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Aggregation analysis of the planktonic rotifers in brackish waters of southern Baltic

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Rotatoria
Dendrites
Brackish waters
Southern Baltic

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Abstract

The work was based on three-year studies of zooplankton carried out at the same time in the Vistula Lagoon (Poland) and Darss-Zingst Boddenkette (GDR). The aggregation analyses of *Rotatoria* taxons were performed on the basis of qualitative composition, abundance, and similarity indices in a spatial and time system using dendrites.

1. Introduction

Estimation of the quantitative structure and intrapopulation relations in the zooplankton (*Rotatoria*) of brackish Boddenkette waters of the southern Baltic and of the Vistula Lagoon (Poland) was based on an analysis of aggregations. An introduction to the problem of aggregation analysis, *ie* of the statistics section which developed and became of practical significance due to the development of electronics and computers, was based on the works by Sneath and Sokal [17], Bijnen [5] and Kucharczyk [7].

2. Material and method

Three-year studies of the zooplankton were carried out in the Vistula Lagoon and Darss-Zingst – Boddenkette from May till October in 1975, 1977, and 1978.

Zooplankton samples (totally 705 samples, in this 255 ones from Boddenkette) were collected from the same stations once or twice each month in the above mentio-

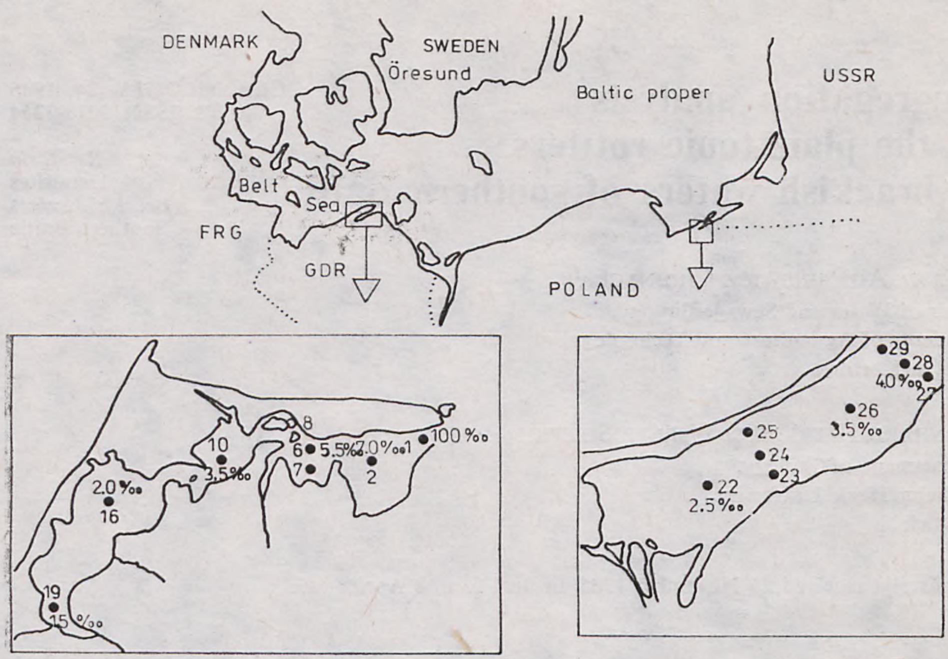

Fig. 1. Maps of the Darss-Zingst Boddenkette and Vistula Lagoon showing distribution of the sampling stations and salinity

Table 1. Morphometric table of Darss-Zingst Boddenkette and Vistula Lagoon

Morphometrical feature	Darss-Zingst Boddenkette (Schnese, Hubel [16])	Vistula Lagoon (Łomniewski [8])		
		Poland	USSR	Totals
Area	197 km^2	328 km^2	510 km^2	838 km^2
Length	55.6 km	35.1 km	55.6 km	90.7 km
Breadth max		11.0 km	13.0 km	
Breadth $\bar{x}$		8.9 km	9.5 km	9.2 km
Depth max		4.4 m	5.1 m	
Depth $\bar{x}$	1.7 m	2.4 m	2.8 m	2.6 m
Shore length		111 km	159 km	270 km
Capacity	0.4 km^3	0.8 km^3	1.5 km^3	2.3 km^{3}0
Catchment area	1594 km^2			24300 km^2

ned periods. The sampling stations were selected according to the hydrological specificity of the water bodies under study (Fig. 1, Table 1). In Vistula Lagoon zooplankton samples were collected with a 5 l Ruttner sampler, at 1 m depth intervals. The samples were filtered and analyzed microscopically by usual methods. Abundance of particular species or higher taxa was expressed as a number of individuals in 1 l of water. The Boddenkette samples (Fig. 1) were collected with a 1 l Ruttner sampler at 0.5 – 1 m depth and analyzed by means of an inverted microscope.

The data were analyzed statistically for stations and months. For the arithmetic mean, values over three years for months or stations were used respectively. Calculations of basic statistical parameters were performed with ODRA 1204 computer, in the Center of Mathematical Calculations of the Academy of Agriculture and Technology in Olsztyn. The shortest distance between the objects (stations or taxa) was calculated from the equation by Marczewski and Steinhaus [9]:

$$r(a_i, a_j) = \frac{\sum_{i=1}^{p} |a_i - a_j|}{\sum_{i=1}^{p} \max(|a_i|, |a_j|, |a_i - a_j|)}; \quad i, j = 1, 2, \ldots, p.$$

Then advantage was taken of the *goptord* procedure presented by Kucharczyk [7]. It allows for quasi-optimal ordering of the objects. The *goptord* procedure utilizes the method by Szczotka [19], *ie* of such ordering of the objects $(a_1, a_2, \ldots, a_p)$ that the index:

$$Q(a_1, a_2, \ldots, a_p) = \sum_{v=1}^{p-1} v \sum_{s=1}^{p-v} r(a_s, a_{s+v})$$

reaches a maximum at p being the number of the objects. Due to the fact that even at relatively small p it is not possible to go through all object permutations, the quasi-optimal ordering is found by the method of translocation of the pairs of objects. Such an ordering can be achieved on the basis of distances between the objects, with the use of the method proposed by Szczotka [19], *ie* assuming a minimal value of the index as a criterion:

$$Q_B = \sum_{i=1}^{K} \frac{2}{n_i(n_i-1)} \sum_{s,t=1}^{n_i} r(a_s, a_t)$$

where k is a number of aggregations and n_i is a number of the objects in the i-th aggregation. This value minimizes the sum of mean distances in the aggregations.

3. Results

Agglomeration tendencies in spatial and time systems were analyzed basing on the abundance (number) of 27 *Rotatoria* taxons in coastal, brackish waters of the southern Baltic. The results of three-year studies are given in the tables presenting taxon numbers, arranged according to quasi-optimal linear sequence (Tables 2 and 3). This synthetic presentation of the results combines the advantages of a dendrite and of Czekanowski's sets. The method proposed by Romaniszyn [12] was also used in studies on agglomerations of planktonic organisms of the southern Baltic [6] and the Vistula Lagoon [2, 3].

Table 2. Average numbers of *Rotatoria* on stations of the Vistula Lagoon and Darss-Zingst Boddenkette during three-year studies, according to the linear arrangement of the dendrites

Code number	Taxons	Station															
		16	19	10	8	6	7	2	1	26	27	29	24	22	25	23	28
19	*Notholca striata* (Müller)										0.23						0.17
18	*Notholca squamula* (Müller)										0.16				0.18	0.25	
1	*Ascomorpha* sp.									0.05				0.08		0.43	
7	*Brachionus rubens* (Ehrenberg)												0.19	0.87	0.08	0.18	
6	*Brachionus diversicornis* (Daday)												0.46		0.82	0.07	
17	*Notholca accuminata* (Ehrenberg)		0.06	0.03	0.09	0.21	0.03	0.43	0.18	0.18	0.30	0.17	0.38	0.15	0.36	0.43	
15	*Keratella cruciformis* (Thompson)									0.55	1.7	0.8			0.36		1.6
20	*Polyarthra* sp.									0.31	0.37		0.58	3.41	2.5	4.3	
2	*Asplanchna* sp.	0.13		0.38	0.13			0.02		0.55	0.51	1.25	0.92	7.0	2.4	2.2	1.02
22	*Synchaeta* 80 – 120 μm				0.48		1.67		0.36				0.38	4.0			
8	*Brachionus urceolaris* (Müller)									2.5	6.6	3.9	4.1	2.1	1.02	2.5	5.1
21	*Synchaeta* 120 μm				0.79	1.46	1.34	1.68	0.30			0.07	0.13		1.9		0.26
26	*Lecane luna* (Müller)			0.23	1.20	0.23	0.41	0.07									
10	*Colurella* sp.				0.02	2.74	0.90		0.14							0.08	
11	*Euchlanis dilatata* (Ehrenberg)									12.7	4.9	9.32	13.5	11.4	6.1	13.1	9.0
13	*Hexarthra fennica* (Levander)									91.6	25.9	28.7	52.1	25.2	10.9	9.6	26.0
3	*Brachionus angularis* (Gosse)	2.75	4.95	0.44	2.01	0.46	0.06			55.8	26.4	55	117	113	139	160	29.2
4	*Brachionus calyciflorus* (Pallas)	154	346	38	93.1	25.3	20.2	7.8	1.6	31	59.4	34.3	82.3	57	34	101	67.1
16	*Keratella quadrata* (Müller)	55.2	21	86.4	174.3	168.2	54	67	27	74.1	62	30.2	69.5	41	20.3	46	50
23	*Synchaeta* < 80 μm	103	88	86	66	58	123	178	33	31	38	16	43	43	39	70	16
9	*Conochilus* sp.	162	111	35	27	17	15	5.7	2.7			0.32		0.26			
25	*Brachionus plicatilis* (Müller)	9.46	0.8	52	199	76	50.6	38	4.3								
5	*Brachionus quadridentatus* (Herman)	592	65	439	274	708	342	269	120	4.1	11	6.8	1.2	4.8	2.8	1.0	11.5
12	*Filinia longiseta* (Ehrenberg)	915	1044	1257	1085	430	323	434	120	327	209	186	247	258	234	261	183
24	*Trichocerca* sp.	2216	1638	1226	447	139	31	290	21	2.9	2.1	1.15	6.1	6.1	2.4	4.2	1.0
14	*Keratella cochlearis* (Gosse)	6688	5519	5858	2627	1680	1297	611	656	275	252	230	197	156	163	143	109
27	*Notomata* sp.			36	10	2.7	180										

Table 3. Average numbers of *Rotatoria* in particular months of the three-year studies in the Vistula Lagoon and Darss-Zingst Boddenkette, according to linear arrangement of the dendrites

Code number	Taxons	Month and region											
		VII B	VIII B	VI B	V B	V VL	X B	IX B	VIII VL	VII VL	VI VL	IX VL	X VL
18	*Notholca squamula* (Müller)					0.11			0.1		0.2		
6	*Brachionus diversicornis* (Daday)									0.9			
1	*Ascomorpha* sp.					0.1				0.4			
19	*Notholca striata* (Müller)					0.31							
7	*Brachionus rubens* (Ehrenberg)					0.5			0.04	0.2			
17	*Notholca accuminata* (Ehrenberg)			0.05	0.59	1.34	0.04	0.05					
15	*Keratella cruciformis* (Thompson)					0.32				1.09	2.42	0.15	0.37
20	*Polyarthra* sp.					1.3				1.25	1.8	1.18	2.9
2	*Asplanchna* sp.			0.08	0.08	3.5		0.18		2.3	1.8	0.6	1.3
8	*Brachionus urceolaris* (Müller)					2.7			0.6	14.9	1.5	0.7	
11	*Euchlanis dilatata* (Ehrenberg)								16.5	33.7	1.4	5.32	
3	*Brachionus angularis* (Gosse)	0.97		3.91	0.25	2.3			159.2	256.7	19.2	12.2	3.3
4	*Brachionus calyciflorus* (Pallas)	3.73	0.1	51.3	261	39.2	0.15	0.07	39.7	198.5	48.0	6.6	0.6
13	*Hexarthra fennica* (Levander)					211.4					0.39		1.5
16	*Keratella quadrata* (Müller)	26.3	15	116	125.5	229	162	57.1	5.4	72.2	47.0	2.4	5.6
23	*Synchaeta* < 80 μm	243	8.6	11.7		141	284	73	3.8	30.5	24.1	11.0	8.8
14	*Keratella cochlearis* (Gosse)	9889	4033	1731	41	12	407	403	453	298	152	157	82
12	*Filinia longiseta* (Ehrenberg)	922	739	1606	28	211	63	253	168	458	529	26.2	4.6
24	*Trichocerca* sp.	2442	403	547		0.37	0.06	14.9	7.34	7.04	1.63	2.08	0.5
5	*Brachionus quadridentatus* (Herman)	407	241	683	2.74	0.2	3.3	162	5.0	20.1	7.2	0.2	
25	*Brachionus plicatilis* (Müller)	12.3	87.5	195			0.17	37.1					
9	*Conochilus* sp.	71.7	84.6	47.7			1.5	37.9	0.2			0.2	
27	*Notommata* sp.	151	22.1										
22	*Synchaeta* 80-120 μm					0.5	2.0	0.65					
21	*Synchaeta* > 120 μm		0.41	1.35	0.5		2.45	0.6	0.24	0.16			1.25
26	*Lecane luna* (Müller)	0.16	0.75	0.03			0.7	0.67					
10	*Colurella* sp.		0.06	0.1				2.52				0.06	

B – Darss-Zingst Boddenkette; VL – Vistula Lagoon

3.1. Groups of stations in Boddenkette and Vistula Lagoon on the basis of *Rotatoria* numbers

Sets of stations were obtained in an objective way on the basis of a dendrite division criterion, calculating and comparing quotients of relevant distances (D).

Dendrite of stations of the two reservoirs is divided at a similarity $(S)=53.4\%$ into 8 groups, but 6 weaker divisions are also possible (Fig. 2). Station 16 formed separate cluster, even at the lowest coefficient of similarity $(S)=13.4\%$, due to a very

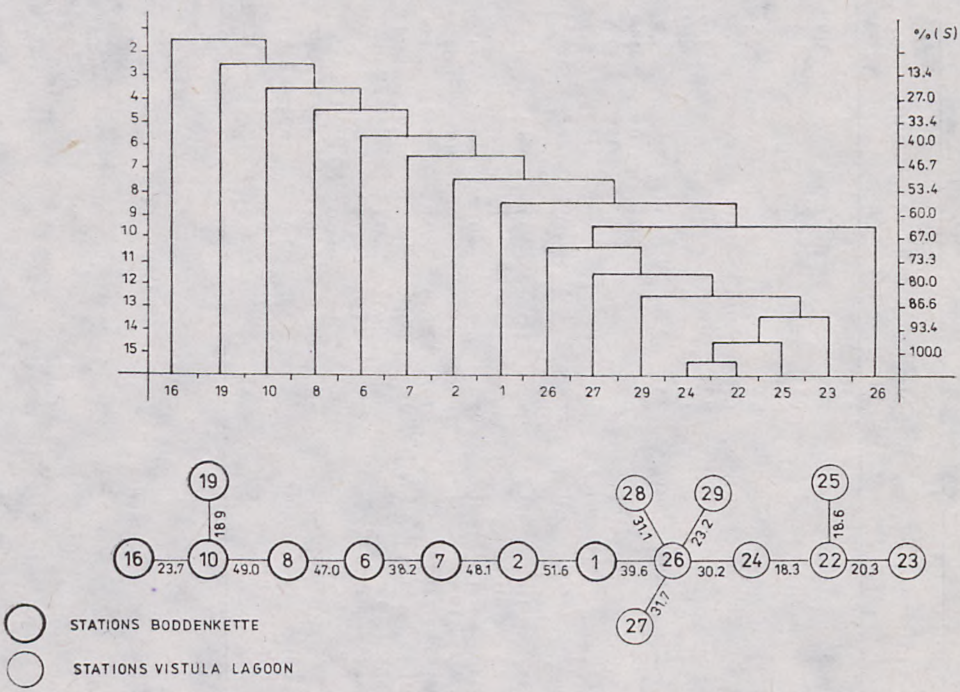

Fig. 2. Dendrite and clusters of sampling stations in the Vistula Lagoon and Darss-Zingst Boddenkette in the three-year studies

high number of *Rotatoria*. At similarity $(S)=53.4\%$ characteristic common environmental elements of the cluster consist of connection between station 1 Boddenkette and the Vistula Lagoon stations of higher salinity, based on the numbers of *Rotatoria*. In a branched dendrite, small distance $(D)=39.6\%$ connects station 1 with 26 and the remaining stations of the Vistula Lagoon (Table 2, Fig. 2).

3.2. Groups of *Rotatoria* taxons resulting from similarities of Rotatoria numbers at the stations in Boddenkette and the Vistula Lagoon

The dendrite of 27 *Rotatoria* taxons broke down to 17 clusters at high similarity of 65.4%, but 15 weaker divisions were also possible (Fig. 3). Apart from a strong cluster of the species present at all stations of Boddenkette and the Vistula Lagoon,

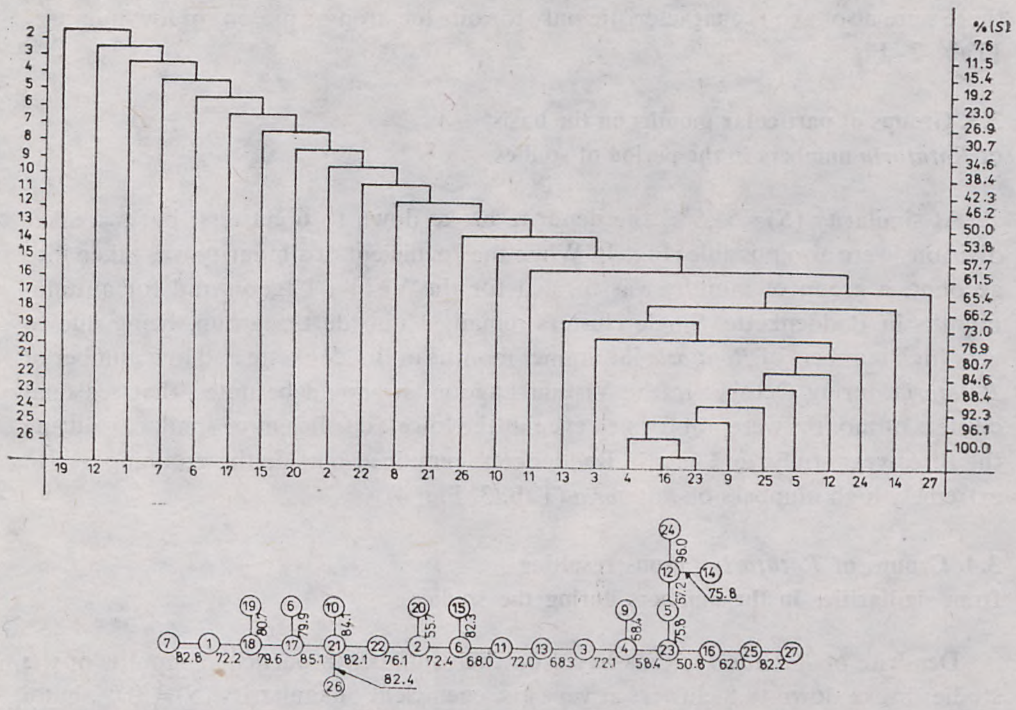

Fig. 3. Dendrite and clusters of *Rotatoria* taxons in the Vistula Lagoon and Darss-Zingst Boddenkette in a spatial system

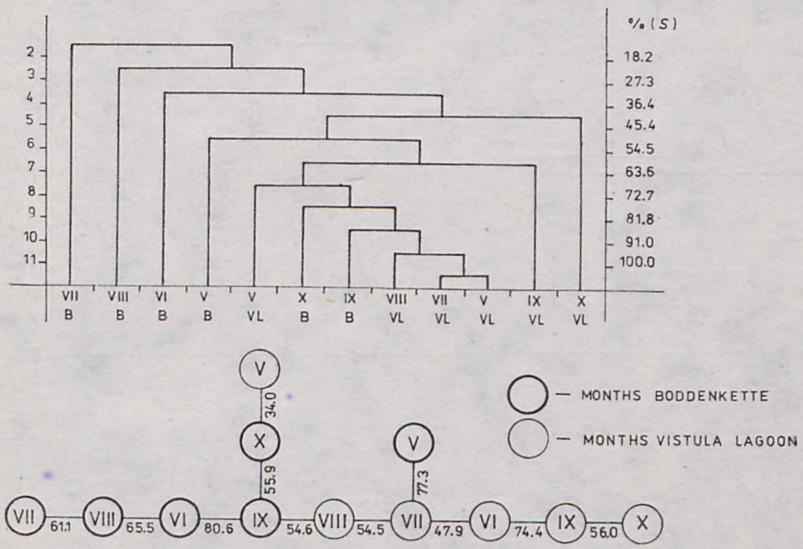

Fig. 4. Dendrite and clusters of particular months in the three-year studies in the Vistula Lagoon and Darss-Zingst Boddenkette

there were also taxons characteristic only for one location or present in low numbers (Tab. 2, Fig. 3).

3.3. Groups of particular months on the basis of *Rotatoria* numbers in the period of studies

At similarity $(S) = 54.5\%$, the dendrite broke down to 6 clusters, but 5 weaker divisions were also possible (Fig. 4). When the coefficient of similarity was taken into account, a group of months was formed for the Vistula Lagoon and for autumn months in Boddenkette. Single clusters remained outside the group, being due to very high numbers of *Rotatoria* in summer months in Boddenkette and low number of *Rotatoria* during October in the Vistula Lagoon. It should be noted that seasonal clusters of months were not formed even at the lowest coefficient of similarity during the three-year study, and July in Boddenkette remained outside the grouping due to extremely high numbers of *Rotatoria* (Tab. 3, Fig. 4).

3.4. Groups of *Rotatoria* taxons resulting from similarities in the numbers during the studies

Dendrite of *Rotatoria* taxons based on their number in particular months of the studies broke down to 8 clusters at very low coefficient of similarity $(S) = 31\%$, but 6 weaker divisions were also possible (Fig. 5). At higher, more optimal coefficients of

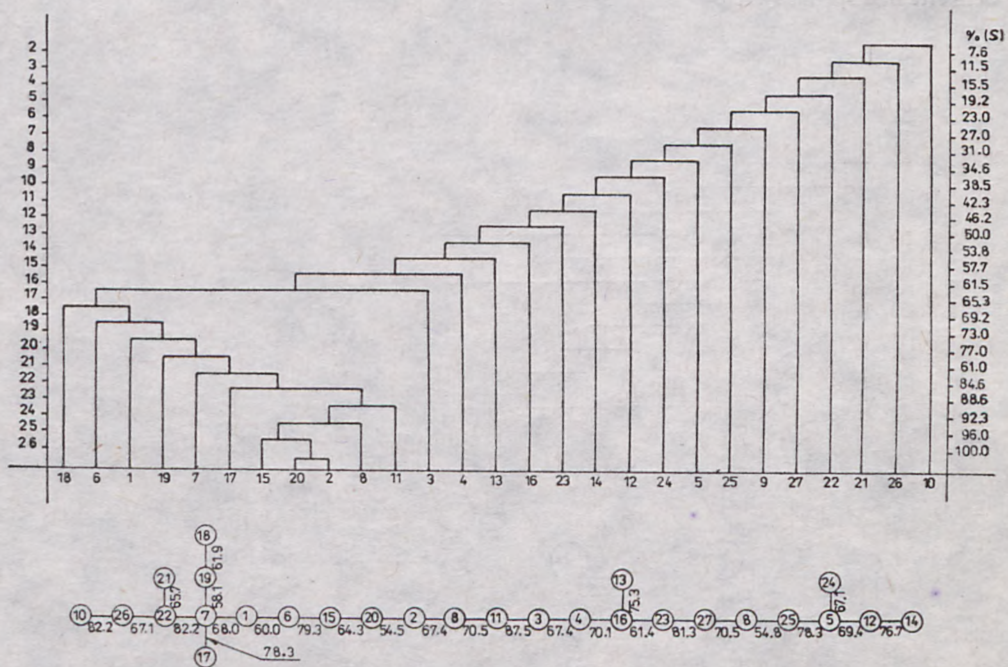

Fig. 5. Dendrite and clusters of *Rotatoria* taxons in the Vistula Lagoon and Darss-Zingst Boddenkette in a time system

similarity all species occurring in high numbers formed separate groups. According to Chojnacki [6], a cluster is of biological meaning if it embraces maximally many elements, even through the coefficient of similarity is not very high. Low coefficient of similarity (S)=31% of this cluster suggests different seasonal dynamics of *Rotatoria* species in the waters under study (Tab. 3, Fig. 5).

4. Discussion and conclusions

On the basis of qualitative composition and an abundance of *Rotatoria* species, a similarity was found between Boddenkette and the Vistula Lagoon stations of high salinity. Darss-Zingst Boddenkette and the Vistula Lagoon represent estuarine water bodies subjected to strong continental effects, as well as sea effects. They are characterized by variations in many factors. Studies on water chemism, carried out along with biological studies [13, 14, 16], revealed that both water areas were subjected to eutrophication, and contained high levels of nutrients. Distribution of nutrients suggests that predomination of Baltic waters, poorer with respect to nutrient resources, results in a decrease of nutrient content at stations 1, 2, 26, 27, 28. The Vistula Lagoon was characterized by higher aggregate numbers of *Rotatoria*, despite lower nutrient levels. It was also characterized by higher biological production than south-west part, where nutrient content was higher. In Dass-Zingst Boddenkette, *Rotatoria* numbers were higher at stations of lower salinity and higher nutrient content. Other groups of stations differed with respect ot *Rotatoria* abundance and taxon numbers (Tab. 2, Fig. 2).

Cluster of *Rotatoria* taxons, resulting from similarities of *Rotatoria* numbers in a spatial system, was composed mainly of the species present at all stations, the coefficient of similarity being very high (S)=65.4%. The strongest group was represented by a cluster of 11 taxons, in which the highest numbers consisted of: (14) *K. cochlearis* (Gosse) (mainly the form tecta), (24) *Trichocera* sp., (12) *F. longiseta* (Ehrenberg), (5) *Br. quadridentatus* (Herman), (4) *Br. calyciflorus* (Pallas) (Tab. 2, Fig. 3), known as in dices of high water trophy [10, 11] (numbers in brackets denote the code numbers).

Groups of *Rotatoria* numbers in a time system differed in the three-year period of studies (Tab. 3, Fig. 4, 5). Even at the lowest coefficients of similarity, no seasonal groups were obtained for the dominating *Rotatoria*. Branched dendrite, as well as linear arrangement of the months, based on *Rotatoria* numbers, resulted in separate month clusters of June, July and August in Boddenkette, even though coefficients of similarities were low (Fig. 4). This suggests variations in the environmental conditions in this period, considerable variations in the numbers, and intensive changes in structure of the species domination (Tab. 2).

Mass development of microfiltrators took place in summer months. Most of the planktonic rotifers, occurring in the estuaries under study, belonged to this class [1, 4, 15, 20].

Boddenkette and the Vistula Lagoon differed with respect to some morphometric features (Tab. 1), water salinity (Fig. 1), but most of all as regards higher domination of small specimen numbers in summer: (12) *F. longiseta*, (14) *K. cochlearis* (Tab. 3). High numbers of these species (which feed mainly on detritus) are characteristic of shallow coastal lakes [18, 21].

Analysis of the grouping trends in *Rotatoria* taxons was based on qualitative composition, abundance and coefficient of similarity in spatial and time systems. These were used to prepare the dendrites which revealed that:

(i) stations of higher salinity and lower trophy (both in Boddenkette and the Vistula Lagoon) were more similar than the other stations,

(ii) the highest coefficient of similarity $(S) = 65.4\%$ was obtained for the cluster of *Rotatoria* which were present at all stations of Boddenkette and the Vistula Lagoon. It was composed of species characteristic of waters of high trophy: *K. cochlearis, F. longiseta, Br. quadridentatus, Br. calyciflorus,*

(iii) the greatest differences and the lowest coefficients of similarity were noted for the time system related to the seasonal dynamics of the dominating *Rotatoria* species.

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