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Analysis of *Ciliata* from polluted sector of the River Drwinka on the basis of binary data*

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Abstract — In the course of two seasons (1978 and 1979) 68 samples were collected in the polluted sector of the river Drwinka. The fauna of *Ciliata* was found to be distinctly differentiated in a linear way, in agreement with the pollution gradient. On the basis of the differentiation three zones of river purity were distinguished. An attempt has been made to determine quantitatively the pollution degree basing on the indicator values of *Ciliata*.

Key words: Ciliates, indicator organisms, river pollution, saprobiology, self-purification.

1. Introduction

The variability of the fauna of *Ciliata* along the polluted river Drwinka, which flows across the territory of the Forest of Niepołomice, was presented. An attempt was undertaken to estimate the degree of water purity basing upon indicator values of the species occurring in it. This paper is a complementary work of complex investigations carried out by the Department of Hydrobiology of the Institute of Environmental Biology of the Jagiellonian University on hydrochemistry, algae, and macrofauna.

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2. Investigation territory

The river Drwinka is a lowland river of a moderate gradient, not exceeding 0.5 per mille and flow capacity from 0.7 to 0.1 m^3/sec. It flows in a controlled river bed resembling a canal with fairly steep banks. Its bottom and its banks are overgrown with vascular plants of the *Myriophyllo-Nupharetum* community (D u b i e l 1973). In the investigated sector the river Drwinka takes in two small tributaries: the streams Ruski Potok and the Lane Błoto. The river under investigation is supplied with great quantities of pollutions; their main source, and a permanent one are waste waters from the hen farm and the sewage from the town Niepołomice. The river Drwinka and its tributaries take in also pollutions from the atmosphere, emitted into it by the nearby located Lenin Steel Works (Z a j ą c 1977).

A precise description of the river Drwinka, its hydrochemical characteristics, and estimation of its self-purification possibility was presented by J o p (1980).

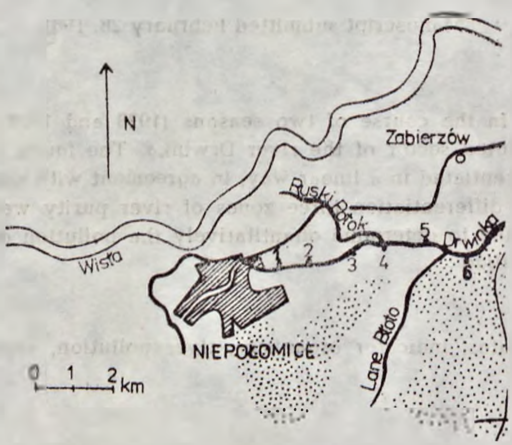

Fig. 1. Location of stations

A 6 km long sector of the river below the town Niepołomice (fig. 1) was chosen for investigations of the fauna of *Ciliata*. In that sector the self-purification process proceeded most intensively. Four stations from among those considered in the hydrochemical elaboration of the river Drwinka (J o p 1980) were chosen for investigations. Two other stations in the middle part of the investigated sector were additionally designated. All the stations were denoted with successive numbers from 1 to 6, starting from the source of pollution. The denotations in J o p's paper (1980), corresponding with the above ones, are presented below:

Author's denotation	1	2	3	4	5	6
J o p (1980)	2	2a	—	—	2b	2c

Station 3 was located 1 km below station 2 and station 4 about 1 km downwards from station 3 in the region of the estuary of the stream Ruski Potok.

3. Methods

Samples of the bottom sediment (100 to 200 cm^2) were collected at each station. Samples were transported to the laboratory in 1 l glasses filled to $^3/_4$th of their capacity with water collected at the station. A few hours after sampling, the material was checked and the species identified. Investigations covered the period from spring to autumn during two seasons (1978 and 1979). Each year samples were collected six times at 1 to 1.5 month's intervals. 68 samples constituted the total investigation material.

For statistical analysis the data were reduced to 42 species: namely, those which were found more than three times during the investigations.

On the basis of the species composition the values of the saprobic index were calculated for each sample by P a n t l e and B u c k's (B i c k 1963) and Z e l i n k a and M a r v a n's (1961) methods. For each pair of the 42 species 2×2 contigency tables were made and the Chi-square values were calculated as a measure of association. Basing upon Jaccard's coefficients a dendrogram (fig. 3) was calculated by the unweighted pair group method analysis (UPGMA) (S o k a l, S n e a t h 1963).

4. Results and discussion

4.1. Linear arrangement of species

The frequencies of the species found at particular stations were concisely presented in Table I. Table II shows the percentage of common species for every pair of stations calculated on the basis of the whole investigation period. The linear system of stations along the river and along the pollution gradient is reflected in the species composition of *Ciliata*. The percentage of common species quickly decreases with the distance of the stations. The two stations most remote from each other: 1 and 6 have no common species at all.

The food spectrum of *Ciliata* changes at particular stations in a linear way too (fig. 2). A gradually decreasing participation of bacteriophageous

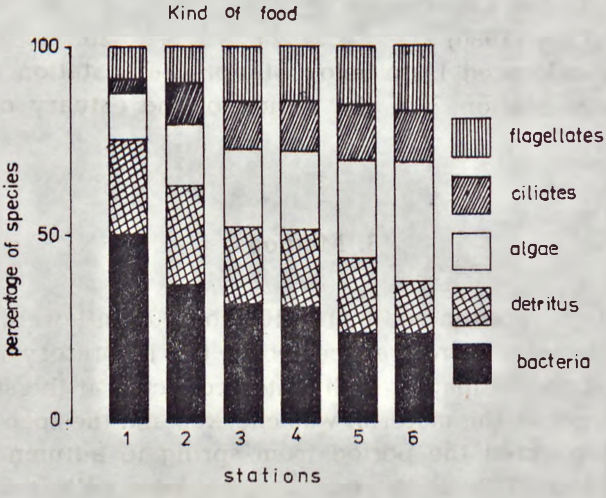

Fig. 2. Food spectrum of *Ciliata* at particular stations

forms at a concomitant increase in participation of species feeding on algae. For determination of the spectrum, data quoted by B i c k and K u n z e (1971) and the author's own observations were used.

Among the species characteristic of the most polluted station 1 the following sapropelic forms, occurring there regularly, should be mentioned: *Metopus es*, *M. contortus*, *Plagiopyla nasuta*, *Caenomorpha medusula*, and *Colpidium campylum*, *C. colpoda*, *Paramecium aurelia*. *Brachonella spiralis* and a non identified species of the family *Dysteriidae*, occurring in samples fairly regularly, were found only at that station. Most of the samples from that station contained also *Paramecium caudatum* and *Chilodonella cucullulus*, species of a large range of tolerance, and *Ciliata* found most frequently at the first four stations.

At station 2 the species composition is similar but some new species, not found at the previous station such as *Loxocephalus luridus*, *Stentor coeruleus*, and *Litonotus lamella*, and some sporadically occurring species such as *Spirostomum teres* can also be found there.

The next two stations, 3 and 4, are characterized by the highest diversity of *Ciliata* in the given sector of the river. *Ciliata*, connected in most cases with a heterotrophic food chain beginning from dead organic matter, occur most numerously in highly eutrophized waters, rich in bacteria. The species composition in the region of stations 3 and 4 shows that this is the final stage of a very intensive decomposition of organic matter initiated in the region of the town Niepołomice.

There occur also saprobic species but not so numerously as at the two former stations. Apart from them, a great number of species occurs there which were not represented at all at higher stations. These are:

Frontonia leucas, Spirostomum minus, Hemiophrys pleurosigma, Loxodes striatus, Euplotes patella, Stylonychia mytilus, Uroleptus sp. *Dileptus anser* (station 4) and others. This evident difference in the species composition can be ascribed, most probably, to oxygen deficiencies recorded at the first two stations (J o p 1980). At stations 3 and 4 species sensitive to oxygen deficiency occur in mass quantities, e.g. *Loxodes striatus*, a species very characteristic of this sector of the river, which in anaerobic conditions disappears quickly (G o u l d e r 1971).

The last two stations, 5 and 6, are characterized by a smaller number of species. There occur species characteristic of clean or moderately

Table I. Frequency of species at particular stations

Species	Stations					
	1	2	3	4	5	6
1. Brachonella spiralis (Smith)	4	-	-	-	-	-
2. Dysteriidae sp.	8	-	-	-	-	-
3. Colpidium campylum (Stokes)	7	3	-	-	-	-
4. Amphileptus sp.	8	2	-	-	-	-
5. Paramecium aurelia Ehrb.	6	4	1	1	-	-
6. Metopus contortus (Quennerstedt)	5	2	1	1	-	-
7. - es O.F.M.	11	9	4	2	-	-
8. Plagiopyla nasuta Stein	7	2	1	1	1	-
9. Colpidium colpoda (Ehrb.)	6	2	3	1	-	-
10. Cyclidium sp.	3	7	2	1	-	-
11. Prorodon teres Ehrb.	4	5	2	1	-	-
12. Caenomorpha medusula Perty	9	6	4	1	-	-
13. Chilodonella cucullulus (O.F.M.)	10	10	8	7	-	-
14. Paramecium caudatum Ehrb.	9	11	11	6	4	-
15. Spirostomum teres Clap. et L.	2	5	10	8	2	-
16. Aspidisca costata (Dujardin)	2	2	7	2	-	-
17. Glaucoma scintillans (Ehrb.)	3	6	1	1	-	-
18. Loxocephalus luridus Eberhard	-	7	9	1	-	-
19. Loxodes striatus (Engelman)	-	2	7	10	3	-
20. Stentor coeruleus Ehrb.	-	4	10	9	3	-
21. - polymorphus (Muller)	-	2	2	3	-	-
22. Urocentrum turbo (O.F.M.)	-	2	6	3	1	-
23. Litonotus lamella (Ehrb.)	-	5	4	1	-	-
24. - anguilla Kahl	-	1	2	4	3	-
25. Lacrymaria sp.	-	1	4	6	2	-
26. Aspidisca lynceus Ehrb.	-	-	2	4	1	1
27. Spirostomum minus Roux 1901	-	-	5	8	6	-
28. Pleuronema sp.	-	-	3	5	-	1
29. Stylonychia mytilus Ehrb.	-	1	1	4	2	3
30. Uroleptus sp.	-	-	4	4	2	2
31. Frontonia leucas Ehrb.	-	-	7	10	7	4
32. Euplotes patella (Muller)	-	-	3	5	5	2
33. Hemiophrys pleurosigma Stokes	-	-	6	4	3	-
34. Homalozoon vermiculare Stokes	-	-	2	6	6	2
35. Urostyla sp.	-	-	1	6	5	4
36. Bursaria truncatella O.F.M.	-	-	1	5	2	3
37. Histriculus erethisticus (Stokes)	-	-	-	4	3	1
38. Dileptus anser (O.F.M.)	-	-	-	4	7	4
39. Strombidium gyrans (Stokes)	-	-	-	2	1	4
40. Coleps hirtus Nitzsch	-	-	-	1	6	3
41. Cinetochilum margaritaceum Perty	-	-	-	-	5	5
42. Halteria grandinella (O.F.M.)	-	-	-	-	4	4

Table II. Percentage of species common for every pair of stations

	1	2	3	4	5	6
1	100	62.50	40.63	36.11	12.30	0.00
2	88.24	100	68.75	61.11	37.50	6.67
3	76.47	91.67	100	88.89	75.00	60.00
4	76.47	91.67	100.00	100	91.66	86.67
5	17.65	20.83	56.25	61.11	100	93.33
6	0.00	4.17	28.13	36.11	58.33	100

polluted waters such as: *Strombidium gyrans, Halteria grandinella,* and *Dileptus anser*, saprobic species being completely absent.

The region of station 4 is very interesting with regard to the fact that, on the one hand, species meet there which are characteristic of heavily polluted waters and, on the other hand, forms connected with a fairly clean environment. The applied sampling method permits only to determine a certain average species composition for the station. It is possible that particular species occupy various microhabitats more or less separated from one another. Our present knowledge of spatial relationships in complex fresh-water communities of protozoans is, however, markedly unsatisfying (Cairns, Yongue 1977).

The presented results permit to distinguish two main zones in the investigated river sector: the heavily polluted zone including stations from 1 to 4, and the relatively clean zone, i.e. stations 5 and 6. The region of station 4 can be determined as a transitive zone. Such a division is well depicted by the dendrogram (fig. 3), calculated on the basis of total data for the whole investigation period.

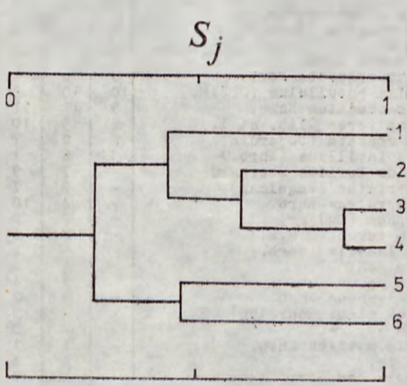

Fig. 3. Dendrogram (UPGMA) calculated on the basis of Jaccard's coefficient presenting the division of the investigated sector of the river into two main zones

4.2. Species associations

The results of the Chi-square test on species associations were presented in a diagram (fig. 4). Three groups of species were distinguished in it and denoted with the letters A, B, and C. A very distinct linear arrangement of the obtained groups is evident. The diagram was constructed basing upon positive correlations with which the particular lines correspond. The negative correlations found there make the linear system still more evident. Within each group there are no negative correlations. whereas, their greatest number (26) is found between

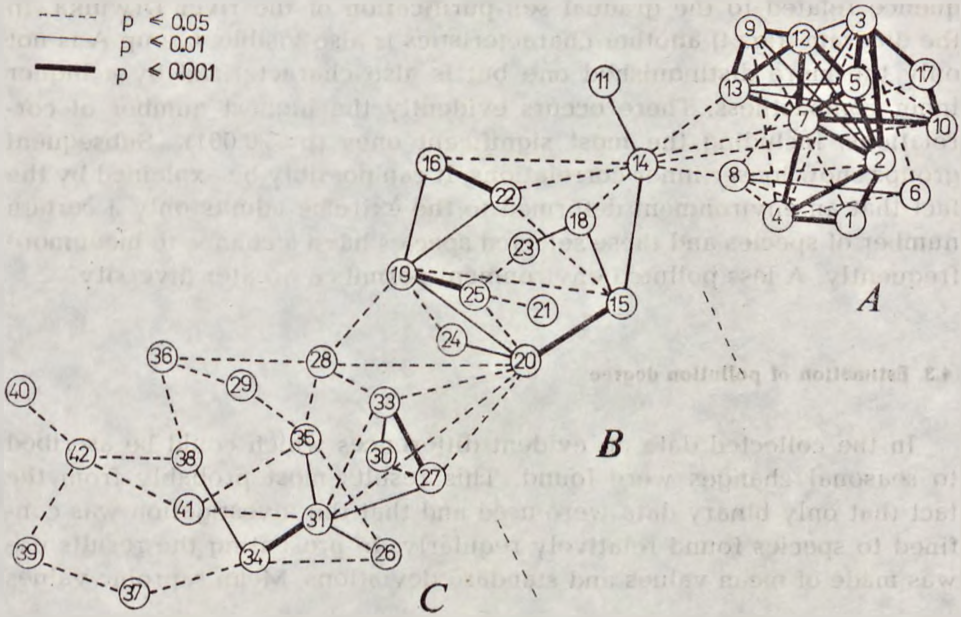

Fig. 4. „Constellation" of species on the basis of Chi-square values. Numbers corresponding to particular species arranged according to Table 1

species of groups A and C (excluding transient species 14 and 11). Between the groups A and B and between B and C there are 4 and 5 negative correlations respectively. The linear system of the distinguished groups of species is evidently correlated with the pollution gradient.

In group A occur species characteristic of waters highly polluted and these are found almost exclusively at the first stations. The arythmetical mean from the values of indicator species within group A equals 4.38 and indicates to a polysaprobic zone (S l à d e č e k 1973). The central place in this group (the highest number of significant correlations within the group) belongs to *Metopus es* (7), indicator species for H_2S.

Group B is connected with the previous one only through one species *Paramecium caudatum* (14) occurring regularly at the first four stations. The mean indicator value of species of group B is 2.65 and lies within the α-mezosaprobic zone. The highest number of correlations in that group is found with *Loxodes striatus*, which according to B i c k and K u n z e (1971) is associated with the α-mezosaprobic species like *Prorodon teres* and *Spirostomum teres;* this has found confirmation in the present work. The mean indicator value of species of group C equals 2.22 (β-mezosaprobic zone). The central position is occuppied by *Frontonia leucas,* an indicator species of the β-mezosaprobic zone.

The distinguished groups (communities) reflect the characteristic sequence related to the gradual self-purification of the river Drwinka. In the diagram (fig. 4) another characteristics is also visible. Group A is not only the more distinguished one but is also characterized by a higher inner compactness. There occurs evidently the highest number of correlations, including the most significant ones ($p \leqslant 0.001$). Subsequent groups show looser inner correlations. It can possibly be explained by the fact that an environment deformed to the extreme admits only a certain number of species and these selected species have a chance to meet more frequently. A less polluted environment permits a greater diversity.

4.3. Estimation of pollution degree

In the collected data no evident differences which could be ascribed to seasonal changes were found. This results most probably from the fact that only binary data were used and that the investigation was confined to species found relatively regularly. In presenting the results use was made of mean values and standard deviations. Mean saprobic values

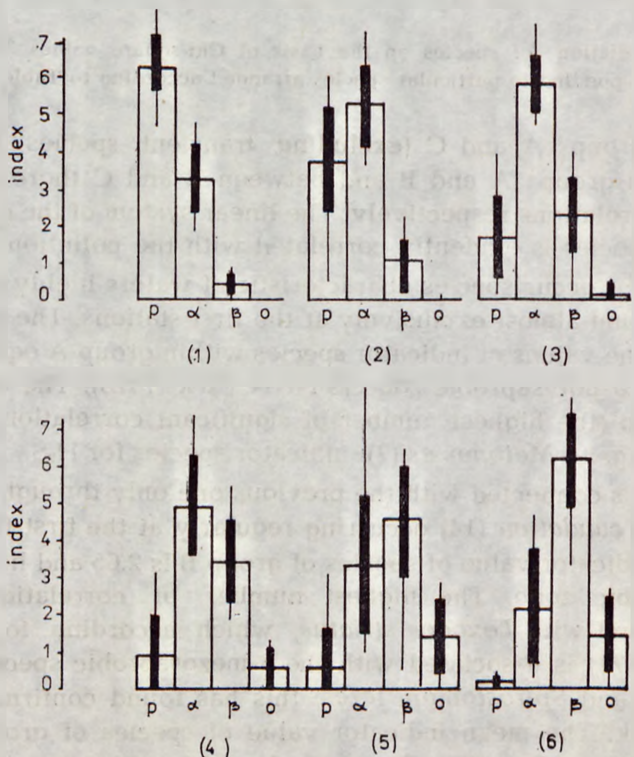

Fig. 5. Mean values of the saprobic index for each station according to Zelinka and Marvan

for particular stations, calculated according to Zelinka and Marvan's method (1961) were shown in fig. 5 in the form of histograms. The standard deviation (± SD) was marked with a thick line and the whole range was marked with a thin one. The histograms indicate to a quickly improving state of purity of the river with the increase in distance from the region of sewage discharge. In the 6 km long sector a change occurs from station 1 of a polysaprobic (or transitory poly-α-mezosaprobic) character to β-mezo-saprobic station 6. Figure 6 shows mean values of

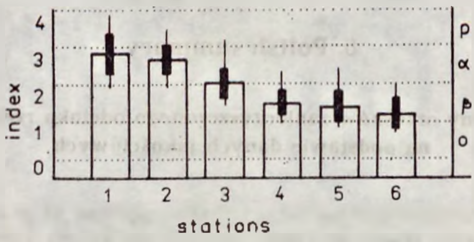

Fig. 6. Mean values of the saprobic index according to Pantle and Buck

the saprobic index calculated by use of Pantle and Buck's (Bick 1963) method. It presents a picture very similar to the former one. The obtained results are in general outlines, in agreement with the results of the hydrochemical analysis given by Jop (1980). With regard to the fact that the river Drwinka takes in mostly organic wastewaters it was possible to apply successfully the system of indicator organisms and therefore the analysis of water purity based only upon qualitative data on the fauna of *Ciliata* gave results similar to those of hydrochemical analysis.

5. Conclusions

1. The fauna of *Ciliata* is markedly differentiated in a linear way along the 6 km long sector of the river Drwinka below Niepołomice.

2. Differentiation in the species composition of *Ciliata* is closely correlated with the self-purification process occurring there.

3. On the basis of the species composition of *Ciliata* the investigated sector of the river can be divided into following zones:

a. highly polluted zone from Niepołomice to station 3 included,

b. zone of transitory character — region of station 4,

c. relatively clean zone — the sector including stations 5 and 6.

4. Methods of quantitative determination of water pollution degree based upon the indicator values of *Ciliata* give in the case of the river

Drwinka results in rough outlines consistent with the results of hydrochemical analysis.

Acknowledgment

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6. Polish summary

Analiza fauny orzęsków zanieczyszczonego odcinka rzeki Drwinki na podstawie danych jakościowych

W ciągu dwóch sezonów (1978—1979) pobrano ogółem 68 prób na 6-kilometrowym zanieczyszczonym odcinku rzeki Drwinki (ryc. 1). W tabeli I zestawiono frekwencje 42 gatunków orzęsków na poszczególnych stanowiskach. Stwierdzono bardzo wyraźne liniowe zróżnicowanie fauny orzęsków wzdłuż gradientu zanieczyszczeń (tabela II). Także w sposób liniowy zmienia się spektrum pokarmowe. W miarę oddalania się od źródła zanieczyszczeń maleje liczba gatunków bakteriożernych, a wzrasta ilość form glonożernych (ryc. 2).

Na podstawie składu gatunkowego orzęsków wyróżniono w badanym odcinku rzeki następujące strefy czystości wody: strefę silnie zanieczyszczoną (stanowiska 1—3), strefę przejściową (rejon stanowiska 4) oraz obejmującą stanowiska 5 i 6 strefę względnie czystą (ryc. 3). Dla każdej pary gatunków wartość X^2 stanowi miarę współwystępowania. Otrzymane wyniki przedstawiono w postaci diagramu (ryc. 4). Wyodrębnione grupy gatunków obrazują charakterystyczny dla Drwinki ciąg sukcesyjny związany ze stopniowym samooczyszczaniem się rzeki.

Podjęto próbę liczbowego określenia stopnia zanieczyszczenia rzeki według metod Zelinki i Marvana oraz Pantle i Buck'a (ryc. 5 i 6). Otrzymane wyniki są zgodne z wynikami analiz hydrochemicznych przytoczonymi w pracy Jopa (1980).

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