERS

1. INTRODUCTION

The problem of ecological changes resulting from water pollution also concerns the coastline and lagoon waters of the Polish shore which are exposed to the advancing process of eutrophication. There has therefore been a growing interest in studies and investigations on the mechanism, causes, and results of this phenomenon [12, 20, 21, 27, 28, 30], in recent years.

Zooplankton is one of the basic links in trophic changes taking place in a water body. It is closely connected in the trophic chain with the phytoplankton and the abiotic factors of the environment. Numerous zooplankton species serve as an important indication in characterizing waters from an ecological point of view [6, 11, 14, 18, 19, 23, 24, 29].

Studies on the species composition, distribution, and frequency dynamics of the Vistula Lagoon zooplankton are to be found in numerous papers [1, 2, 3, 4, 5, 16, 17, 18], the data of which also contain much valuable information on the predominance of specific species.

However, determining the quantitative structure concerning the occurrence of zooplankton as an index of the eutrophication of the Vistula Lagoon is being undertaken for the first time as a subject for discussion. Furthermore, an effort is being made to determine the similarity between particular sampling stations on the basis of zooplankton numbers.

2. MATERIAL AND METHODS

Material for the present study was collected from May to November 1977, and from February to November 1978. During the years mentioned, samples of zooplankton were taken every month from the same stations,

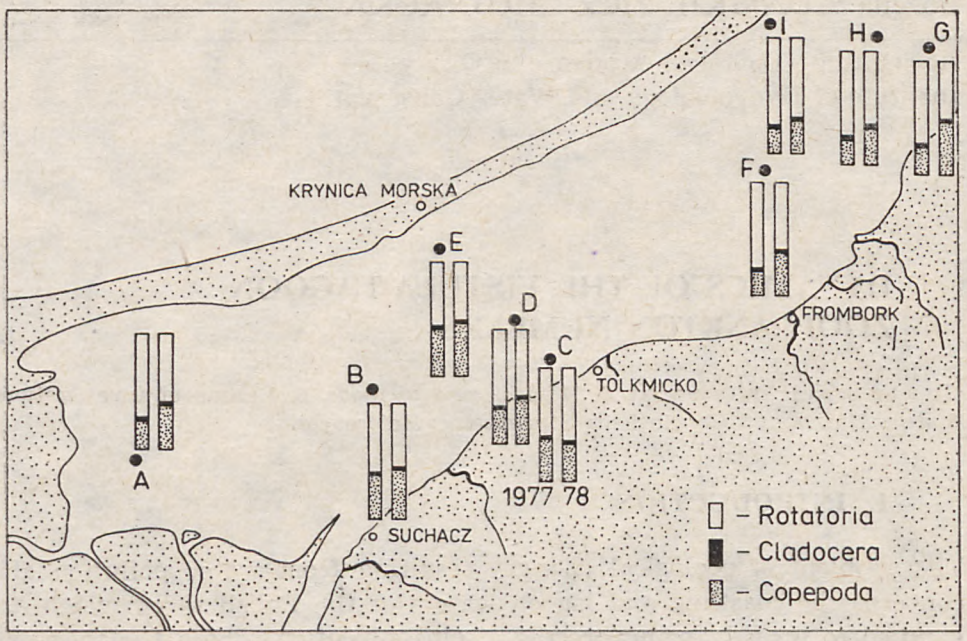

Fig. 1. Distribution of stations in the Vistula Lagoon with consideration given to the percentage of principal zooplankton components

Rys. 1. Rozmieszczenie stanowisk na Zalewie Wiślanym z uwzględnieniem procentowego udziału głównych składników zooplanktonu

selected so as to reflect the hydrological specificity of the Vistula Lagoon (Fig. 1). Determination by means of nine permanent stations from three profiles of the Vistula Lagoon, that is, longitudinal from the south-west to the north-east, transverse from Tolkmicko to Krynica Morska, and parallel to the State boundary, enabled the comparison of zooplankton numbers at stations located mid-lagoon (A, B, D, F, H) with gradually increasing salinity, and at stations located along the shore (C, E, G, I).

Detailed discussions on the physical and chemical factors of the water body have been published in other studies [20, 21] from which selected data will be utilized in the present study.

Plankton samples were obtained by means of a five-litre Ruttner sampler at the following levels, depending upon the depth of the station: 0 m, 1 m, 2 m, 3 m and 4 m. The sample was then filtered by means of a No. 25 Apstein-type net. Samples were fixed with Utermöhl fluid and preserved in 4% formalin. Each plankton sample was brought to the same volume of 50 ml for laboratory analysis in order to unify the calculations. Microscopic examination was carried out in a 1 cm^3 chamber. Three cubic centimeters of water were examined each time. A total of 368 samples (Table 1) was collected and examined microscopically. Numbers of particular species and taxons were expressed by the number

Table 1. Number of samples at specific depts during the period of investigation

Tab. 1. Liczba prób na poszczególnych głębokościach w okresie badań

Depth Głębokość [m]	Number of samples Liczba prób	
	1977 (V–XI)	1978 (II–XI)
0	61	63
1	61	63
2	52	45
3	9	14
Total Razem	183	185

of individuals per 1 m^3 of water for the purpose of comparison with other coastal basins [23, 24], and with the Soviet part of the Vistula Lagoon [30].

3. RESULTS OF INVESTIGATIONS

On the basis of the material collected analyses were made of the number of 35 species and forms of rotifers, 10 species of cladocerans, 10 species of copepods together with their juvenile stages (nauplia and copepodits). In addition, the following were included in the zooplankton complex: *Hydracarina*, nauplia stages of the crustaceans *Ritropanopeus harrisi* and *Balanus improvisus*, as also larvae of *Polychaeta*, *Lamellibranchiata*, *Gastropoda*, *Ostracoda*.

3.1. SPATIAL DISTRIBUTION OF ZOOPLANKTON

Spatial distribution of zooplankton in the Vistula Lagoon depends upon a number of factors, of which salinity is of decisive importance. The results of the two-year analyses of the zooplankton at particular stations in the Vistula Lagoon are presented in Tables 2 to 10. The species of zooplankton occurring here belong to euryhaline fresh water, fresh water and marine euryhaline. Earlier studies [1, 17, 18, 19] have shown — on the basis of detailed qualitative analyses of zooplankton — that the number of species declines as salinity of the water increases. The species composition of the zooplankton throughout the Vistula Lagoon is not uniform. The differences in the species composition and numbers of plankton components occurring at specific stations depend upon the various levels of salinity and ecological factors.

Table 2. Zooplankton composition at station A during the investigations
Tab. 2. Skład zooplanktonu na stanowisku A w okresie badań

Taxonomic units Jednostki taksonomiczne	Frequency at station Frekwencja na stanowisku Number of samples Liczba prób		Average numbers in 1000 ind./m³ Średnia liczebność w tys. osobn./m³		Percentage Udział procentowy	
	18	13				
	1977	1978	1977	1978	1977	1978
Ascomorpha saltans Bartsch	1	–	3	–	0,1	–
Asplanchna priodonta Gosse	12	1	13	20	1,4	0,3
Brachionus angularis Gosse	14	7	83	180	11,2	21,6
Brachionus cylaciflorus Pallas	7	3	72	22	4,9	1,1
Brachionus calyciflorus amphiceros Ehrenberg	8	1	315	23	24,2	0,4
Brachionus diversicornis (Daday)	5	–	21	–	1,	–
Brachionus rubens Ehrenberg	1	1	3	7	0,1	0,1
Brachionus urceolaris Müller	4	–	14	–	0,5	–
Euchlanis dilatata Ehrenberg	3	–	10	–	0,3	–
Filinia longiseta (Ehrenberg)	10	5	30	22	2,9	1,9
Kellicottia longispina (Kellicott)	1	–	3	–	0,1	–
Keratella cochlearis (Gosse)	18	10	50	54	8,6	9,3
Keratella cochleris tecta (Gosse)	5	–	11	–	0,5	–
Keratella quadrata (Müller)	12	4	57	28	6,6	1,9
Notholca acuminata (Ehrenberg)	4	–	8	–	0,3	–
Pedalia fennica (Levander)	6	6	35	14	2,0	1,4
Polyartha dolichoptera Idelson	1	2	13	7	0,3	0,1
Polyarthra vulgaris Carlin	10	4	22	15	2,1	1,0
Rotatoria non determinata	–	2	–	3	–	0,1
Synchaeta litoralis Russelet	15	12	51	192	6,3	19,8
Synchaeta pectinata Ehrenberg	4	2	20	10	0,8	0,3
Trichocerca pusilla (Lauterborn)	3	2	9	22	0,3	0,7
Bosmina longirostris (Müller)	10	1	35	7	3,4	0,1
Chydorus sphaericus (Müller)	1	1	7	3	0,1	0,1
Diaphanosoma brachyurum (Levin)	3	3	19	22	0,5	1,1
Evadne nordmanni Loven	–	1	–	3	–	0,1
Leptodora kindti (Focke)	1	–	3	–	0,1	–
Pleuroxus uncinatus Baird	4	–	8	–	0,3	–
Podon polyphemoides (Leuckart)	–	2	–	3	–	0,1
Simocephalus vetulus (Müller)	1	1	3	7	0,1	0,1
Acartia bifilosa (Giesbrecht)	–	1	–	3	–	0,1
Acartia tonsa (Dana)	–	1	–	3	–	0,1
cop. *A. tonsa*	2	–	7	–	0,1	–
cop. *Cyclops sp.*	4	5	17	21	0,6	1,8
Eurytemora affinis (Poppe)	9	5	7	18	0,6	1,5
cop. *E. affinis*	12	8	26	35	3,0	4,7
Harpacticoida	2	1	8	7	0,2	0,1
Mesocyclops leuckartii (Claus)	2	–	5	–	0,1	–
cop. *M. leuckarti*	3	–	6	–	0,2	–
Hydracarina	–	1	–	3	–	0,1
Lamellibranchiata	6	2	51	77	2,9	2,6
Ostracoda	3	–	7	–	0,2	–
nauplii	17	11	74	144	12,1	27,2

Table 3. Zooplankton composition at station B during the investigations
Tab. 3. Skład zooplanktonu na stanowisku B w okresie badań

Taxonomic units Jednostki taksonomiczne	Frequency at station Frekwencja na stanowisku Number of samples Liczba prób		Average numbers in 1000 ind./m³ Średnia liczebność w tys. osobn./m³		Percentage Udział procentowy	
	21	12				
	1977	1978	1977	1978	1977	1978
Ascomorpha saltans Bartsch	–	2	–	7	–	0,1
Asplanchna priodonta Gosse	7	–	10	–	0,5	–
Brachinous angularis Gosse	15	9	77	191	8,1	15,9
Brachinous calyciflorus Pallas	7	–	102	–	5,0	–
Brachinous calyciflorus amphiceros Ehrenberg	11	6	76	65	5,8	3,6
Brachinous quadridentatus Hermann	3	1	58	13	1,2	0,1
Brachinous rubens Ehrenberg	5	–	6	–	0,2	–
Brachinous urceolaris Müller	4	3	13	8	0,3	0,2
Euchlanis dilatata Ehrenberg	3	3	70	50	1,5	1,4
Filinia longiseta (Ehrenberg)	20	9	80	327	11,1	27,1
Keratella cochlearis (Gosse)	20	11	35	105	4,9	10,7
Keratella cochlearis tecta (Gosse)	2	3	8	10	0,1	0,3
Keratella quadrata (Müller)	17	4	70	20	8,3	0,7
Notholca acuminata (Ehrenberg)	2	–	3	–	0,1	–
Pedalia fenica (Lavender)	8	3	126	16	7,0	0,4
Polyarthra dolichoptera Idelson	2	–	8	–	0,1	–
Polyarthra vulgaris Carlin	3	–	23	–	0,5	–
Proales sp.	2	–	5	–	0,1	–
Rotatoria non determinata	3	–	7	–	0,1	–
Synchaeta litoralis Russelet	15	1	130	23	11,7	0,2
Synchaeta monopus Plate	5	–	12	–	0,4	–
Synchaeta pectinata Ehrenberg	2	–	7	–	0,1	–
Trichocerca pusilla (Lauterborn)	3	5	16	20	0,3	0,9
Bosmina longirostris (Müller)	7	5	22	9	1,1	0,4
Chydorus sphaericus (Müller)	2	–	5	–	0,1	–
Diaphanosoma brachyurum (Lievin)	5	2	6	20	0,2	0,4
Pleuroxus uncinatus Baird	–	1	–	7	–	0,1
Simocephalus vetulus (Müller)	1	1	7	7	0,1	0,1
Acartia tonsa (Dana)	4	–	7	–	0,2	–
cop. *A. tonsa*	7	3	9	17	0,4	0,5
Eurytemora affinis (Poppe)	13	3	18	14	1,6	0,4
cop. *E. affinis*	21	11	60	66	8,8	6,7
Harpacticoida	4	–	7	–	0,2	–
Mesocyclops leuckarti	2	1	7	7	0,1	0,1
cop. *M. leuckarti*	5	3	30	48	1,0	1,3
nauplii	21	12	122	255	17,8	28,2
Lamellibranchiata	3	2	27	15	0,6	0,3
Ostracoda	3	–	12	–	0,3	–

Table 4. Zooplankton composition at station C during the investigations
Tab. 4. Skład zooplanktonu na stanowisku C w okresie badań

Taxonomic units Jednostki taksonomiczne	Frequency at station Frekwencja na stanowisku — Number of samples Liczba prób		Average numbers in 1000 ind./m³ Średnia liczebność w tys. osobn./m³		Percentage Udział procentowy	
	21	21				
	1977	1978	1977	1978	1977	1978
1	2	3	4	5	6	7
Ascomorpha saltans Bartsch	–	1	–	7	–	0,1
Asplanchna priodonta Gosse	5	2	8	17	0,3	0,2
Brachionus angularis Gosse	13	12	84	204	7,5	11,6
Brachionus calyciflorus Pallas	6	3	86	48	3,5	0,7
Brachionus calyciflorus amphiceros Ehrenberg	10	9	42	191	2,8	8,2
Brachionus diversicornis (Daday)	1	–	3	–	0,1	–
Brachionus quadridentatus Hermann	2	2	8	12	0,1	0,1
Brachionus rubens Ehrenberg	1	–	7	–	0,1	–
Brachionus urceolaris Müller	3	1	12	30	0,3	0,1
Colurella sp.	–	1	–	3	–	0,1
Euchlanis dilatata Ehrenberg	7	5	25	25	1,2	0,6
Filinia longiseta (Ehrenberg)	17	15	196	321	22,8	22,8
Keratella cochlerisa (Gosse)	17	16	31	152	3,6	11,6
Keratella cochlearis tecta (Gosse)	–	7	–	19	–	0,3
Keratella quadrata (Müller)	12	14	138	36	11,3	2,4
Notholca acuminata (Ehrenberg)	3	1	6	3	0,1	0,1
Notholca squamula (Müller)	–	1	–	10	–	0,1
Pedalia fennica (Levander)	6	6	57	21	2,8	0,6
Polyarthra vulgaris Carlin	5	7	8	22	0,3	0,7
Proales sp.	–	1	–	3	–	0,1
Rotatoria non determinata	3	2	4	3	0,1	0,1
Synchaeta litoralis Russelet	21	16	165	183	13,1	10,9
Synchaeta pectinata Ehrenberg	–	1	–	43	–	0,2
Testudinella patina (Hermann)	–	1	–	3	–	0,1
Trichocerca pusilla (Lauterborn)	3	4	11	22	0,2	0,4
Bosmina coregoni maritima (Müller)	–	1	–	7	–	0,1
Bosmina longirostris (Müller)	9	6	24	18	1,5	0,5
Diaphanosoma brachyurum (Lievin)	2	3	7	22	0,1	0,3
Evadne nordmanni, Loven	–	2	–	10	–	0,1
Sida cristallina (Müller)	–	2	–	15	–	0,1
Acartia bifilosa (Giesbrecht)	–	2	–	22	–	0,2
cop. *A. bifilosa*	1	–	3	–	0,1	–
Acartia tonsa (Dnaa)	5	4	7	17	0,3	0,3
cop. *A. tonsa*	4	5	13	8	0,3	0,2
Centropages hamatus (Lilljeborg)	–	1	–	7	–	0,1
Eurytemora affinis (Poppe)	14	9	21	37	2,0	1,6
cop. *E. affinis*	20	20	57	33	7,8	3,2

Table 4 – continued

1	2	3	4	5	6	7
Harpacticoida	5	10	13	12	0,4	0,6
Mesocyclops leuckarti (Claus)	1	2	7	3	0,1	0,1
cop. *M. leuckarti*	–	1	–	3	–	0,1
cop. *Cyclops sp.*	6	5	7	13	0,3	0,3
nauplii	21	21	117	205	16,7	20,5
Temora longicornis (Müller)	–	1	–	3	–	0,1
Balanus improvisus	–	1	–	10	–	0,1
Hydracarina	–	1	–	3	–	0,1
Lamellibranchiata	4	3	17	17	0,5	0,2
Ostracoda	1	–	10	–	0,1	–
Polychaeta	–	1	–	7	–	0,1

The small numbers of crustaceans such as *Evadne nordmani* Loven, *Centropages hamatus* (Lilljeborg), *Pseudocalanus elongatus* Boeck, *Temora longiformis* (Müller) found at the stations of the Vistula Lagoon in 1978, is related in the first place to differences in the level of salinity of 1—5‰ noted in a vertical profile during salinity stratification in February [21].

Nauplia stages of *Copepoda* showed a high level of frequency and numbers at all the stations (Tables 2 to 10). The highest level at particular stations was, however, recorded for the following rotifer species: *Filinia longiseta, Keratella cochlearis, Keratella quadrata, Brachionus angularis, Brachionus calyciflorus, Brachionus calyciflorus amphiceros, Synchaeta litoralis* and *Synchaeta baltica*. As to crustaceans, mention should be made of *Eurytemora affinis* and *Acartia tonsa* together with young copepodit stages which were more numerous than adult forms. Of the cladocerans *Bosmina longirostris* and *Diaphanosoma brachyurum* were found to occur. Likewise, larvae of *Lamellibranchiata* were numerous. Since the species mentioned, which occurred in large numbers, were also frequently found in the samples, they can be considered to predominate at particular stations (Tables 2—10).

Interesting results were obtained by comparing average numbers of zooplankton organisms at the 9 permanent stations during these investigations (Table 11 and Fig. 2).

The highest values were obtained for station F in 1977 and for stations C, E in 1978. Comparison and interpretation of zooplankton numbers for the period of investigation does not indicate any regularity. As can be seen, the highest density of zooplankton during the first year of these investigations was noted at station F located in mid-part of the lagoon, while in the second year similar numbers were observed at two shoreline stations C, E (Table 11, Fig. 2). As compared with 1977 considerably higher numbers of dominant species were noted at these stations.

Table 5. Zooplankton composition at station D during the investigations
Tab. 5. Skład zooplanktonu na stanowisku D w okresie badań

Taxonomic units Jednostki taksonomiczne	Frequency at station Frekwencja na stanowisku Number of samples Liczba prób		Average numbers in 1000 ind./m³ Średnia liczebność w tys. osobn./m³		Percentage Udział procentowy	
	21	27				
	1977	1978	1977	1978	1977	1978
Asplanchna priodonta Gosse	2	7	3	10	0,1	0,3
Brachionus angularis Gosse	14	9	150	131	10,1	5,4
Brachionus calyciflorus Pallas	6	4	93	32	2,7	0,6
Brachionus calyciflorus amphiceros Ehrenberg	9	5	190	106	8,2	4,4
Brachionus diversicornis (Daday)	3	–	8	–	0,1	–
Brachionus quadridentatus Hermann	2	2	13	15	0,1	0,1
Brachionus urceolaris Müller	6	1	33	3	1,0	0,1
Euchlanis dilatata Ehrenberg	5	7	19	61	0,5	2,0
Filinia longiseta (Ehrenberg)	16	14	98	311	7,6	20,0
Keratella cochlearis (Gosse)	17	18	31	102	2,6	8,5
Keratella cochlearis tecta (Gosse)	2	8	7	8	0,1	0,3
Keratella quadrata (Müller)	14	17	231	29	15,6	2,3
Notholca acuminata (Ehrenberg)	2	2	10	8	0,1	0,1
Pedalia fennica (Levander)	6	11	549	23	13,3	1,2
Polyarthra vulgaris Carlin	5	2	5	8	0,1	0,1
Rotatoria non determinata	3	2	6	3	0,1	0,1
Synchaeta baltica Ehrenberg	11	13	9	288	0,5	17,3
Synchaeta litoralis Russelet	8	2	209	35	8,1	0,3
Synchaeta monopus Plate	1	–	7	–	0,1	–
Synchaeta pectinata Ehrenberg	2	3	5	28	0,1	0,4
Synchaeta stylata Wierzejski	–	2	–	5	–	0,1
Trichocerca pusilla (Lauterborn)	4	3	15	24	0,3	0,3
Trichocerca sp.	–	1	–	3	–	0,1
Bosmina longirostris (Müller)	7	3	35	4	1,2	0,1
Diaphanosoma brachyurum (Lievin)	3	4	8	17	0,1	0,3
Evadne nordmanni, Loven	–	3	–	24	–	0,3
Podon polyphemoides (Leuckart)	–	5	–	9	–	0,1
Acartia bifilosa (Giesbrecht)	–	2	–	82	–	0,8
cop. *A. bifilosa*	–	3	–	3	–	0,1
Acartia longiremis Lilljeborg	–	1	–	7	–	0,1
Acartia tonsa (Dana)	10	5	10	25	0,5	0,6
cop. *A. tonsa*	10	9	17	14	0,8	0,6
Centropages hamatus (Lilljeborg)	–	2	–	10	–	0,1
Eurytemora affinis (Poppe)	13	16	14	30	0,9	2,2
cop. *E. affinis*	21	23	58	72	6,2	7,6
Harpacticoida	7	11	5	19	0,2	1,0
Mesocyclops leuckarti (Claus)	–	3	–	22	–	0,3
cop. *M. leuckarti*	–	1	–	3	–	0,1
cop. *Cyclops sp.*	6	2	8	8	0,2	0,1
nauplii	21	27	166	176	17,6	21,8
Temora longicornis (Müller)	–	3	–	7	–	0,1
Hydracarina	–	1	–	3	–	0,1
Lamellibranchiata	3	–	70	–	1,0	–
Ostracoda	3	–	14	–	0,2	–
Polyacheta	–	1	–	7	–	0,1

Table 6. Zooplankton composition at station E during the investigations
Tab. 6. Skład zooplantonu na stanowisku E w okresie badań

Taxonomic units Jednostki taksonomiczne	Frequency at station Frekwencja na stanowisku Number of samples Liczba prób		Average numbers in 1000 ind./m³ Średnia liczebność w tys. osobn./m³		Percentage Udział procentowy	
	19	15				
	1977	1978	1977	1978	1977	1978
Asplanchna priodonta Gosse	3	3	7	10	0,2	0,2
Brachionus angularis Gosse	11	9	211	196	18,2	[b]10,6
Brachionus calyciflorus Pallas	5	4	76	53	3,0	1,3
Brachionus calyciflorus amphiceros Ehrenberg	6	6	42	89	2,0	3,2
Brachionus diversicornis (Daday)	2	–	17	–	0,3	–
Brachionus quadridentatus Hermann	2	3	10	12	0,2	0,2
Brachionus urceolaris Müller	4	–	10	–	0,3	–
Euchlanis dilatata Ehrenberg	1	4	3	23	0,1	0,6
Filinia longiseta (Ehrenberg)	18	12	73	319	10,3	22,9
Keratella cochleris (Gosse)	13	11	65	150	6,7	9,9
Keratella cochlearis tecta (Gosse)	4	5	4	18	0,1	0,5
Keratella cruciformis (Thompson)	2	–	7	–	0,1	–
Keratella quadrata (Müller)	12	4	57	9	5,4	0,2
Notholca acuminata (Ehrenberg)	2	–	5	–	0,1	–
Notholca squamula (Müller)	1	–	7	–	0,1	–
Pedalia fennica (Levander)	5		114	–	4,5	–
Polyarthra vulgaris Carlin	3	–	3	–	0,1	–
Rotatoria non determinata	1	4	10	3	0,1	0,1
Synchaeta baltica Ehrenberg	13	8	25	91	2,5	4,4
Synchaeta litoralis Russelet	5	–	115	–	4,5	–
Trochocerca pusilla (Lauterborn)	4	2	6	20	0,2	0,2
Trichocerca sp.	–	2	–	10	–	0,1
Bosmina coregoni maritima (Müller)	5	–	9	–	0,4	–
Bosmina longirostris (Müller)	3	4	9	8	0,2	0,2
Diaphanosoma brachyurum (Lievin)	5	6	11	18	0,4	0,6
Acartia tonsa (Dana)	4	2	12	18	0,4	0,2
cop. *A. tonsa*	3	4	11	28	0,3	0,7
Eurytemora affinis (Poppe)	16	8	16	182	2,0	9,0
cop. *E. affinis*	17	15	69	189	9,2	17,0
Harpacticoida	4	3	9	10	0,3	0,2
Mesocyclops leuckarti (Claus)	3	3	11	16	0,3	0,3
cop. *Cyclops sp.*	3	1	12	10	0,3	0,1
nauplii	19	15	122	194	18,2	17,4
Temora longicornis (Müller)	1	–	3	–	0,1	–
Lamellibranchiata	5	–	237	–	9,3	–
Ostracoda	3	–	10	–	0,2	–

Table 7. Zooplankton composition at station F during the investigations

Tab. 7. Skład zooplanktonu na stanowisku F w okresie badań

Taxonomic units Jednostki taksonomiczne	Frequency at station Frekwencja na stanowisku Number of samples Liczba prób		Average numbers in 1000 ind./m³ Średnia liczebność w tys. osobn./m³		Percentage Udział procentowy	
	22	30				
	1977	1978	1977	1978	1977	1978
Asplanchna priodonta Gosse	2	–	10	–	0,1	–
Brachionus angularis Gosse	9	8	136	158	5,5	6,1
Brachionus calyciflorus Pallas	4	4	92	11	1,7	0,2
Brachionus calyciflorus amphiceros Ehrenberg	7	8	120	49	3,8	1,9
Brachionus quadridentatus Hermann	6	3	23	17	0,6	0,2
Brachionus urceolaris Müller	5	–	28	–	0,6	–
Echlanis dilatata Ehrenberg	–	6	–	14	–	0,4
Filinia longiseta (Ehrenberg)	11	13	212	352	10,5	22,0
Keratella cochlearis (Gosse)	14	18	171	177	10,8	15,4
Keratella cochlearis tecta (Gosse)	–	3	–	8	–	0,1
Keratella cruciformis (Thompson)	3	1	4	7	0,1	0,1
Keratella quadrata (Müller)	13	18	274	40	16,1	3,5
Notholca acuminata (Ehrenberg)	2	–	5	–	0,1	–
Pedalia fennica (Levander)	6	8	824	66	22,3	2,5
Polyarthra vulgaris Carlin	3	1	6	3	0,1	0,1
Rotatoria non determinata	1	2	3	3	0,1	0,1
Synchaeta baltica Ehrenberg	10	17	9	176	0,4	14,4
Synchaeta litoralis Russelet	4	–	378	–	6,8	–
Trichocerca pusilla (Lauterborn)	6	4	17	11	0,5	0,2
Trichocerca sp.	–	1	–	10	–	0,1
Bosmina coregoni maritima (Müller)	3	2	41	7	0,6	0,1
Bosmina longirostris (Müller)	3	–	8	–	0,1	–
Diaphanosoma brachyurum (Lievin)	–	5	–	11	–	0,3
Evadne nordmanni Loven	–	4	–	7	–	0,1
Sida cristallina (Müller)	–	1	–	7	–	0,1
Acartia bifilosa (Giesbrecht)	2	8	7	6	0,1	0,2
cop. *A. bifilosa*	–	2	–	10	–	0,1
Acartia longiremis Lilljeborg	–	2	–	5	–	0,1
cop. *A. longiremis*	–	3	–	6	–	0,1
Acartia tonsa (Dana)	9	6	17	14	0,7	0,4
cop. *A. tonsa*	13	11	26	25	1,5	1,3
cop. *Cyclops sp.*	1	1	3	40	0,1	0,2
Eurytemora affinis (Poppe)	8	15	20	35	0,7	2,5
cop. *E. affinis*	20	24	60	50	5,4	5,8
Harpacticoida	4	14	23	14	0,4	1,0
nauplii	18	30	124	140	10,0	20,2
Pseudocalanus elongatus Boeck	–	1	–	7	–	0,1
cop. *P. elongatus*	–	1	–	3	–	0,1
Balanus improvisus	4	7	5	11	0,1	0,4
Ostracoda	1	–	7	–	0,1	–
Polychaeta	3	2	3	5	0,1	0,1

Table 8. Zooplankton composition at station G during the investigations
Tab. 8. Skład zooplanktonu na stanowisku G w okresie badań

Taxonomic units Jednostki taksonomiczne	Frequency at station Frekwencja na stanowisku Number of samples Liczba prób		Average numbers in 1000 ind./m³ Średnia liczebność w tys. osobn./m³		Percentage Udział procentowy	
	20	21				
	1977	1978	1977	1978	1977	1978
Asplanchna priodonta Gosse	5	2	5	3	0,1	0,1
Brachionus angularis Gosse	7	8	91	52	4,0	2,6
Brachionus calyciflorus Pallas	3	1	11	3	0,2	0,1
Brachionus calyciflorus amphiceros Ehrenberg	7	9	249	105	10,9	5,8
Brachionus quadridentatus Hermann	3	3	112	26	2,1	0,5
Brachionus urceolaris Müller	4	2	68	12	1,7	0,1
Euchlanis dilatata Ehrenberg	5	5	10	29	0,3	0,9
Filinia longiseta (Ehrenberg)	13	13	264	276	21,5	22,1
Keratella cochlearis (Gosse)	17	19	54	156	5,7	18,3
Keratella cochlearis tecta (Gosse)	–	5	–	17	–	0,5
Keratella cruciformis (Thompson)	4	3	7	11	0,2	0,2
Keratella quadrata (Müller)	16	12	133	44	13,3	3,3
Notholca acuminata (Ehrenberg)	3	–	4	–	0,1	–
Notholca squamula (Müller)	–	1	–	7	–	0,1
Notholca striata (Müller)	2	–	5	–	0,1	–
Pedalia fennica (Levander)	3	3	371	187	7,0	3,4
Polyarthra vulgaris Carlin	2	1	3	10	0,1	0,1
Rotatoria non determinata	1	5	7	5	0,1	0,1
Synchaeta baltica Ehrenberg	8	5	22	29	1,1	0,9
Synchaeta litoralis Russelet	3	–	476	–	8,9	–
Synchaeta oblonga Ehrenberg	2	–	5	–	0,1	–
Trichocerca pusilla (Lauterborn)	4	3	13	9	0,3	0,2
Bosmina coregoni maritima (Müller)	–	1	–	7	–	0,1
Bosmina longirostris (Müller)	–	3	–	11	–	0,2
Diaphanosoma brachyurum (Lievin)	4	2	4	15	0,1	0,2
Evadne nordmanni Loven	–	1	–	7	–	0,1
Acartia tonsa (Dana)	3	6	8	24	0,1	0,9
cop. *A. tonsa*	10	12	26	36	1,6	2,7
Centropages hamatus (Lilljeborg)	–	1	–	3	–	0,1
Eurytemora affinis (Poppe)	5	5	8	37	0,3	1,1
cop. *E. affinis*	18	18	53	40	6,0	4,4
Harpacticoida	8	7	17	8	0,8	0,3
nauplii	20	21	95	233	11,9	30,1
Balanus improvisus	3	5	4	13	0,1	0,4
Gastropoda	–	1	–	10	–	0,1
Lamellibranchiata	–	2	–	7	–	0,1
Ostracoda	2	–	122	–	1,5	–
Polychaeta	1	1	3	10	0,1	0,1
Ritropanopeus harrisi	–	3	–	17	–	0,3

Table 9. Zooplankton composition at station H during the investigations
Tab. 9. Skład zooplanktonu na stanowisku H w okresie badań

Taxonomic units Jednostki taksonomiczne	Frequency at station Frekwencja na stanowisku Number of samples Liczba prób		Average numbers in 1000 ind./m³ Średnia liczebność w tys. osobn./m³		Percentage Udział procentowy	
	21	25				
	1977	1978	1977	1978	1977	1978
Asplanchna priodonta Gosse	4	5	3	11	0,1	0,2
Brachionus angularis Gosse	9	8	93	92	4,3	4,1
Brachionus calyciflorus Pallas	4	1	27	7	0,6	0,1
Brachionus calyciflorus amphiceros Ehrenberg	7	10	352	105	12,8	4,5
Brachionus diversicornis (Daday)	–	1	–	3	–	0,1
Brachionus quadridentatus Hermann	3	9	114	31	1,8	1,2
Brachionus urceolaris Müller	3	3	79	12	1,2	0,2
Euchlanis dilatata Ehrenberg	1	4	3	122	0,1	2,1
Filinia longiseta (Ehrenberg)	13	15	449	276	33,2	17,8
Keratella cochlearis (Gosse)	16	9	65	237	5,4	19,3
Keratella cochlearis tecta (Gosse)	4	3	3	26	0,1	0,3
Keratella cruciformis (Thompson)	4	4	4	18	0,1	0,3
Keratella quadrata (Müller)	17	17	111	70	9,7	5,1
Notholca acuminata (Ehrenberg)	–	1	–	10	–	0,1
Notholca squamula (Müller)	–	1	–	3	–	0,1
Notholca striata (Müller)	3	1	3	7	0,1	0,1
Pedalia fennica (Levander)	8	4	176	143	7,3	2,5
Rotatoria non determinata	3	1	4	7	0,1	0,1
Synchaeta baltica Ehrenberg	10	14	16	196	0,8	11,8
Synchaeta litoralis Russelet	4	–	158	–	3,3	–
Synchaeta monopus Plate	2	–	7	–	0,1	–
Bosmina longirostris (Müller)	3	–	9	–	0,1	–
Diaphanosoma brachyurum (Lievin)	4	4	3	15	0,1	0,3
Evadne nordmanni Loven	–	5	–	12	–	0,3
Podon polyphemoides (Leuckart)	–	4	–	12	–	0,2
Sida cristallina (Müller)	–	2	–	5	–	0,1
Acartia bifilosa (Giesbrecht)	1	4	3	8	0,1	0,1
cop. *A. bifilosa*	–	1	–	3	–	0,1
Acartia longiremis Lilljeborg	–	1	–	7	–	0,1
Acartia tonsa (Dana)	8	3	13	82	0,5	1,1
cop. *A. tonsa*	13	14	16	56	1,1	3,4
Centropages hamatus (Lilljeborg)	–	2	–	3	–	0,1
Eurytemora affinis (Poppe)	12	8	10	17	0,6	0,6
cop. *E. affinis*	20	21	38	50	3,9	4,5
Harpacticoida	6	6	6	15	0,2	0,4
nauplii	21	25	126	177	13,7	19,0
Temora longicornis (Müller)	–	1	–	3	–	0,1
Balanus improvisus	9	7	4	10	0,2	0,3
Hydracarina	–	3	–	3	–	0,1
Lamellibranchiata	–	2	–	8	–	0,1
Ostracoda	3	–	94	–	1,5	–
Polychaeta	1	1	7	3	0,1	0,1
Ritropanopeus harrisi	3	1	3	13	0,1	0,1

Table 10. Zooplankton composition at station I during the investigations
Tab. 10. Skład zooplanktonu na stanowisku I w okresie badań

Taxonomic units Jednostki taksonomiczne	Frequency at station Frekwencja na stanowisku Number of samples Liczba prób		Average numbers in 1000 ind./m³ Średnia liczebność w tys. osobn./m³		Percentage Udział procentowy	
	20	21				
	1977	1978	1977	1978	1977	1978
Asplanchna priodonta Gosse	3	2	4	18	0,1	0,2
Brachionus angularis Gosse	9	8	17	85	1,1	4,2
Brachionus calyciflorus Pallas	5	2	43	18	1,6	0,2
Brachionus calyciflorus amphiceros Ehrenberg	6	8	64	86	2,8	4,3
Brachionus quadridentatus Hermann	2	4	100	17	1,5	0,4
Brachionus urceolaris Müller	2	3	62	11	0,9	0,2
Euchlanis dilatata Ehrenberg	–	6	–	17	–	0,6
Filinia longiseta (Ehrenberg)	12	14	217	195	19,1	16,9
Keratella cochlearis (Gosse)	11	20	170	198	13,7	24,6
Keratella cochlearis tecta (Gosse)	4	3	3	13	0,1	0,2
Keratella cruciformis (Thompson)	6	3	6	7	0,2	0,1
Keratella quadrata (Müller)	11	11	89	42	7,2	2,8
Notholca squamula (Müller)	–	3	–	7	–	0,1
Pedalia fennica (Levander)	7	3	170	143	8,7	2,7
Polyarthra vulgaris Carlin	–	1	–	10	–	0,1
Rotatoria non determinata	–	3	–	4	–	0,1
Synchaeta baltica Ehrenberg	17	8	19	51	2,4	2,5
Synchaeta litoralis Russelet	3	–	111	–	2,4	–
Synchaeta monopus Plate	1	–	3	–	0,1	–
Bosmina coregoni maritima (Müller)	1	–	3	–	0,1	–
Bosmina longirostris (Müller)	1	–	3	–	0,1	–
Diaphanosoma brachyurum (Lievin)	4	4	4	18	0,1	0,4
Evadne nordmanni Loven	–	1	–	7	–	0,1
Leptodora kindti (Focke)	1	–	3	–	0,1	–
Podon polyphemoides (Leuckart)	–	1	–	7	–	0,1
Sida cristallina (Müller)	1	1	3	7	0,1	0,1
Acartia bifilosa (Giesbrecht)	3	1	7	3	0,1	0,1
Acartia tonsa (Dana)	–	6	–	14	–	0,5
cop. *A. tonsa*	3	9	13	40	0,3	2,2
Eurytemora affinis (Poppe)	15	12	42	14	4,7	1,1
cop. *E. affinis*	19	20	78	61	10,9	7,6
Harpacticoida	12	3	8	36	0,7	0,7
nauplii	20	21	134	198	19,7	25,8
Temora longicornis (Müller)	1	–	3	–	0,1	–
Balanus improvisus	4	6	5	16	0,1	0,6
Lamellibranchiata	–	2	–	13	–	0,2
Ostracoda	2	–	70	–	1,0	–
Polychaeta	2	3	5	9	0,1	0,2
Ritropanopeus harrisi	2	1	3	10	0,1	0,1

Table 11. Changes in zooplankton numbers at the Vistula Lagoon stations
Tab. 11. Zmiany liczebności zooplanktonu na stanowiskach Zalewu Wiślanego

Station Stanowisko	1977		1978	
	Number of samples Liczba prób	Average number of zooplankton Średnia liczebność zooplanktonu [in w 1000/m³]	Number of samples Liczba prób	Average number of zooplankton Średnia liczebność zooplanktonu [in w 1000/m³]
A	18	579	13	448
B	21	684	12	904
C	21	698	21	1003
D	21	987	27	805
E	19	677	15	1114
F	22	1008	30	693
G	20	799	21	774
H	21	921	25	932
I	20	682	21	768

Table 12. Range of fluctuations in zooplankton numbers of the Vistula Lagoon
Tab. 12. Zakres wahań liczebności zooplanktonu Zalewu Wiślanego

Station Stanowisko	1977				1978			
	Date Data	Minimum 1000 individ. Minimum 1000 osobn. per m³	Date Data	Maximum 1000 individ. Maksimum 1000 osobn. per m³	Date Data	Minimum 1000 individ. Minimum 1000 osobn. per m³	Date Data	Maximum 1000 individ. Maksimum 1000 osobn. per m³
A	9.11	116	2.6	1680	27.11	80	15.8	1370
B	9.11	89	20.5	2096	27.11	54	15.8	2146
C	9.11	172	20.5	1768	28.11	164	31.5	2145
D	5.10	209	20.5	3785	28.11	80	18.8	2216
E	6.10	271	1.7	2119	31.10	247	31.5	2708
F	6.10	46	21.5	3083	31.10	175	18.7	1726
G	6.10	75	2.7	2496	31.10	160	30.6	1775
H	6.10	142	2.7	3284	31.10	150	18.8	3083
I	6.10	131	2.7	1652	31.10	124	18.7	1893

The rotifers *Keratella cochlearis, Filinia longiseta* and *Brachionus calyciflorus amphiceros* occurred here numerously (Tables 4, 6). The higher numbers of zooplankton organisms at these stations might be symptomatic for the lability limit of waters α and β (mixo)oligohaline, as proved by ecological investigations carried out by Różańska [18].

Zooplankton numbers show a tendency to increase along the mid-part of the lagoon at stations A, D, H as the level of salinity increases. Similar dependencies were likewise obtained for phytoplankton numbers

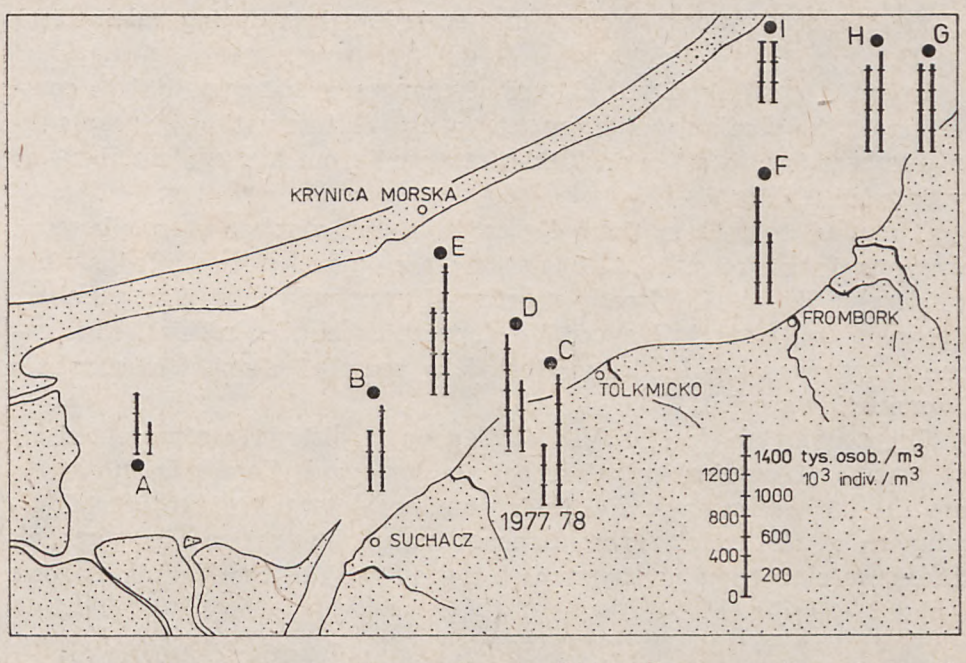

Fig. 2. Average zooplankton numbers at Vistula Lagoon stations during the period under investigation

Rys. 2. Średnia liczebność zooplanktonu na stanowiskach Zalewu Wiślanego w okresie badań

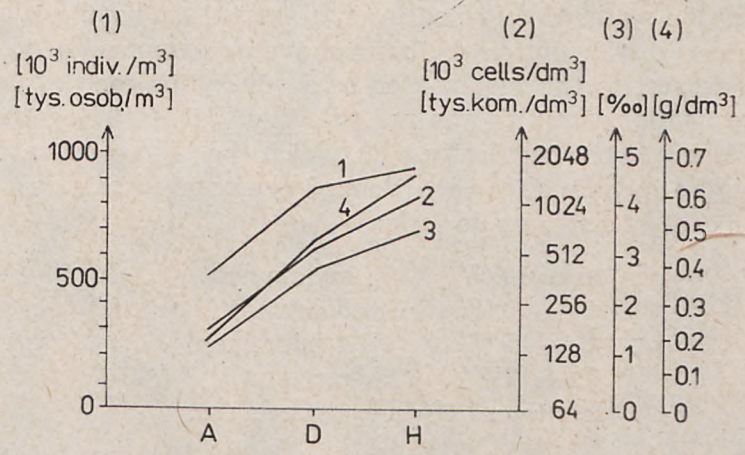

Fig. 3. Zooplankton numbers — *1* of the Vistula Lagoon as compared with phytoplankton numbers — *2* [according to Pliński, Simm], salinity — *3* and organic matter contents — *4* [according to Różański, Więcławski]

Rys. 3. Liczebność zooplanktonu — *1* Zalewu Wiślanego na tle liczebności fitoplanktonu — *2* [wg Plińskiego, Simma], zasolenia — *3* i zawartości materii organicznej — *4* [wg Różańskiej, Więcławskiego]

and for the conventional organic matter index (loss during calcination) (Fig. 3).

In order to obtain a full picture of changes in the quantitative composition at the particular stations, the range of fluctuation in zooplankton numbers is also given in Table 12, apart from average numbers as presented in Tables 2—11.

It can be seen from these figures that the number of zooplankton organisms found at particular stations and months fluctuated within considerable limits. As already mentioned previously, the high numbers of zooplankton were influenced by dominating rotifer species. Fluctuations in numbers are likewise effected by seasonal changes in numbers of dominating species.

The zooplankton of the Vistula Lagoon id distinctly represented by two groups of dominats, that is by *Rotatoria* and *Copepoda*. *Rotatoria* were the most numerous, and their numbers determined the special distribution of the zooplankton. Irrespective of fluctuations in numbers, rotifers were the dominant group at the stations in the Vistula Lagoon (Tables 2—10, Fig. 1).

3.2. DOMINANCE AND REGULARITY (STABILITY) IN THE OCCURRENCE OF ZOOPLANKTON

The problem of dominance constitutes an important factor determining the internal structure of a given complex. In view of the quantitative character of the material collected for the present study, the analysis of dominance was carried out on the basis of average numbers of taxonomic units with respect to the zooplankton as a whole, for each of the years under investigation. Results are presented in Table 13 together with results referring to the regularity with which the taxons occur. The position occupied by a species in a dominant-recedent series was determined by means of a five grade scale:

over 10.0%	eudominant,
5.1—10.0%	dominant,
2.1— 5.0%	subdominant,
1.0— 2.0%	recedent,
less than 1.0%	subrecedent.

This division enables the determining of a taxon with a substantial proportional share with respect to other forms at a station, or during the period of investigation.

Tables 2—10, presenting the grouping of zooplankton at particular stations, indicate differentiation of the environmental conditions in the Vistula Lagoon. Plankton organisms showed spatial differentiation. These

Table 13. Dominance and regularity of occurence of the Vistula Lagoon zooplankton during the period of investigations

Tab. 13. Dominacja i regularność występowania zooplanktonu Zalewu Wiślanego w okresie badań

Taxonomic units Jednostki taksonomiczne	Dominance [%] Dominacja		Regularity of occurrence at station Regularność występowania [%] na stanowiskach	
	1977	1978	1977	1978
1	2	3	4	5
Rotatoria				
Ascomorpha saltans Bartsch	0,1	0,5	11,1	33,3
Asplanchna priodonta Gosse	2,5	1,4	100,0	77,8
Brachionus angularis Gosse	5,1	4,6	100,0	100,0
Brachionus calyciflorus Pallas	2,3	1,7	100,0	88,0
Brachionus calyciflorus amphiceros Ehrenberg	3,6	3,7	100,0	100,0
Brachionus diversicornis (Daday)	0,7	0,1	44,0	11,0
Brachionus quadridentatus Hermann	1,2	1,4	88,9	88,0
Brachionus rubens Ehrenberg	0,1	0,1	11,1	11,1
Brachionus urceolaris Müller	1,7	1,0	66,7	66,7
Colurella sp.	–	0,2	–	11,1
Euchlanis dilatata Ehrenberg	1,5	2,4	77,8	88,9
Filinia longiseta (Ehrenberg)	7,1	6,3	100,0	100,0
Kellicottia longispina (Kellicott)	0,1	0,2	11,1	11,1
Keratella cochlearis (Gosse)	7,1	8,3	100,0	100,0
Keratella cochlearis tecta (Gosse)	1,0	2,4	100,0	88,9
Keratella cruciformis (Thompson)	0,9	0,7	55,6	55,6
Keratella quadrata (Müller)	6,1	5,5	100,0	100,0
Notholca acuminata (Ehrenberg)	1,0	0,3	77,8	44,4
Notholca squamula (Müller)	0,1	0,2	11,1	33,3
Notholca striata (Müller)	0,3	0,1	22,2	11,1
Pedalia fennica (Levander)	2,8	2,6	100,0	88,9
Polyarthra dolichoptera Idelson	0,3	0,2	22,2	11,1
Polyarthra vulgaris Carlin	1,7	1,2	77,8	66,7
Proales sp.	0,1	0,2	11,1	22,2
Synchaeta baltica Ehrenberg	4,1	5,5	100,0	100,0
Synchaeta litoralis Rousselet	3,3	0,5	100,0	100,0
Synchaeta monopus Plate	0,4	–	44,4	–
Synchaeta pectinata Ehrenberg	0,6	0,2	33,3	33,3
Synchaeta stylata Wierzejski	0,1	0,2	11,1	11,1
Synchaeta oblonga Ehrenberg	0,1	–	11,1	–
Testudinella patina (Hermann)	0,1	0,2	11,1	11 1
Trichocerca pusilla (Lauterborn)	1,7	1 4	88,9	33,3
Cladocera				
Bosmina coregoni maritima (Müller)	0,6	0,3	33,3	33,3
Bosmina longirostris (Müller)	2,2	1,0	88,9	66,7
Chydorus sphaericus (Müller)	0,1	0,1	22,2	11,1
Diaphanosoma brachyurum (Lievin)	1,9	1,9	88,9	100,0
Evadne nordmanni Loven	–	1,0	–	77,8
Leptodora kindti (Focke)	0,1	0,1	22,2	22,2

Table 13 — continued

1	2	3	4	5
Pleuroxus uncinatus Baird	0,1	0,2	11,1	11,1
Podon polyphemoides (Leuckart)	–	1,2	–	44,4
Sida cristallina (Müller)	0,1	0,2	11,1	44,4
Simocephalus vetulus (Müller)	–	0,3	–	11,1
Copepoda				
Acartia bifilosa (Giesbrecht)	0,1	1,0	33,3	66,7
cop. *A. bifilosa*	–	0,5	–	44,4
Acartia longiremis Lilljeborg	–	0,2	–	33,3
cop. *A. longiremis*	–	0,2	–	11,1
Acartia tonsa (Dana)	2,0	2,0	77,8	88,9
cop. *A. tonsa*	3,5	3,7	100,0	88,9
Centropages hamatus (Lilljeborg)	–	0,3	–	44,4
cop. *Cyclops sp.*	1,0	1,2	66,7	66,7
Eurytemora affinis (Poppe)	4,9	4,8	100,0	100,0
cop. *E. affinis*	8,2	8,5	100,0	100,0
Harpacticoida	2,2	2,6	88,9	88,9
Mesocyclops leuckarti (Claus)	0,3	0,5	44,4	44,4
cop. *M. leuckarti*	0,3	0,2	11,1	22,2
Pseudocalanus elongatus Boeck	–	0,2	–	11,1
cop. *P. elongatus*	–	0,2	–	11,1
Temora longicornis (Müller)	0,1	0,2	22,2	33,3
nauplii	8,7	10,7	100,0	100,0
Inne				
Balanus improvisus	0,9	1,0	55,6	66,7
Ritropanopeus harrisi	0,3	0,2	33,3	33,3
Hydracarina	–	0,2	–	11,1
Lamellibranchiata	1,3	0,5	66,7	66,7
Ostracoda	1,2	–	44,4	–
Polychaeta	0,6	0,9	88,9	66,7

changes are of a directional character. Thus, for example, typical brackish water forms such as *Pedalia fennica, Keratella cruciformis* occurred in greater numbers at sites with a higher level of salinity.

The results obtained show that zooplankton species characterized by a high level of frequency and by high numbers are also dominants at stations in the Vistula Lagoon (Tables 2—10, 13).

The regularity with which taxons occur at all of the stations was calculated on the basis of numbers and frequency by applying the following Radwan formula [14]:

$$C = \frac{100 \cdot Sa}{S}$$

where: C — consistency (expressed in %),
Sa — number of stations at which the species of from occurred,
S — total number of stations.

The results obtained are presented in Table 13 and served as a ba-

sis for defining the regularity of occurrence of taxons in the Vistula Lagoon. In this respect, four categories were established:

1. Very permanent taxonomic units present at 61% to 100% of the stations investigated. This group was made up of 27 species and forms of zooplankton in 1977 and 28 in 1978, all in very large numbers.

2. Permanent taxonomic units, the presence of which ranged from 41% to 60% at particular stations. In 1977 there were 6 taxons in this group, in 1978 — 7.

3. Additional taxonomic units, the presence of which ranged from 21% to 41% of the stations investigated. This group consisted of 10 taxons in 1977, and 7 in 1978.

4. Incidental taxonomic units, the presence of which did not exceed 20% of the stations under investigation. This group consisted of 10 species and forms in 1977, and 12 taxons in 1978.

The frequent occurrence of a high number of common taxons in considerable numbers, as against only a small number of rare forms, may constitute evidence that disturbance of the natural biocenosis of the water body has taken place. Certain rotifer species, characterized by large numbers in the Vistula Lagoon, are considered by Scandinavian authors [6, 7, 8, 9] to constitute a good index of eutrophication. According to these authors th e following rotifer species were the most frequently noted indices of the eutrophication of Swedish and Finnish waters: *Filinia longiseta, Keratella cochlearis, Brachionus angularis, Branchionus calyciflorus* and *Branchionus calyciflorus amphiceros.*

3.3. AN ATTEMPT TO DETERMINE SIMILARITY OF THE VISTULA LAGOON STATIONS ON THE BASIS OF ZOOPLANKTON NUMBERS

Numbers and species composition of zooplankton at particular stations of the Vistula Lagoon showed certain differences, thereby enabling an attempt to be made to define the similarity between stations investigated. Material for such a similarity analysis consisted of the number of zooplankton organisms per m^3 at specific stations in 1978.

The degree of similarity for nine stations was determined by means of the Marczewski and Steinhaus formula, as given by Romaniszyn [15]. This formula enables the determination of the degree of differentiation:

$$S = \frac{w}{a+b+w} 100\%$$

where: S — similarity of two stations compared (expressed in %),
a — number of individuals at one station,
b — number of individuals at the second station,
w — number of individuals jointly for the stations compared.

Tabl. 14. Similarity of Vistula Lagoon stations as compared with zooplankton numbers (Czekanowski's table)

Tab. 14. Podobieństwo stanowisk Zalewu Wiślanego na tle liczebności zooplanktonu (tablica Czekanowskiego)

	A	B	C	D	E	F	G	H	I
A	100,00	35,09	42,00	36,95	32,84	39,11	23,74	25,60	30,22
B	35,09	100,00	57,14	51,94	58,95	56,04	53,85	39,60	50,28
C	42,00	57,14	100,00	61,95	59,19	60,48	54,17	46,18	51,16
D	36,95	51,94	61,95	100,00	52,40	56,87	45,98	50,57	48,37
E	32,84	58,95	59,19	52,40	100,00	55,34	48,36	41,03	48,08
F	39,11	56,04	60,48	56,87	55,34	100,00	55,21	53,56	56,76
G	23,74	53,85	54,17	45,98	48,36	55,21	100,00	55,13	70,24
H	25.60	39,60	46,18	50,57	41,03	53,56	55,13	100,00	58,48
I	30,22	50,28	51,16	48,37	48,08	56,76	70,24	58,48	100,00

In accordance with this formula similarity corresponds to the following distance:

$$r=\frac{a+b-2w}{a+b-w}100\%$$

Similarity coefficients calculated as above were listed in an unordered Czekanowski table (Table 14) and presented in the form of a histogram (Fig. 4) giving similarity of stations based on zooplankton numbers.

A branched dentrite (Fig. 5) was constructed by means of a method given by Romaniszyn [15]. Positional concentrations [15] were obtained by assuming the criterion of natural division of dentrites into concentrations and calculating the quotients of the distances of the neighbouring segments. Distance quotients of the neighbouring segments listed in diminishing order were found to be as following:

58.00	
46.15	1.256
44.87	**1.028**
43.24	1.037
43.13	**1.002**
41.05	**1.050**
39.52	**1.038**
29.76	1.327

The dentrite for the stations investigated thus breaks down by nature into 8 concentrations, though division into 7, 6 or 4 concentrations is likewise possible (Fig. 6).

A diagram of similarity of stations in which the scale of similarity has been expressed in distances was constructed after the linear arrangement of the branched dendrite (Fig. 7). The similarity diagram shows

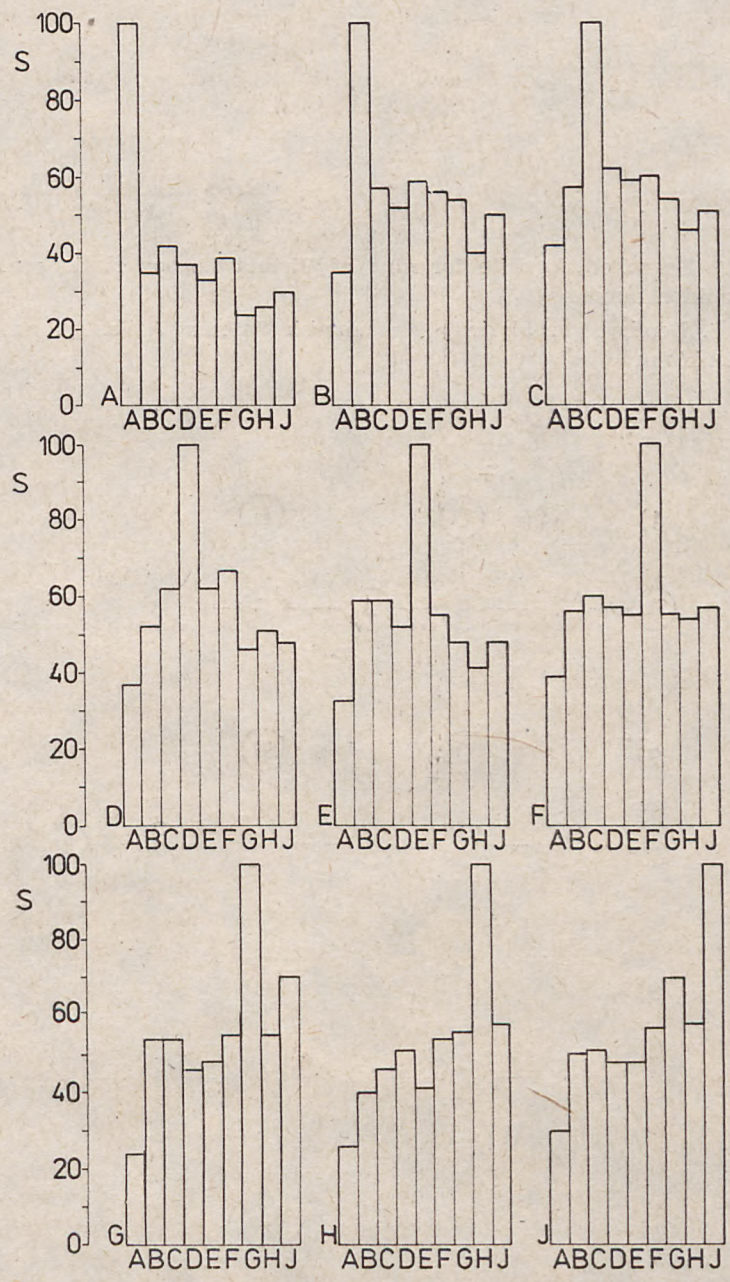

Fig. 4. Similarity histogram of zooplankton numbers for Vistula Lagoon stations (expressed in percentage on the basis of the Marczewski and Steinhaus formula)

Rys. 4. Histogram podobieństwa liczebności zooplanktonu stanowisk Zalewu Wiślanego (podobieństwo wyrażone w odsetkach opierając się na wzorze Marczewskiego i Steinhausa)

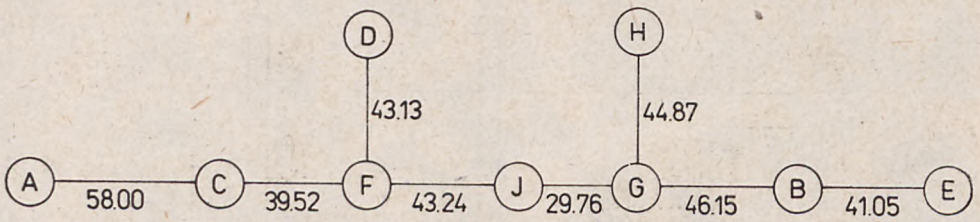

Fig. 5. Branched dendrite for nine of Vistula Lagoon stations as compared with zooplankton numbers

Rys. 5. Dendryt rozgałęziony 9 stanowisk Zalewu Wiślanego na tle liczebności zooplanktonu

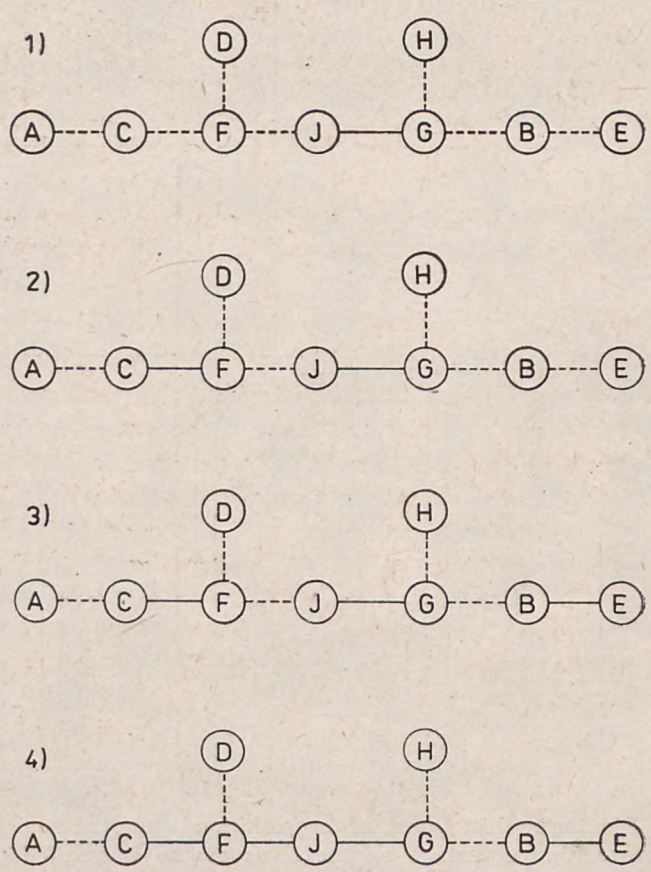

Fig. 6. Natural division of dendrite for concentrations at stations 8, 7, 6 and 4 of the Vistula Lagoon; numbers 1) - 4) used to define concentrations of the above

Rys. 6. Podział naturalny dendrytu stanowisk Zalewu Wiślanego na 8, 7, 6 i 4 skupienia; 1) - 4) — kolejność tych skupień

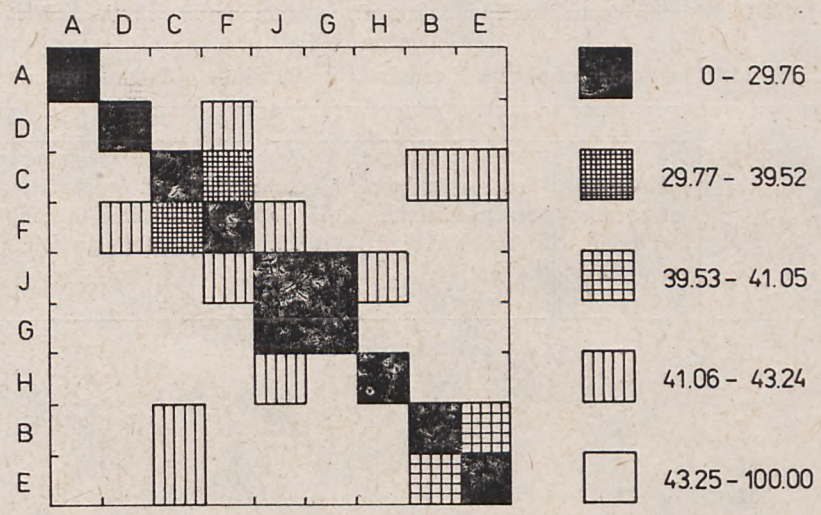

Fig. 7. Similarity diagram for nine of the Vistula Lagoon stations as compared with zooplankton numbers (similarity scale expressed in lengths)

Rys. 7. Diagram podobieństw 9 stanowisk Zalewu Wiślanego na tle liczebności zooplanktonu (skala podobieństwa jest wyrażona w odległościach)

distinctly maintained weak and strong division, and also emphasises the order of concentrations. Regularity of the linear order of stations in the succession A — D — C — F — I — G — H — B — E is confirmed by the distribution of black fields along the basic diagonal.

Stations A, D, H show a characteristic arrangement along the basic diagonal, and form separate concentrations. Previously discussed zooplankton numbers show a tendency to increase at stations mentioned, along the central line of the lagoon, as salinity increases. It can be concluded from the diagram that stations I, G indicated a concentrating tendency as compared with the number of zooplankton organisms, with a similarity of over 70%. These stations are also similar as concerns hydrological conditions. Station A, which is a fresh-water station and differs from the remaining ones in the Vistula Lagoon with respect to its hydrological character, differs basically both in histograms (Fig. 4) and the diagram (Fig. 7).

3.4. SEASONAL CHANGES IN NUMBERS OF ZOOPLANKTON ORGANISMS

Observations on seasonal changes in zooplankton numbers in the Vistula Lagoon refer to the vegetation period from May to November 1977, and from February to November 1978. Table 15 presents numbers of zooplankton organisms for particular months of the period under investigation. Monthly fluctuations show similarities for both of the

Table 15. Monthly fluctuations in numbers of zooplankton organisms in the Vistula Lagoon

Tab. 15. Fluktuacje miesięczne liczebności zooplanktonu Zalewu Wiślanego

Month Miesiąc	1977		1978	
	Number of samples Liczba prób	Average number of zooplankton Średnia liczebność zooplanktonu $\left[\frac{in}{w}\ 1000/m^3\right]$	Number of samples Liczba prób	Average number of zooplankton Średnia liczebność zooplanktonu $\left[\frac{in}{w}\ 1000/m^3\right]$
II	–	–	11	732
III	–	–	9	434
IV	–	–	19	773
V	27	1668	24	1144
VI	26	824	22	1031
VII	24	1629	26	934
VIII	30	604	27	1405
IX	26	328	15	485
X	29	223	18	248
XI	12	257	14	139

above mentioned years. Intensified zooplankton development takes place in May and during one of the summer months (Fig. 8). During the two years under discussion a decline in the numbers of zooplankton organisms was noted in June 1977 and in July 1978. Both these months showed a lower than normal water temperature, which might have been the cause of the drop in numbers [21]. As already mentioned, domination by rotifers with intensified development taking place during the summer season is typical of the zooplankton of the Vistula Lagoon.

In evaluating seasonal changes occurring in zooplankton numbers, attention was paid to mutual quantitative changes and to quantitative changes in dominating species. Table 16 presents the results of the average numbers of the main zooplankton components in particular months.

When analysing zooplankton species occurring in large numbers it was found that their reproductive capacity exerted the greatest influence on the zooplankton as a whole. Natural fluctuations in zooplankton populations due to specific factors and a detailed analysis of the latter, is extremely difficult. Several general characteristics of the succession of plankton organisms in the Vistula Lagoon can be set out on the basis of earlier qualitative studies [1, 2, 16, 17, 18] and the present data.

The first forms to make their appearance in cold-water are stenothermal and eurythermal species. *Synchaeta* baltica and *Synchaeta sp.* occur in large numbers in February. The number of these forms obser-

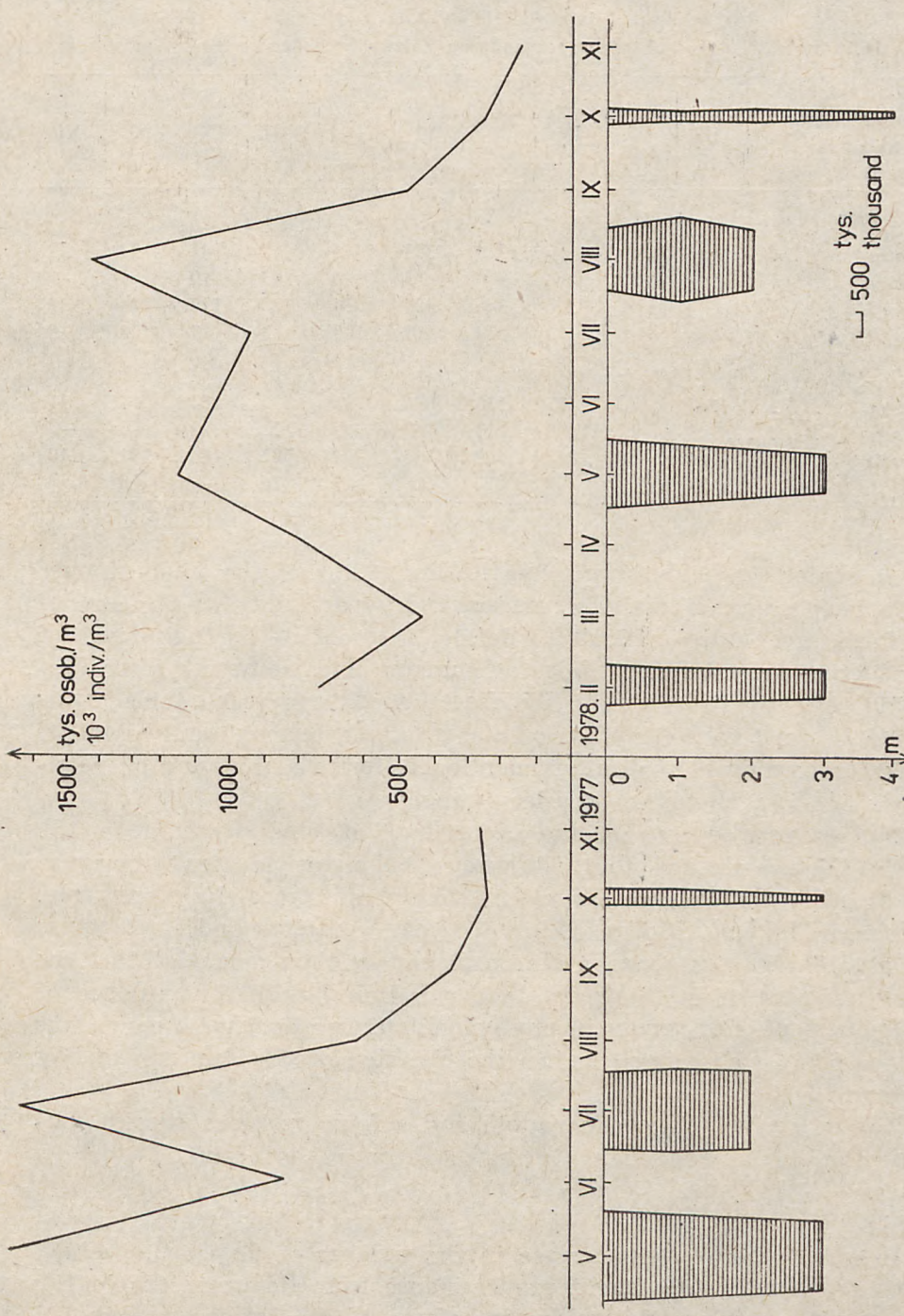

Fig. 8. Seasonal distribution of zooplankton numbers in the Vistula Lagoon
Rys. 8. Sezonowe rozmieszczenie liczebności zooplanktonu Zalewu Wiślanego

Table 16. Numbers of principal zooplankton groups in the Vistula Lagoon during the period of investigations

Tab. 16. Liczebność głównych grup zooplanktonu Zalewu Wiślanego w badanym okresie

Zooplankton components Składniki zooplanktonu	II	III	IV	V	VI	VII	VIII	IX	X	XI
1977										
Rotatoria				1334	383	1466	452	142	93	129
Cladocera				–	13	20	43	10	9	–
Copepoda				346	429	54	120	177	124	133
Inne				4	19	109	8	7	8	5
1978										
Rotatoria	667	344	407	558	876	726	855	283	17	31
Cladocera	23	12	8	14	7	7	22	29	–	–
Copepoda	44	86	360	569	143	202	522	196	231	110
Inne	8	3	7	17	16	13	26	–	8	–

ved in winter was 653 000/m³, constituting 89.2% of the total number of zooplankton organisms. The extraordinary variability in the size of this form, frequently difficult to define, is proof of its high level of reproductive capacity. According to Naumann and Nauwerck after Pejler [10] representatives of the Synchaeta genus can reach their maximum at a relatively early period due to their feeding on live algae, whereas according to the author mentioned, forms also diving on detritus occur in larger numbers at a later time.

Studies carried out on the occurrence of phytoplankton in the Vistula Lagoon showed that all species belonging to this group are present in December, with *Centricae* [22] represented fairly numerously. As regards diatoms, Pliński [12] states that *Centricae* and *Penatae*, as well as *Chlorophytae* occur in March. It can be thus concluded that the early maximum of the *Synchaeta* genus is linked with the presence of the above mentioned groups of phytoplankton. The *Synchaeta* genus was likewise fairly well represented in the plankton of the Pomoranian Bay in winter [25].

Pedalia fennica, *Copepoda* nauplii and a few *Crustacea* species constituted additional components in the plankton of the Vistula Lagoon in winter.

Spring (IV—VI)

In spring there is an increase in the number of *Copepoda* leading, in certain months, to a slight predominance over *Rotatoria* (Table 16). High numbers of young development stages of the former were noted in particular. The number of nauplii in May 1978 reached 396 000/m³. The species composition of the zooplankton increased by species which

did not occur at an earlier period. Number of some *Rotatoria* species become greater. Dominating *Filinia longiseta* makes its appearance in the succession of species, its numbers reaching 519 000/m³ in this period. Maximum numbers of zooplankton organisms were recorded in May in 1977 (Table 15), with the principal components consisting of *Pedalia fennica* (468 000/m³), *Keratella quadrata* (386 000/m³), *Synchaeta litoralis* (334 000/m³).

June constitutes the initial development phase of phytoplankton [12] in the Vistula Lagoon, and decomposition of amassed organic matter. Hence, forms feeding totally or partially on bacteria and dead organic matter should make their appearance in the zooplankton [10]. This refers to the *Filinia* genus and to *Bosmina* of the *Crustacea* genus. Apart from *Filinia longiseta* occurring en masse in the Vistula Lagoon, the following were also noted in fairly large numbers: *Brachionus angularis, Brachionus quadridentatus, Keratella cochlearis, Keratella quadrata*. Juvenile stages of *Copepoda* and nuplii of *Rithropanopeus harrisi* and *Balanus improvisus* were also present in the phytoplankton.

Summer (VII—IX)

Rotifers dominated decidedly during the summer season, and accounted for up to 90% of the total zooplankton. Due to mass occurrence of rotifers in July 1977 and August 1978, the zooplankton reached its peak in numbers at this time (Table 15). *Keratella cochlearis* was the dominant seasonal species, attaining a maximum of 272 000 individuals/m³. The rotifer population consisted of large numbers of the following: *Brachionus angularis* (231 000/m³), *Brachionus calyciflorus amphiceros* (102 000/m³), *Filinia longiseta* (217 000/m³).

The proportion of *Cladocera* was insignificant, despite the fact that summer is the season in which their greatest numbers are observed, attaining 43 000/m³ in August (Table 16). Only small numbers of this group were noted in the Soviet part of the Vistula Lagoon (Zhudova [31]).

Juvenile nauplii stages of *Copepoda* were noted in large numbers, the maximum of 346 000/m³ being reached in August 1978. Juvenile developmental stages of *Acartia tonsa and Eurytemora affinis* made their appearance in the zooplankton in summer, their numbers increasing gradually. Larvae of *Lamellibranchiata* also occur in the plankton in quantities up to 120 000/m³, higher than that of *Gastropoda* larvae (87 000/m³).

At the turn of summer and autumn (September), it was noted that *Copepoda* exceeded other components of the zooplankton. Hence, a second increase in *Copepoda* numbers in one year was observed (Table 16).

Autumn (X—XI)

A distinct decline in the numbers of *Rotatoria* commenced in October (Table 16). Numbers of *Keratella* and *Brachionus* representatives declined in autumn, and the number of *Filinia longiseta* in the plankton

was lower. Species observed in early spring again made their appearance, these were *Pedalia fennica* which attained 22 000/m³ in November 1977, and species of the *Synchaeta* genus, the total number of which was 44 000/m³ at the same time.

Of the *Copepoda* the species *Eurytemora affinis* was represented in large numbers, with adult and copepodit stage individuals predominating over nauplius forms. The autumn months of the years in which investigations were carried out, were characterized by the predominance of *Copepoda* over the remaining zooplankton taxons (Table 16).

3.5. VERTICAL DISTRIBUTION OF ZOOPLANKTON

Vertical distribution of zooplankton in the Vistula Lagoon depends upon numerous factors, of which the intensity of water mixing and visibility are of decisive significance. Results of statistical calculations made for the Vistula Lagoon indicate that the numbers of zooplankton organisms were fairly evenly distributed at particular depths, with a tendency toward higher numbers at depths of 0 m and 1 m (Table 17).

Table 17. Numbers of zooplankton organisms at particular depths of the Vistula Lagoon

Tab. 17. Liczebność zooplanktonu na poszczególnych głębokościach Zalewu Wiślanego

Depth Głębokość [m]	Number of samples Liczba prób		Average numbers/m³ Średnia liczebność/m³	
	1977	1978	1977	1978
0	61	63	838 000	844 000
1	61	63	828 000	874 000
2	52	44	699 000	767 000
3	9	12	677 000	700 000
4	–	3	–	607 000

In analyzing the occurrence of zooplankton at specific depths, the vertical distribution of the number of organisms has been presented only for these months which are characteristic for the various seasons (Fig. 8). Characteristic of the upper layer of water, from 0 m to 1 m, in the Vistula Lagoon, is that it has the highest numbers of zooplankton organisms, irrespective of the season. The numbers of zooplankton organisms decrease with the depth of water. The vertical distribution of zooplankton is in line with the observations carried out for phytoplankton [13].

The lack of any distinct differentiation in the distribution of zooplankton at particular depths is related in the first place to the ecological and hydrological conditions of the Vistula Lagoon.

4. RECAPITULATION

There has hitherto been a lack of papers in the literature of the numbers of zooplankton organisms in the Vistula Lagoon. Only the paper by Gieysztor et al. [5] contains fragmentary data on this subject. These results refer only to average numbers of *Cladocera and Rotatoria*. According to the authors mentioned, species of *Keratella* and *Brachionus* genera were the dominating ones in the Vistula Lagoon, but no quantitative data were published.

In order to define the fertility of the Vistula Lagoon on the basis of numbers of zooplankton organisms, comparisons were made between quantitative relations of the plankton in the lagoon and those in analogous water bodies. Papers by Wiktor [23, 24] on the Szczecin Lagoon and by Zhudova [31] on the Soviet part of the Vistula Lagoon are here of basic significance. Data referring to numbers of crustaceans and rotifers in the water bodies mentioned, are presented in Table 18.

Quantitative data on the rotifers and crustaceans of the Szczecin Lagoon for the period 1968—1970 in the paper by Wiktor [26] are given

Table 18. Zooplankton numbers in the Vistula Lagoon (Polish and Soviet parts) and in the Szczecin Lagoon, expressed as average of individuals per m^3

Tab. 18. Liczebność zooplanktonu w Zalewie Wiślanym (część polska i radziecka) i Zalewie Szczecińskim wyrażona w średniej liczebności osobn./m^3

Month Miesiąc	Polish part of Vistula Lagoon Zalew Wiślany część polska		Soviet part of Vistula Lagoon Zalew Wiślany część radziecka Zhudova		Szczecin Lagoon Zalew Szczeciński Wiktor		Vistula Lagoon Zalew Wiślany Gieysztor
	1977	1978	1974	1975	1950	1951	1958
				CRUSTACEA			
IV	—	360 000	37 300	136 800	—	—	Data for *Copepoda*
V	346 000	583 000	85 000	269 600	50 554	9 542	lacking
IX	187 000	325 000	—	—	94 639	53 809	Brak danych dla *Copepoda*
							Cladocera average
							Cladocera średnio
				ROTATORIA			
	1 466 000	876 000	219 600	135 800	140 237	93 000	Average
							Średnio
	July Lipiec	June Czerwiec	May Maj	April Kwiecień	June Czerwiec	June Czerwiec	360 000 – 1 000 000
	Maximum numbers Liczebność maksymalna				Maximum numbers Liczebność maksymalna		

in numbers of individuals per m^2, thereby rendering comparison with the Vistula Lagoon difficult. Taking into account the period mentioned, the average numbers of rotifers and crustaceans during their maximum occurrence in the Szczecin Lagoon were as follows: 2 900 000 individuals/m^2 and 1 500 000 individuals/m^2 respectively. Taking into consideration the fact that the average depth of stations in the Szczecin Lagoon was 5—6 m, the numbers of zooplankton organisms expresed as the number of individuals per m^3 was lower than that given for the Vistula Lagoon. Hence zooplankton numbers for the Vistula Lagoon were considerably higher than those given for the Soviet par of this lagoon and for the Szczecin Lagoon.

The occurrence of large numbers of rotifer species distinctly dominating in the Vistula Lagoon is characteristic of the zooplankton in this water body.

By comparing numbers of zooplankton organisms in the Vistula Lagoon with the water bodies under discussion one can state that these numbers, especially as concerns dominating rotifer species, enable it to be classified as belonging to water bodies of higher trophy.

The following species appear to be indicators of progressive eutrophication: *Brachionus angularis, Brachionus calyciflorus* and *Brachionus calyciflorus amphiceros*. The dominance of these species as compared to numerous earlier studies by Różańska [16, 17, 18, 19], is considerably higher and falls into the class dominant-eudominant at particular stations. The zooplankton picture, vertical distribution, and character of seasonal changes, are all determined by species occurring in large numbers. This was the first time that studies were carried out on the seasonal vertical distribution of zooplankton. Calculations of basic statistical parameters (arithmetic means) carried out for particular depths of the Vistula Lagoon, showed that the zooplankton was equally distributed with a slight tendency toward higher numbers at 0 m and 1 m levels.

In comparing present results with earlier studies [1, 2, 5, 16, 17, 18, 19] it can be seen that *Rotatoria* show the greatest differences in numbers and species composition. On the other hand *Cladocera* show a high level of regularity and stability.

5. CONCLUSIONS

1. The numbers of zooplankton organisms increase along the central line of the lagoon in a north-easterly direction, in accordance with salinity, phytoplankton numbers, and organic matter contents.

2. *Rotatoria* are the dominating group in the zooplankton.

3. Taxonomic units characterized by high numbers and frequency of occurrence are also dominants in the Vistula Lagoon.

4. Similarity analyses carried out on the basis of numbers of zooplankton organisms at the stations in the Vistula Lagoon, indicate concentration tendencies at similarity of from 41% to 70%.

5. As concerns seasonal changes, observations showed intensified occurrence of species of the *Synchaeta* genus at the turn of winter and spring, and *Copepoda* consisting mainly of *Eurytemora affinis* in spring. Dominance of *Rotatoria* was noted during the summer period, and a second increase in numbers of *Eurytemora affinis*, as well as the return of forms adapted to a cold environment, in the autumn.

6. Ecological factors and hydrological conditions of the Vistula Lagoon influence the even vertical distribution of zooplankton, with a slight tendency toward higher numbers at depths of 0 m and 1 m.

7. The Vistula Lagoon, as compared to other water bodies, has a high level of fertility and far advanced trophy.

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DYNAMIKA LICZEBNOŚCI ZOOPLANKTONU ZALEWU WIŚLANEGO

Streszczenie

Materiały do niniejszej pracy zebrane zostały od maja do listopada 1977 r. i od lutego do listopada 1978 r. Próby zooplanktonu pobierano w wymienionych latach co miesiąc z tych samych 9 stanowisk Zalewu Wiślanego, wyznaczonych tak, aby uwzględniały specyfikę hydrologiczną zbiornika (rys. 1). Próby planktonowe pobierane były 5-litrowym czerpaczem Ruttnera z następujących poziomów: 0 m, 1 m, 2 m, 3 m i 4 m. Badania mikroskopowe przeprowadzono w komorze o pojemności 1 cm^3 wody. Ogółem zebrano i poddano analizie mikroskopowej 368 prób (tab. 1).

Zastosowanie analizy statystycznej pozwoliło stwierdzić zmienność przestrzenną składu gatunkowego i liczebności zooplanktonu (tab. 2—11, rys. 2). Wyniki dwuletnich badań wykazały, że średnia liczebność osobników wzrasta wzdłuż śródzalewia w kierunku północno-wschodnim, podobnie jak zasolenie, materia organiczna i liczebność fitoplanktonu (rys. 3). Średnia liczebność w omawianym okresie wynosiła od 448 000 do 579 000 osobn./m^3 w najbardziej wysłodzonej części południowo-zachodniej zbiornika oraz od 921 000 do 932 000 osobn./m^3 w pobliżu granicy państwowej. Przestrzenne rozmieszczenie zooplanktonu w Zalewie Wiślanym jest uzależnione od wielu czynników, spośród których zasolenie i warunki pokarmowe mają szczególnie duże znaczenie.

Interesujące wyniki uzyskano analizując liczebność zooplanktonu pod względem regularności występowania jednostek taksonomicznych, dominacji i frekwen-

cji (tab. 13). Okazało się, że formy charakteryzujące się wysoką liczebnością i wysoką frekwencją występowania są również dominantami w Zalewie Wiślanym. Niektóre z gatunków wrotków, występujących w bardzo wysokiej liczebności, podane są w literaturze jako indykatory eutrofizacji zbiorników wodnych.

Na podstawie liczebności zooplanktonu przy pomocy wzoru Marczewskiego i Steinhausa dokonano analizy podobieństwa stanowisk. Otrzymane wyniki ułożone zostały w histogram i diagram podobieństwa 9 stanowisk Zalewu Wiślanego (rys. 4, 7). Dendryt stanowisk zbiornika i jego podział przedstawiono na rys. 5, 6. Podobieństwo stanowisk na tle liczebności zooplantonu powyżej 70% wykazały stanowiska G, I. Zasadniczo różnie okazało się stanowisko A. Podobieństwa stanowisk mieściły się w granicach od 42 do 70%.

W sezonowości zaznaczyła się wyraźna sukcesja gatunków. Okres zimowy cechuje znacznie zubożony skład gatunkowy i wysoka liczebność gatunków *Synchaeta baltica* i *Sychaeta sp.* Wiosną, podobnie jak i jesienią, nasila się występowanie skorupiaków, zwłaszcza gatunku *Eurytemora affinis*. Okres letni cechuje najwyższa liczebność zooplanktonu, a w szczególności wrotków (tab. 15, 16). Do gatunków wrotków, które pojawiły się masowo w okresie wiosenno-letnim, należały *Keratella cochlearis* 272 000 osobn./m³, *Brachionus angularis* 231 000 osobn./m³, *Filinia longiseta* 217 000 osobn./m³, *Brachionus calyciflorus amphiceros* 102 000 osobn./m³. Udział *Cladocera* był nieznaczny, najwyższa notowana liczebność tej grupy w sierpniu wynosiła 43 000 osobn./m³.

Bardzo wysoką liczebność wykazały stadia nauplii *Copepoda*, których maksymalna liczebność w sierpniu wynosiła 346 000 osobn./m³.

Pionowe rozmieszczenie zooplantonu Zalewu Wiślanego zależy głównie od intensywności mieszania wód i widzialności. Wyniki obliczeń statystycznych wykazały równomierne, niezależnie od sezonu, rozmieszczenie liczebności zooplanktonu z tendencją do nieco podwyższonej liczebności na głębokościach 0 m i 1 m (tab. 17, rys. 8). Charakter pionowego rozmieszczenia zooplanktonu pokrywa się z obserwacjami przeprowadzonymi dla fitoplanktonu.

Porównanie liczebności zooplanktonu Zalewu Wiślanego z innymi zbiornikami słonawowodnymi i częścią radziecką zalewu pozwala stwierdzić, że jest on zbiornikiem niezwykle bogatym w zooplankton, zwłaszcza pod względem liczebności *Rotatoria* (tab. 18).

REFERENCES

1. Adamkiewicz-Chojnacka, B., *Występowanie i skład gatunkowy zooplanktonu Zalewu Wiślanego w latach 1974—1975*, Studia i Materiały Oceanologiczne 21, 1978, 123—144.
2. Adamkiewicz-Chojnacka, B., J. Majerski, *Zooplankton Zalewu Wiślanego w okresie letnim*, Zesz. Nauk. ART w Olsztynie 1980, 9.
3. Biernacka, I., *Przyczynek do znajomości pierwotniaków Zalewu Wiślanego*, Pol. Arch. Hydrob., 1956, III.
4. Drzycimski, I., Z. Różańska, *Nowe gatunki Harpacticoida (Copepoda) Zalewu Wiślanego*. Zesz. Nauk. WSR w Olsztynie 1967, 23, 556, 61—68.
5. Gieysztor, M., A. Klimowicz, A. Praszkiewicz, *Recherches sur le zooplankton et les mollusques des eaux saumâtres de la Pologne hors de la mer Baltique*, Verch. Internat. Ver. Limnolog., Stuttgart 1958, XIII, 950—952.

6. Hakkari, L., *Zooplankton species as indicators of environment*, Aqua Fennica, 1972, 46—57.
7. Järnefelt, H., *Plankton als Indikator der Trophiegruppen der Seen*, Ann. Acad. Sci. Fenn., 1952, A4, 18.
8. Lillieroth, S., *Über Folgen kulturbedingter Wasserstandsenkungen für Makrophyten- und Planktongemeinschaften in seichten Seen des südschwedischen Oligotrophiegebietes*, Acta Limnol., Lund 1950, 3, 1.
9. Pejler, B., *Taxonomical and ecological studies on planktonic Rotatoria from central Sweden*, Kungl. Svedska Vetenskapsakademiens Handlingar, Fjärde 1957, 6, 1.
10. Pejler, B., *The zoopankton of Ösbysjön Djursholm II, Further ecological aspects*, Oikos 1962,13, 216—231.
11. Pejler, B., *Rotifer plankton in brackish and freshwater localities in central Sweden*, Oikos 1972, 23, 416—419.
12. Pliński, M., *Kierunki zmian strukturalnych w fitoplanktonie estuariów Bałtyku południowego*, Zesz. Nauk. Uniw. Gdańskiego, Rozprawy i Monografie, 1979, 15, 136.
13. Pliński, M., A. Simm, *Sezonowe zmiany w składzie, rozprzestrzenianiu i liczebności fitoplanktonu w Zalewie Wiślanym w latach 1974 i 1975*, Studia i Materiały Oceanologiczne 21, 1978, 53—80.
14. Radwan, S., *Wrotki pelagiczne jezior Pojezierza Łęczyńsko-Włodawskiego, Studium faunistyczno-ekologiczne*, Rozprawy Naukowe Akad. Roln. w Lublinie 1973, 1—57.
15. Romaniszyn, W., *Próba interpretacji tendencji skupiskowych zwierząt w oparciu o definicję podobieństwa i odległości*, Wiadomości Ekologiczne, 1970, XVI, 4, 306—327.
16. Różańska, Z., *Wrotki Zalewu Wiślanego*. Zesz. Nauk. WSR w Olsztynie 1962, 12, 174, 335—337.
17. Różańska, Z., *Zoopankton Zalewu Wiślanego*, Zesz. Nauk. WSR w Olsztynie 1963, 16, 278, 41—57.
18. Różańska, Z., *Zalew Wiślany jako zbiornik mixohalinowy i jego charakterystyka*, Zesz. Nauk. WSR w Olsztynie 1964, 17, 339, 405—422.
19. Różańska, Z., *Zooplankton i krótka charakterystyka hydrologiczna Zalewu Wiślanego i Zalewu Szczecińskiego w świetle badań XX-lecia*, Studia i Materiały MIR, ser. A, 1967, 4, 27—37.
20. Różańska, Z., F. Więcławski, *Badania czynników środowiskowych Zalewu Wiślanego w warunkach antropopresji*, Studia i Materiały Oceanologiczne 21, 1978, 9—36.
21. Różańska, Z., F. Więcławski, *Zmiany czynników eutrofizacji wód Zalewu Wiślanego* [in press].
22. Szarejko-Łukaszewicz, D., *Badania jakościowe fitoplanktonu Zalewu Wiślanego w roku 1953*, Prace MIR, 1957, 9, 439—451.
23. Świeżawska-Wiktorowa, K., *Zooplankton Zalewu Szczecińskiego*, cz. I, Prace MIR, 9, 501—547.
24. Wiktor, K., *Zooplankton Zalewu Szczecińskiego*, cz. II, Prace MIR, 10A, 229—258.
25. Wiktor, K., *Zooplankton Zatoki Pomorskiej*, Prace MIR, 1963, 12A, 51—78.
26. Wiktor, K., *Zmiany w rozwoju planktonu Zalewu Szczecińskiego jako wynik zmian w warunkach fizyko-chemicznych środowiska, spowodowanych gospodarką człowieka*, Prace MIR, 1972, 4, 63—132.
27. Wiktor, K., *Zmiany w produktywności biologicznej Bałtyku jako efekt postępującej eutrofizacji*, Wiadomości Ekologiczne, 1975, 21, 2, 95—103.

28. Wiktor, K., *Zmiany w biocenozach przybrzeżnych i przyujściowych Bałtyku jako wynik wzrostu zanieczyszczeń*, Studia i Materiały Oceanologiczne 15, 1976, 143—167.
29. Wiktorowie, J. K., *Szkic biologiczny polskich zalewów przybałtyckich*, Przyroda Polski Zachodniej, 1959, 1/2, 7—28.
30. Wiktor, K., M. Pliński, *Changes in plankton resulting from the Eutrophication of a Baltic Firth*, Merentutkimalait. Julk./Havsforskningsinst. Skr., 1975, 239, 311—315.
31. Zhudova, A. M., *Zooplankton Vislichnogo zaliva i ego dinamika*, Gidrobiologicheckii zhurnal, 1978, 14, 1, 67—70.