STUDIES ON PHYTOPLANKTON COMMUNITY STRUCTURE IN RELATION TO ORGANIC POLLUTION IN THE GANGA RIVER

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Abstract

Present study deals with the investigations on the impact of sewage discharge on the structure of phytoplankton community in the river Ganges. For conducting the investigations an area of approximately 10 km riverspan situated just below outfall of the main untreated raw sewage was chosen. Samples were collected from twenty sampling stations located equidistance. It is evidenced by the community structure analysis that nearly half of the study area is under considerable stress. In this area species diversity (H) is found to depend on the evenness component (J) which is characteristic of unfavourable environment. The second half of the study area witnessed definite amelioration in water quality as here the species diversity depends on the species richness component (S). This study constitutes a part of a biological surveillance programme on the river Ganges.

Introduction

Structure of various biological communities have been very convincingly used for making qualitative appraisals of diverse habitats (Thiery, 1982; Herricks & Cairns, 1982; Dennis & Patil, 1978; Empain, 1978; Bechtel & Copeland, 1970). Certain biological methods to study different environments have been evolved (Bick, 1963; Mathews *et al.*, 1982; Brain & Mackie, 1982). Shannon and Weaver (1949) were the first to introduce the concept of diversity index to study the structure of biological communities. Later Margalef (1957) used diversity index to indicate the variations in phytoplankton community structure, particularly diatoms, in different localities. In a number of studies it has been demonstrated that clean environments support a more diverse population of any biological community and hence possess higher diversity index values (Wilhm & Dorris, 1968).

Shannon's diversity index takes into account the total number of species present and their relative abundances (Cook, 1976). With the induction of exotic physico-chemical factors in an ecosystem the ecological niches and relative abundances of the existing population of a biological community are affected leading to various shifts in the community pattern (Partick, 1973). Lloyd (1964) identified the components of Shannon's diversity as 'species richness' (S) which is the total species content of any sample and 'equitability' (J) which is the ratio between hypothetical "maximum diversity, (H_{max}) when all the species present possess equal number of individuals) and 'actual diversity', (H). It was found that investigations on these components of species diversity and other shifts in the community pattern constitute a reliable parameter of biological monitoring of environmental conditions (Patten, 1962; Sagar & Hasler 1969; Tramer, 1969; Kircher, 1972; Hajdu 1977).

In this paper biological aspects of water quality monitoring have been studied with reference to change in plankton population.

Area of study

Investigations have been made in the city Varanasi, lying at 20° 18'N longs 83° 10°E in the middle of the Gangetic plain. Location of the sampling sites have been shown in Text-fig. 1. Approximately 10 km span of the river has been investigated at twenty sampling sites located at half km intervals. The study area is located just below

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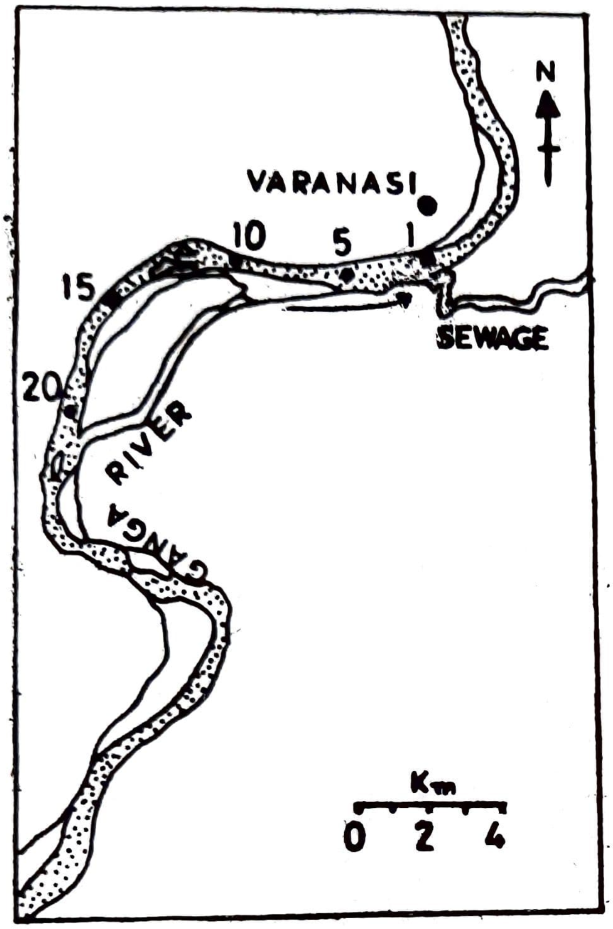
the outfall of the raw sewage. All the samples were taken from the mid stream of the river.



Text-figure 1—Area of study.

Methods

Im all 240 water samples were analysed within a period of one year (from March 1976 to February 1977). Each sampling site was sampled twice in a month. For the collection of phytoplankton a net of 22 no. Bolting silk was used. Identification was done microscopically and counting was done with the help of Haemocytometer.

Diversity Index.

Shannon and Weaver's (1949) formula was used for calculating these values.

$$H = -\sum_{i=1}^{S} ni/N \log_2 ni/N$$

where

H — Diversity index
S — Total number of species
ni — Number of individuals in the species
N — Total number of individuals in all the species present.

Equitability Index

Pielou's (1966) formula has been used for the derivation of these values;

$$J = H/H_{max}$$
$$H_{max} = \log_2 s$$

Where

J — Equitability index
H — Diversity index
H_{max} — Hypothetical maximum diversity (when all the species present contain equal number of individuals)
S — Total number of species

Results

Table 1 shows the range and mean values of N, H, J and S at all the sampling stations. It is recorded that the values of H, J and S increase quite steadily on the subsequent down stream sampling station but the values of N show increase upto certain distance and then starts declining. Change in the various components of community structure in relation to the down stream distance could be more explicit if the results of twenty arbitrarily chosen water samples from all the sampling stations are analysed. Table 2 indicates the correlation co-efficient values (γ) between H, J and S for first and second half of the study area. It is recorded that in the first half both J and S show strong positive correlation with the species diversity but in the second half only S shows significant positive correlation with the species diversity.

Looking to the other aspect of population distribution, it is observed that percentage contribution of single species to the total phytoplankton population varies greatly at different stations. Maximum contribution of single species is highest at station 1 (69.1%) and gradually it declines reaching to lowest at site 20 (3.4%) in the arbitrarily chosen samples. Text-figure 3 shows the number and percentage contribution of all the species at 1, 5, 10, 15 and 20th stations. It is quite obvious that the abundance of individual species gradually becomes more and more even with the down stream distance. Text-figure 4 also indicates that in the same samples a very low percentage of total species (11.8%) contribute to the

Table 1—Data of community structure studies at all the sampling sites

Site No.		N (x10^3 cells/1)	H (Bits/ind)	J	S
1	R	11.34—23.14	1.20—2.01	0.46—0.68	5—8
	M	16.69±32.12	1.61±0.32	0.59±0.03	6.54±0.99
2	R	15.64—31.34	1.23—2.16	0.45—0.70	5—11
	M	19.10±34.48	1.64±0.41	0.60±0.04	7.91±1.16
3	R	18.64—36.45	1.32—2.21	0.47—0.71	6—17
	M	20.71±46.62	1.71±0.48	0.62±0.04	11.3±2.31
4	R	21.36—41.24	1.45—2.35	0.47—0.73	7—21
	M	26.45±51.84	1.84±0.52	0.63±0.05	15.61±2.60
5	R	23.01—44.31	1.60—2.41	0.49—0.76	7—23
	M	26.83±53.21	1.86±0.55	0.65±0.04	15.82±2.63
6	R	28.38—48.62	1.65—2.53	0.49—0.78	8—24
	M	33.59±61.82	1.89±0.59	0.68±0.05	15.84±2.71
7	R	72.84—105.31	1.88—2.76	0.50—0.79	7—30
	M	95.09±63.65	2.10±0.63	0.69±0.06	17.12±3.01
8	R	86.32—121.03	1.93—2.82	0.53—0.81	8—33
	M	101.01±68.29	2.21±0.68	0.71±0.05	18.30±3.20
9	R	93.82—127.31	2.03—2.90	0.55—0.84	8—36
	M	105.12±77.23	2.23±0.73	0.73±0.06	19.41±5.31
10	R	96.37—131.84	2.08—3.02	0.59—0.85	10—41
	M	105.56±78.86	2.34±0.79	0.74±0.07	19.86±5.42
11	R	102.84—138.31	2.18—3.16	0.59—0.87	9—43
	M	116.21±80.34	2.39±0.83	0.76±0.07	20.10±6.21
12	R	103.61—134.36	2.26—3.41	0.61—0.89	10—45
	M	112.26±76.58	2.43±0.84	0.78±0.08	20.32±6.30
13	R	96.61—130.81	2.34—3.62	0.65—0.90	9—42
	M	111.26±79.32	2.41±0.79	0.79±0.08	19.98±5.96
14	R	94.81—129.01	2.41—3.68	0.65—0.89	11—46
	M	110.34±84.02	2.61±0.86	0.80±0.07	21.01±8.21

Table 1—(*Contd.*)

Site No.		N (x10°cells/1)	H (Bits/ind)	J	S
15	R	92.1—04.126.31	2.52—3.71	0.64—0.92	10—44
	M	110.28±86.85	2.80±0.86	0.81±0.06	20.31±7.86
16		85.84—125.31	2.61—3.86	0.64—0.92	12—49
	M	109.32±75.26	2.93±0.90	0.82±0.08	20.34±7.91
17	R	84.31—122.34	2.81—3.89	0.65—0.94	11—51
	M	109.02±81.45	3.21±0.95	0.84±0.09	21.62±8.64
18	R	82.71—119.31	3.01—4.13	0.66—0.95	13—48
	M	106.27±84.32	3.46±0.92	0.85±0.09	20.21±8.34
19	R	78.31—115.38	3.08—4.31	0.67—0.94	17—53
	M	106.17±86.88	3.51±0.96	0.86±0.08	21.61±9.21
20	R	72.41—112.31	3.13—4.53	0.67—0.95	10—56
	M	103.01±82.09	3.64±0.98	0.85±0.09	22.61±9.91

R=Range; M=Mean, ±=SD

50 percent (from 1 to 50%) of total phytoplankton population whereas a very large percentage of species (69%) contribute to only 20 per cent (from 80 to 100%) of total phytoplankton population. Gradually percentage of species contributing to 50 per cent of total population increases on the subsequent stations and there is a tendency to increase the percentage of species contributing to 50 per cent of total population culmi-

Table 2—Correction co-efficient values (r) among different components of community structure

First half of the study area (from 1 to 10 sampling stations)			Second half of the study area. (from 11 to 20 sampling stations)		
	H	J		H	J
H	—	—	H	—	—
J	0.9970	—	J	0.4634	—
S	0.9873	0.9680	S	0.9836	0.4358

The correlation is significant 1% at level (r values of 0.6843 and above) and at 5% level (r values of 0.5523 and above)

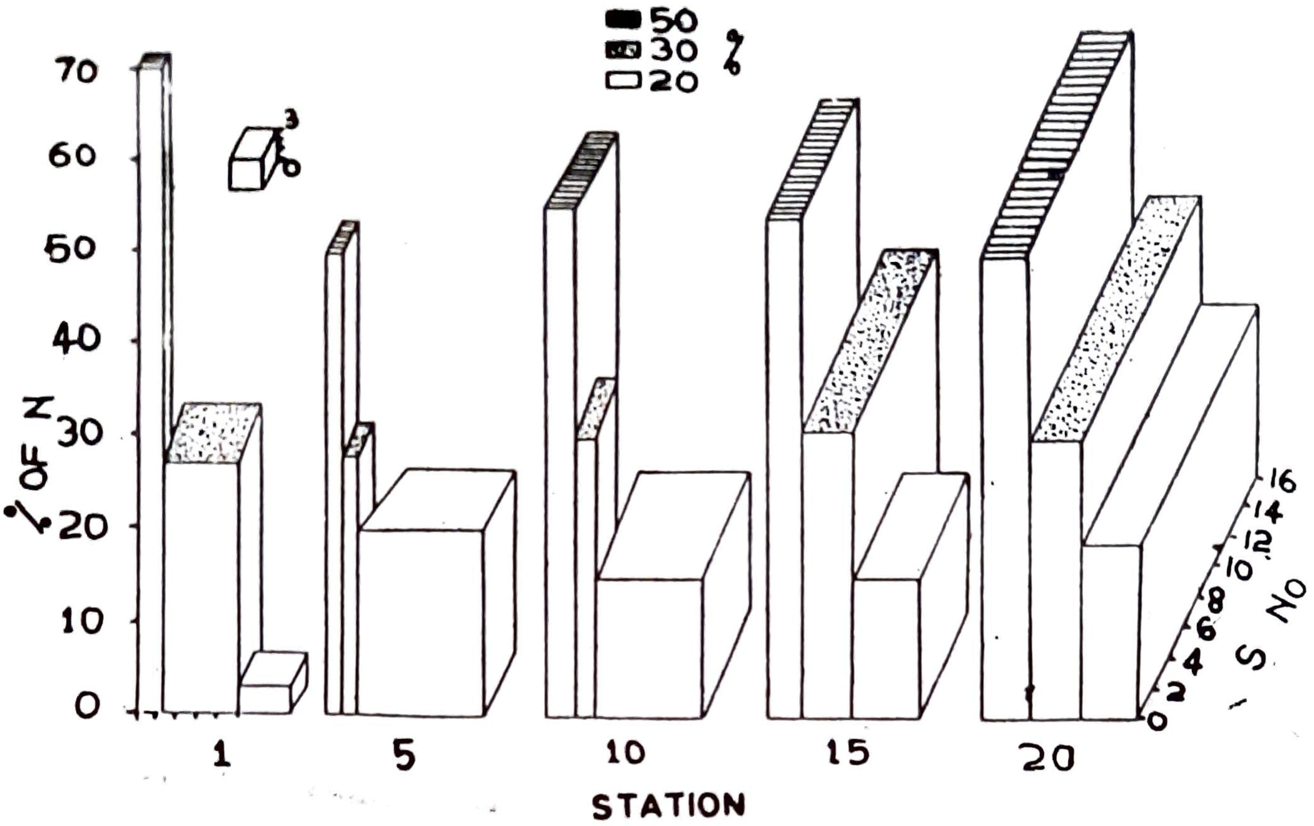
Table 3—Community structure data of arbitrarily chosen water samples at all sampling sites

Station No.	N (X 10^3)	S	H	J
1	8.73	6	1.45	0.56
2	14.82	8	1.79	0.59
3	15.49	10	2.10	0.63
4	20.72	11	2.24	0.64
5	32.79	21	2.95	0.67
6	237.00	24	3.13	0.68
7	261.30	24	3.20	0.69
8	413.10	26	3.36	0.71
9	433.90	27	3.45	0.72
10	387.80	29	3.64	0.75
11	386.00	29	4.10	0.80
12	384.00	29	4.31	0.88
13	355.00	30	4.33	0.89
14	379.00	33	4.60	0.91
15	327.00	33	4.60	0.91
16	382.00	35	4.74	0.92
17	332.00	37	4.75	0.91
18	347.00	39	4.99	0.94
19	310.00	41	5.10	0.94
20	209.76	43	5.16	6.95

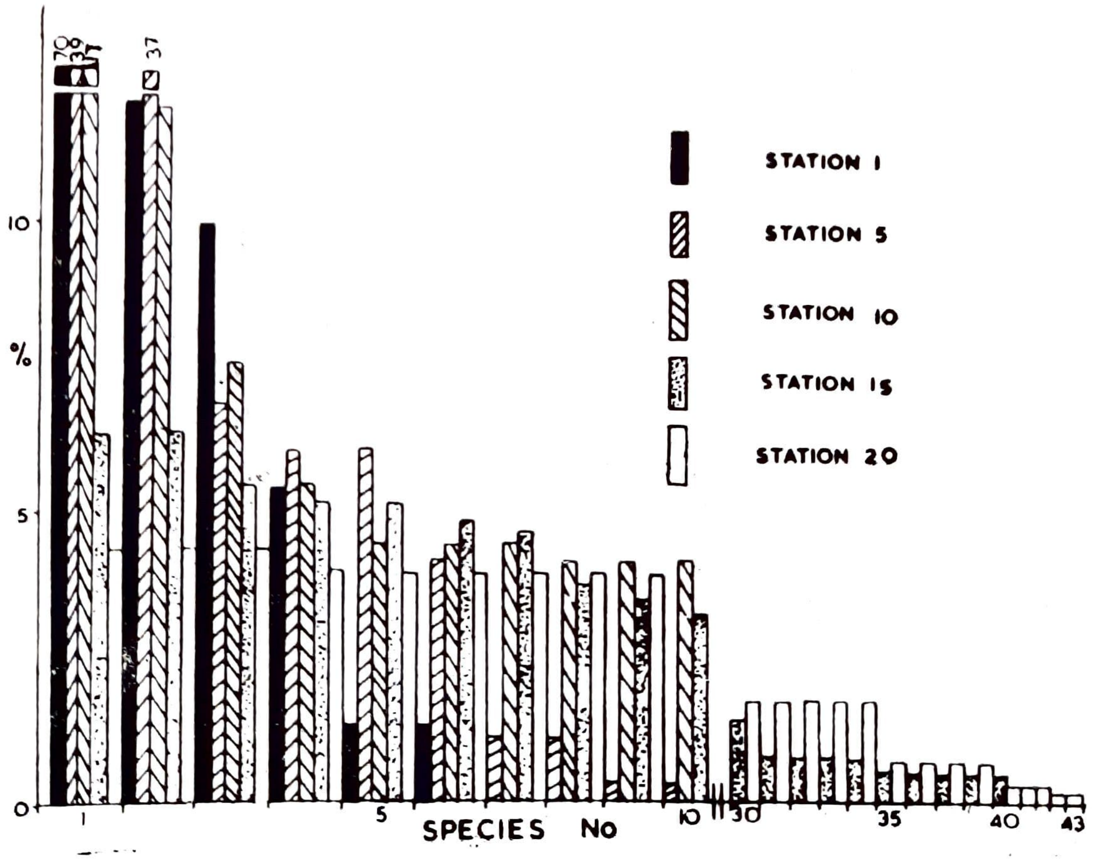
nating at site 20 where maximum percentage of species (30%) contribute to 50 per cent population.

Discussion

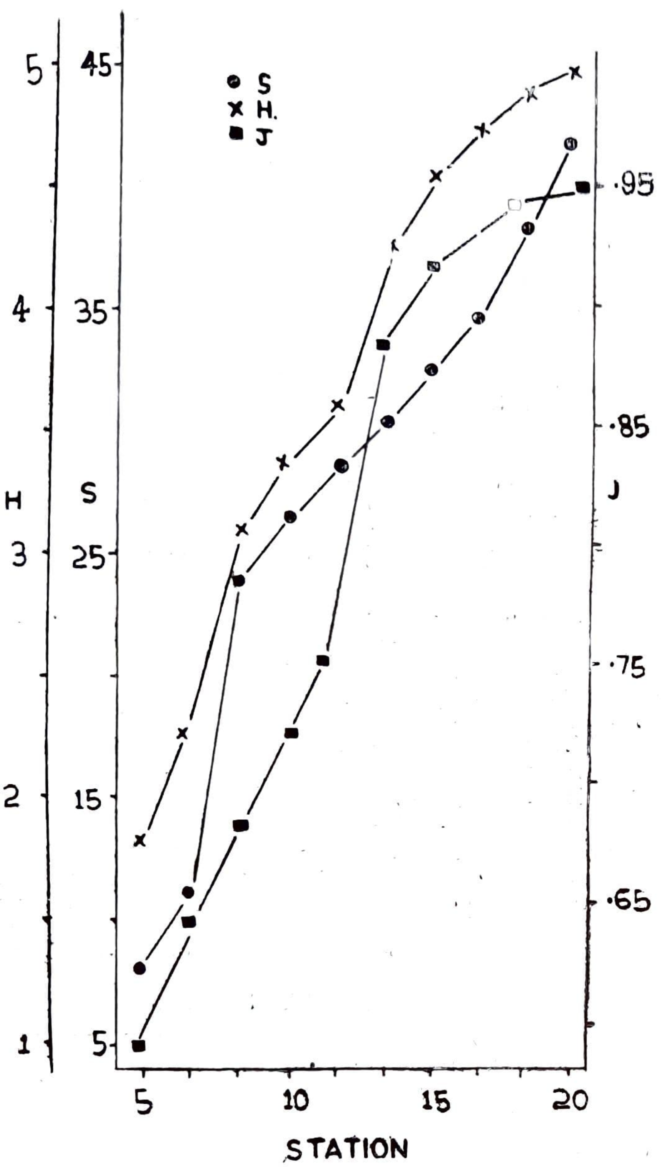
Various methods have been proposed to study the structure of biological communities (Fisher *et al.*, 1943; Preston, 1948; Shannon & Weaver, 1949; Margalef, 1958). The indices derived from the information theory (as Shannon's diversity used in this study also) have been very frequently practised in such studies as these reflect the relative importance of each species present in the community. It is recorded that sharp differences exist in the community pattern of the two investigated areas. It is noted that in the two areas influence of S and J on the species diversity is different. Relative importance of



Text-figure 3—Number and percentage contribution of all the species at 1,5,10,15 and 20th sampling stations.



Text-figure 4—Number and percentage of species contributing to 50 (from 1 to 50), 30 (from 50 to 80) and 20 (from 80 to 100) per cent of total phytoplankton at sampling sites shown in Text-fig. 3.



Text-figure 2—Variation among various components of community structure in arbitrarily chosen water samples.

these components (S & J) in controlling the species diversity has been studied in diverse habitats. Sagar and Hesler (1969) found that equitability among the 10 to 15 most abundant species accounts, largely, for the variation in the phytoplankton community. A further increase in species of low abundance has little to do with the variation in diversity. Tramer (1969) and Kircher (1972) on the basis of their studies on bird population concluded that in the disturbed environments J exercises a more powerful influence over the species diversity but in natural environments S does so. Hajdu (1977) also recorded that in eutrophic fish ponds species diversity was largely J dependent and, on contrary, in unfertilized ponds it was S dependent. In this study it is clearly observed that H shows strong positive correlation with J and S in the first half of the study area. Here J and S also show strong positive correlation. However, in the second half only S shows a strong positive correlation with the species diversity. Mitigation of the influence of J over spceies diversity in the second half of the study area is indicative of a reversion to the normal environmental conditions.

Contribution of single species to the total population influences greately the structure of any community. Van Roalte *et al.* (1976) reported decrease in diatom diversity with the sewage or urea fortification. And contribution of *Navicula salinarum*, which formed 5-9% of diatom population in the controls, became dominant in the fortified plots, comprising 20-25% of the population. Bartha and Hajdu (1979) also found much difference in the number of species contributing to 50 and 95 per cent of phytoplankton population. In this study also it is noted that maximum contribution of single species to the total population ranges from 69 to 3.4 per cent. (Text-fig. 3). Similarly Text-figure 4 also demonstrates the trend in which the distribution of individuals among the different species influenced at the down stream stations.

Conclusions

On the basis of above observations it is quite obvious that sewage discharge exercises considerable influence over the distribution of individuals belonging to the species present and the number of species as well. Half of the study area witnessed fairly low values of H and S and J both strongly influence the species diversity which is indicative of unfavourable environment. However, in the second half the influence of J is reduced and S continues to do so which supposedly indicate the reversion to the natural conditions and dilution of the extraneous causative factors.

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