MICROFLORA OF THE YELLOWSTONE RIVER
II. PERTURBATIONS THROUGH BILLINGS

LOREN L. BAHLS
ENVIRONMENTAL QUALITY COUNCIL
HELENA, MONTANA

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INTRODUCTION

The last floristic survey of the Yellowstone River through Billings was accomplished 20 years ago when the river was receiving a pollution burden much greater than it receives today. In 1955, no bottom organisms occurred in the first 11 miles below waste outfalls at Billings; sewage "fungus" was commonplace; and taste and odor problems were chronic (10).

Today, due largely to the application of pollution control technology, the situation is much improved and the river is getting cleaner (2). Nevertheless, the Yellowstone River from Laurel to Billings remains water quality limited because of discharges from the Laurel and Billings sewage treatment plants, and wastewater discharges from three oil refineries, a sugar beet factory and a coal-fired steam-electric plant. There are also a number of non-point source sediment and oil problems in this reach of the river (5).

This paper describes the response of Yellowstone River algae to a variety of waste discharges originating in the Laurel-Billings municipal/industrial complex. Emphasis is placed on the relationship between the structure of benthic diatom associations and ambient concentrations of selected algal nutrients. This investigation was conducted as a contribution to the biological portion of a waste load allocation study being prepared for this section of the Yellowstone by the Montana Department of Health and Environmental Sciences.

METHODS

Sampling Stations and Schedule

Nine stations were sampled from Laurel downstream to Huntley, including the Clarks Fork River and Yegen Drain:

I. Yellowstone River at Laurel (above Laurel wastewater discharge and confluence with the Clarks Fork River).

II. Clarks Fork River at mouth.

III. Yellowstone River at Duck Creek Bridge.

IV. Yellowstone River at South Bridge (Billings).

V. Yellowstone River below Corette plant.

VI. Yellowstone River at East Bridge (Billings).

VII. Yegen Drain at mouth.

VIII. Yellowstone River below Yegen Drain (above Billings wastewater discharge).

IX. Yellowstone River near Huntley.

Periphyton samples and water samples for algal nutrients were collected at these stations on the dates listed in Table I.

Table I. Sampling Schedule (All samples taken in 1975 except the nutrient sample at Station V, which was collected in 1974)

	Station and Date								
	I	II	III	IV	V	VI	VII	VIII	IX
Nutrient Samples	9/9	9/9	9/9	9/9	7/22	9/9	10/23	10/7	9/9
Periphyton Samples	9/9	9/9	9/9	9/9	9/16	9/9	11/1	11/1	9/9

Field and Laboratory Procedures

At each station, periphyton samples were obtained by scraping natural substrates in proportion to the surface area of each type that was exposed for colonization. (Rocks predominated at most stations.) Substrates from both sluggish and rapidly flowing water were sampled in order to minimize possible bias caused by current effects. This procedure allows for collection of a composite sample that is representative of the range of physical conditions prevailing at each site at the time of collection.

From each sample, a subsample was taken and scanned microscopically to determine the presence and relative importance of non-diatom algae. Then, in a manner prescribed by the Environmental Protection Agency (4), each sample was acidified and oxidized, a permanent mount was prepared, and a diatom species proportional count was performed.

Nutrient analyses were performed at the Department of Health and Environmental Sciences' water laboratory in Helena following methods outlined by the American Health Association (1).

Diversity Measures

Two diversity indexes were applied to the diatom species relative abundance figures obtained from the proportional counts: Margalef's index (9),

$$d = \frac{s - 1}{\ln N}$$

and Shannon's index (12),

$$D = -\sum_{i}^{s} (N_i/N) \log (N_i/N)$$

A series of corollary measures derived from the Shannon index were also applied:

$$DMAX = \log (s)$$

$$DMIN = \log (N) - \left(\frac{N - s + 1}{N}\right) \log (N - s + 1)$$

$$RD = \frac{DMAX - D}{DMAX - DMIN}$$

$$EV = D/DMAX$$

where s = number of taxa in the sample, N_i = number of individuals in taxon i, and N = total number of individuals counted. DMAX and DMIN are theoretical maximum and minimum diversities. RD or redundancy is an expression of dominance by one or more species and is inversely proportional to the wealth of species. (A value of zero is obtained if each individual belongs to a different species and a value of one is obtained if all individuals belong to the same species.) EV or evenness measures the equality of species abundances in a sample; the greater the disparities among species abundances, the smaller will be the evenness.

Another derived measure is Lloyd and Ghelardi's "equitability" (6),

$$e = \frac{s'}{s}$$

where s' is the number of taxa required to produce the observed Shannon index (D) if the taxa are distributed according to MacArthur's "broken stick" model (8). Equitability is more sensitive to pollution than is D; even slight levels of degradation have been found to reduce equitability below 0.5 and generally to a range of 0.0 to 0.3 (4).

RESULTS

Algal Nutrients

The results of algal nutrient analyses are presented in Table II. The Yegen Drain (VII) was a major contributor of all species of nitrogen and phosphorus. The Clarks Fork River (II) introduced appreciably higher levels of nitrate while phosphate was elevated below the Corette plant (V). Overall, comparing nutrient concentrations at Laurel (I) and Huntley (IX), nitrogen species were not appreciably concentrated by discharges through Billings, but phosphate and total phosphorous were.

Non-Diatom Algae

Diatoms dominated the flora at all stations except in and below Yegen Drain where Oscillatoria and Stigeoclonium were the dominant algae, respectively. Euglena and a filamentous bacterium resembling Sphaerotilus were also evident at these two sites. Cladophora glomerata was abundant at Laurel and below the Corette discharge. The remaining 11 genera of non-diatom algae--all greens and blue-greens--were relatively uncommon.

Diatoms

The structure of benthic diatom associations at the nine sites is given in Table III.

The seven major taxa are those that contributed 10 percent or more relative abundance in one or more collections. Pollution tolerances for these taxa were obtained from Cholnoky (3) and Lowe (7). Generally, Achnanthes minutissima and Cymbella affinis are intolerant of organic

Table II. Algal Nutrients in the Yellowstone River Through Billings (All values in mg/l)

Nutrient	Station I	II	III	IV	V	VI	VII	VIII	IX
NO_3 + NO_2 (Total as N)	0.05	0.38	0.05	0.02	0.06	0.05	0.34	0.12	0.06
Ammonia (Total as N)	<0.01	<0.01	<0.01	<0.01	--	<0.01	3.2	0.46	<0.01
Nitrogen (Kjeldahl, Total as N)	0.18	0.45	0.24	0.26	--	0.15	4.0	1.0	0.24
Phosphate (PO_4 as P)	0.006	0.010	0.009	0.004	0.023	0.005	0.100	0.022	0.020
Phosphorus (Total as P)	0.013	0.016	0.013	0.016	--	0.014	0.124	0.032	0.027

Table III. Structure of Benthic Diatom Associations in the Yellowstone River Through Billings

Parameter	Station I	II	III	IV	V	VI	VII	VIII	IX
Major Taxa (%)									
Achnanthes minutissisma	2.0	35.8	25.4	25.0	18.6	21.0	7.4	1.7	9.9
Cymbella affinis	11.6	18.7	23.7	21.2	42.3	15.8	14.4	1.7	16 5
Diatoma vulgare	15.6	0.3	6.7	1.9	3.0	5.7	3.8	2.8	4.9
Navicula cryptocephala v. *veneta*	4.6	8.7	3.8	5.2	3.0	4.1	6.3	29.7	5.5
Navicula mutica								11.7	
Nitzschia dissipata	25.8	8.7	7.3	11.1	16.9	18.0	15 5	5.6	19.7
Nitzschia palea	3.7	2.0	4.7	3.0	1.2	2.7	9.0	27 8	4.1
Total *Nitzschia* species (%)	30.7	15.8	16.8	21.0	20.5	27.1	34.5	41.7	35
Taxa Observed	46	42	51	52	39	47	58	55	46
Taxa Counted (s)	32	28	33	37	27	36	49	37	31
Cells Counted (N)	352	358	342	368	338	366	367	360	345

Table III. (Continued)

Parameter	Station I	II	III	IV	V	VI	VII	VIII	IX
Margalef Diversity (d)	5.29	4.59	5.48	6.09	4.47	5.93	8.13	6.12	5.13
Shannon Diversity (D)	3.74	3.27	3.66	3.81	2.80	3.83	4.47	3.31	3.87
Maximum Diversity (DMAX)	5.00	4.81	5.04	5.21	4.75	5.17	5.61	5.21	4.95
Minimum Diversity (DMIN)	0.87	0.74	0.92	0.97	0.75	0.95	1.29	0.99	0.85
Redundancy (RD)	0.30	0.38	0.33	0.33	0.49	0.32	0.27	0.45	0.26
Evenness (EV)	0.75	0.68	0.73	0.73	0.59	0.74	0.80	0.63	0.78
Equitability (e)	0.59	0.50	0.55	0.54	0.37	0.58	0.67	0.38	0.68

pollution; Diatoma vulgare and Nitzschia dissipata will tolerate only weak organic pollution but thrive where oxidation is complete; and Navicula cryptocephala var. veneta and Nitzschia palea are tolerant of organic pollution. The characteristically aerophilous Navicula mutica is an anomaly in the Yellowstone River. The total abundance of Nitzschia species is generally regarded as a suitable indicator of nitrogenous pollution. With one exception, to be discussed later, these indicator taxa behaved as expected considering their pollution tolerances and the nature and amount of enrichment. Relative abundance values for all major taxa were reasonably close at the stations bracketing the study section (stations I and IX).

The most striking feature about the diversity measures in Table III is the position held by the Yegen Drain collection (VII). Here, taxa observed, taxa counted, Margalef, Shannon, maximum and minimum diversities, evenness and equitability were all conspicuously and unexpectedly maximum. On the other hand, stations in the Clarks Fork River (II), below the Corette plant (V), and below Yegen Drain (VIII) all had depressed diversity levels indicating they were subject to some perturbation. As with relative abundances of the major species, values for diversity measures at the most upstream and downstream stations (I and IX) were fairly close (Table III).

DISCUSSION AND CONCLUSIONS

On the basis of diversity measures, the most severely impacted station on the Yellowstone through Billings was below the Corette plant (V). The great abundance (42.3%) of Cymbella affinis here helped depress diatom diversity to the lowest levels recorded in the present study. Although nutrient data at this site are incomplete and dated, phosphate does appear to be significantly more concentrated here than upstream (Table II). However, the abundance of the saprophobic diatoms C. affinis and Achnanthes minutissima and the relatively minor importance of Nitzschiae indicate chemical water quality below the Corette plant to be rather good. Because C. affinis is a summer diatom, i.e., it prefers warmer waters (7), the stress causing depressed diversity at this location appears to be brought on by elevated temperature from the thermal discharge rather than by some chemical constituent introduced from the ash pond.

While burdened with a much heavier nutrient load (Table II), Yegen Drain (VII) had significantly higher diversity values than other study sites (Table III). Yet when this load was released into the Yellowstone River, diversity values were slightly depressed (Station VIII). One explanation might be that Yegen Drain offers a greater diversity of habitats and a physical environment, in terms of substrate, depth, temperature and flow regime, favorable to a larger variety of benthic diatoms. This situation deserves more attention and illustrates the fact that factors other than pollution load are responsible for biological diversity levels in streams, making them difficult to compare on this basis alone.

Nitzschia palea [illegible]
organic nitrogen compou[illegible]
apparently in response to the [illegible]
Drain (Tables II and III). The [illegible]
acids and liberate free ammonia to [illegible]
sponsible for the rapid reduction in [illegible]
Drain and the eventual recovery to [illegible]
With four times the nitrogen load, it [illegible]
had only one-third the N. palea [illegible]
downstream (VIII). This may be due to [illegible]
physical factors less favorable to N. [illegible]

Except for nitrate (Table II), wat[illegible]
Clarks Fork River (Station II) appears to be [illegible]
relatively low diversity values (Table III [illegible]
discharges through Laurel have no discern[illegible]
stone River periphyton at Duck Creek Bri[illegible]

The phytoplankton data from the [illegible]
not strictly comparable to the data c[illegible]
is evident that water quality has [illegible]
20 years. On the whole, compari[illegible]
Yellowstone River periphyton was not [illegible]
through Billings in 1975. Self-curi[illegible]
flora from pollution may be consid[illegible]

The following individuals
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LITERATURE CITED

1. American Public Health Association. Standard Methods for the Examination of Water and Wastewater, 13th Edition. American Public Health Association, Washington, D. C., 1971.

2. Chaffee, O. "Yellowstone River Getting Cleaner, State Officials Say." Billings Gazette, January 23, 1975.

3. Cholnoky, B. J. Die Ökologie der Diatomeen in Binnengewässern. J. Cramer, Lehre, 1968.

4. Environmental Protection Agency. Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents. National Environmental Research Center, Cincinnati, July, 1973.

5. Karp, R. W., D. A. Klarich and M. K. Borz. Water Quality Inventory and Management Plan, Upper Yellowstone Basin, Montana. Montana Department of Health and Environmental Sciences, Helena, September, 1975.

6. Lloyd, M. and R. J. Ghelardi. "A Table for Calculating the 'Equitability' Component of Species Diversity. J. Animal Ecology, 33:217-225, 1964.

7. Lowe, R. L. Environmental Requirements and Pollution Tolerance of Freshwater Diatoms. Environmental Protection Agency, Cincinnati, November, 1974.

8. MacArthur, R. H. "On the Relative Abundance of Bird Species. Proc. Nat. Acad. Sci., 43:293-295, 1957.

9. Margalef, R. "Diversidad de Especies en las Comunidades Naturales. Proc. Inst. Biol., Apl., 9, 1951.

10. Montana State Board of Health. Pollution of the Yellowstone River as Related to Taste and Odor Problems in Municipal Water Supplies in Montana and North Dakota. A Cooperative Field Investigation Undertaken Jointly with the North Dakota State Department of Health and the U. S. Public Health Service, July, 1950.

11. Schoeman, F. R. A Systematical and Ecological Study of the Diatom Flora of Lesotho with Special Reference to the Water Quality. National Institute for Water Research, Pretoria, South Africa, 1973.

12. Shannon, C. E. and W. Weaver. The Mathematical Theory of Communication. University of Illinois Press, Urbana, 1949.