Ecology of the diatom community of the upper East Gallatin River, Montana with in situ experiments on the effect of current velocity on features of the aufwuchs
by Loren Louis Bahls

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY in Botany
Montana State University

Abstract:
Diatom collections and water chemistry samples were taken and analyzed monthly in 1968 and 1969 from six stations on the East Gallatin River, Montana, one above and five below the effluent of the former Bozeman Sewage Treatment Plant.

The water was found to be of the calcium-magnesium-bicarbonate type. Ortho-phosphate, ammonia, chloride and fluoride increased markedly, below the effluent. All except ortho-phosphate returned to pre-effluent levels within the study area.

A total of 30 genera, 116 species and 138 varieties of diatoms was identified. Nitzschia dissipata was by far the most common diatom in the river, supplanted in dominance only at the station immediately below the effluent by N. epiphytica, a nitrogen heterotroph. The abundance of Nitzschia spp. in the river was related to the presence of consistently high concentrations of total inorganic nitrogen.

The diatom flora of the river was not adversely affected by the effluent; major taxa were the same above and below although their abundance values varied considerably. The upstream station received organic pollution from some unknown source(s).

Plexiglass plates were placed above and below the effluent at measured current velocities for two-week periods. Aufwuchs was scraped from 1.4 dm^2 and analyzed as to dry weight, biomass, chlorophyll and carotenoid absorbance, chlorophyll a weight and relative species composition of the diatom community. The overall mean biomass accrual rate was 0.49 g m^{-2} day^{-1} .

Rates of accrual were nearly identical above and below the effluent although the percentage of total organic accrual due to autotrophic growth alone was almost three times greater at the upstream station. Autotrophic index values indicated recovery of the aufwuchs at the furthest downstream station to the proportion of autotrophs found above the effluent.

Aufwuchs dry weight, biomass and chlorophyll a accumulation correlated negatively with current velocity although some enhancement of accrual was noted up to about 0.400 m/sec. Current was positively correlated with the biomass/dry weight ratio. The growth of Sphaerotilus natans below the effluent was selectively favored by higher velocities.

ECOLOGY OF THE DIATOM COMMUNITY OF THE UPPER EAST GALLATIN RIVER, MONTANA WITH *IN SITU* EXPERIMENTS ON THE EFFECT OF CURRENT VELOCITY ON FEATURES OF THE *AUFWUCHS*

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ABSTRACT

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INTRODUCTION

This paper details a study of the benthic diatoms and water chemistry above and below a sewage treatment plant on the East Gallatin River near Bozeman, Montana. Experiments concerning the effects of current speed on the community of attached bottom organisms are also described.

During the course of this study the Bozeman Sewage Treatment Plant, a primary facility, discharged an average of 0.14 m^3/sec (5 cfs) domestic sewage into the East Gallatin River. This outfall comprised from 10 to 20 % of the total river discharge below the effluent during periods of minimum winter flows. Such an introduction of partially treated sewage was bound to have an effect on the conditions supporting life and the life itself of the river.

The first to note an injurious effect related to the sewage input was a biologist with the Montana Fish and Game Department who in 1966 reported a lack of salmonid reproduction and a significant reduction in salmonid standing crop for several miles below the effluent (personal communication).[1] The effluent itself has since been proven to be lethal to immature trout at concentrations present at minimal river flows (Bahls *et al.*, 1969).

Within a short time thereafter a series of investigations was undertaken to determine effects of the effluent on river conditions

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[1] E. Richard Vincent, Montana Fish and Game Department, Bozeman.

and biota. Soltero (1968, 1969) reported the chemical and physical features; Ehlke (1968) and Ehlke and Soltero (1969) described qualitative and quantitative changes in the bacterial flora below the effluent; and Avery (1969, 1970) characterized the effects of the sewage on the aquatic insects and the salmonids of the river.

Jacobs (1950) had studied the algal flora of the East Gallatin River and noted the effect of the sewage on the numbers of species and individuals. She concluded that the river was not polluted by the Bozeman sewage. This study, however, was conducted shortly after the primary plant began operation, at a time when the population of Bozeman (11,252) was nearly half and the enrollment at Montana State University (2,817) about a third of what it is today. Although she reported diatoms at most of her sampling stations she did not identify taxa. The regional diatom flora thus remained undescribed until the studies of Gumtow (1955), Roeder (1966) and Moghadam (1969).

The East Gallatin River is practically devoid of macrophytes and phytoplankters. The major primary producers are found solely in the periphyton or aufwuchs[2], the latter term coined by Ruttner (1953) to denote a community of organisms that are firmly attached to a substrate but do not penetrate into it. In clear mountain rivers conditions are often excellent for diatom growth (Patrick and Reimer, 1966)

[2]Henceforth in this paper, the underlining of this term will be omitted.

and this group of algae may dominate the aufwuchs as appears to be the case in the East Gallatin.

The species composition and structure of benthic algal communities have often been used to evaluate conditions in rivers receiving pollution, most notably by Butcher (1932, 1940, 1947), Fjerdingstad (1950), Blum (1957) and Patrick (1963). Kolkwitz and Marrson (1908) were among the first to characterize individual diatom taxa according to their degree of affinity for decomposing organic materials. Most other information on the ecological requirements of diatoms is widely scattered throughout the literature except for the recent compendium by Cholnoky (1968).

The more recent trend in studying algal communities of flowing waters emphasizes biomass, chlorophyll and productivity. Certain features of the aufwuchs may be used as indirect measures of water quality and primary production. Margalef (1961) recognized a relationship between diversity and changes in energy flow across an aquatic ecosystem. Unpolluted waters are usually characterized by a large number of species, each with a small number of individuals. With a sudden increase in nutrients (and usually primary production also) certain species take advantage of their innate capacity for population increase, resulting in a decrease of diversity with one or a few species attaining great abundance. Margalef (1951, 1969) has proposed expressions aiming to give indirect estimates of primary production based on present properties of ecosystems and including quantitative terms reflecting the structure of the community (biotic diversity and the phytopigment ratio D_{430}/D_{665}). Weber and McFarland (1969) have proposed the use of the biomass/chlorophyll ratio as an index of water quality. This "autotrophic index" reflects the relative abundance of autotrophic and heterotrophic organisms comprising the aufwuchs.

To study the in situ production (accrual) of aufwuchs and the colonization of benthic algae in lotic environments, investigators have long used various artificial substrates including asbestos, slate, microscope slides, glass plates, sterilized stones, cedar shingles, cinder bricks, styrofoam, cement cylinders, plexiglass plates and sheets of metal and celluloid (Cooke, 1956; Sladeckova, 1962). Plexiglass plates were used in this study because of their inert and durable nature and their non-selectivity (Peters, 1959). Only a few investigators, however, have accounted for the effect of current velocity on the rate of accrual of aufwuchs and the composition of the algal community on artificial substrates (Rawstron, 1961; McIntire, 1966; Ball et al., 1969) and these in only a very general way, comparing but two or a very few categories of current velocity.

The objectives of this investigation were, accordingly, (1) to describe the diatom community of the upper East Gallatin River as a contribution to the regional diatom flora; (2) to determine the effect of organic enrichment on the aufwuchs and the diatom community; and

(3) to determine, using artificial substrates exposed to different water velocities, the effects of current on rate of accrual and various features of the aufwuchs along with species composition of the diatom community.

DESCRIPTION OF THE STUDY AREA

The East Gallatin River is formed by the confluence of Rocky Creek and Bozeman Creek just north of the city of Bozeman, Montana (Figure 1) and flows in a northwesterly direction for 59.5 km (37.0 mi.) to where it merges with the West Gallatin River near Manhattan, Montana. The drainage area of the river includes 384.8 km^2 (148 sq. mi.) at an elevation of about 1,433.2 m (4,701 ft.) above mean sea level and the major land uses are livestock grazing, haying and wheat farming.

The 21 year (1939-1960) average discharge of the East Gallatin measured at a point approximately 0.2 km (0.1 mi.) below the union of Bozeman and Rocky Creeks was 2.44 m^3/sec (86.3 cfs) (U.S.G.S., 1964). Maximum recorded discharge was 35.14 m^3/sec (1,230 cfs) on June 4, 1953 and the minimum was 0.34 m^3/sec (12 cfs) on December 9, 1944 and March 24-26, 1955. The flow is maintained by ground water and surface runoff from the surrounding forested mountainous terrain and augmented by the effluent from the Bozeman Sewage Treatment Plant. The wastewater of this effluent is derived by primary treatment from the "normal" domestic sewage of a population of some 20,000 people.

A major tributary, Bridger Creek, with an average discharge of 1.06 m^3/sec (37.6 cfs) (U.S.G.S., 1959) enters the East Gallatin at a point 2.0 km (1.2 mi.) below the origin of the river and 1.0 km (0.6 mi.) below the sewage effluent. Two minor tributaries, Middle Creek and Middle Cottonwood Creek, enter the river further downstream.

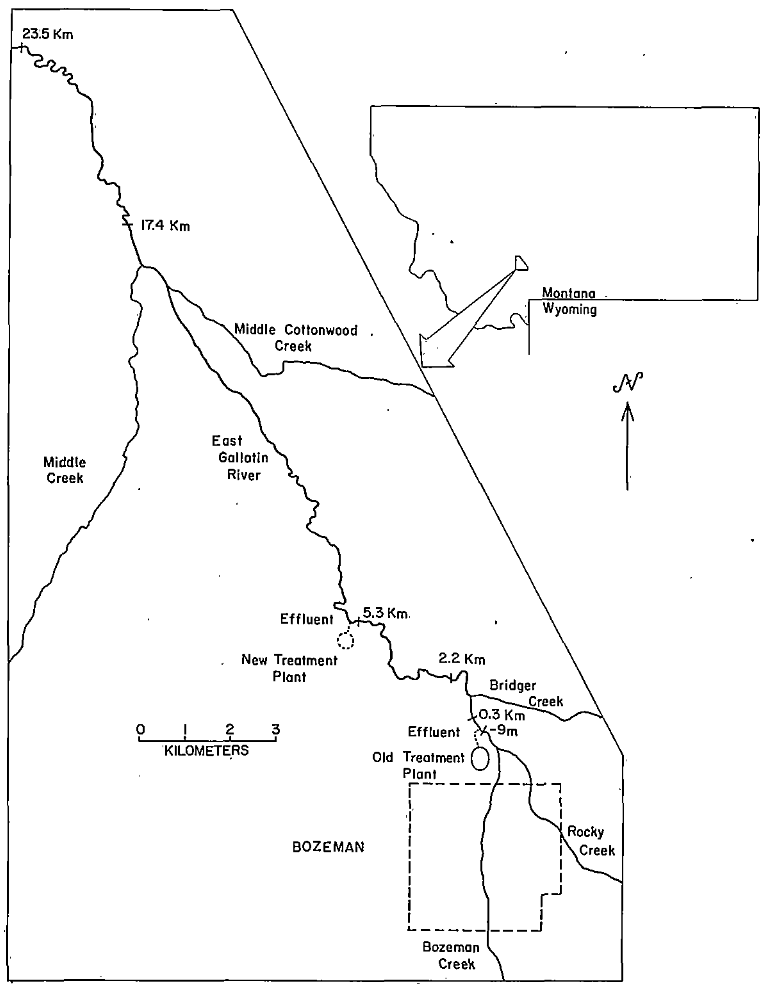

Figure 1. Map of the upper East Gallatin River system showing the locations of sampling stations and effluents of the old and new sewage treatment plants.

The East Gallatin River varies from 2 to 9 m (7 to 30 ft.) in width during low water and in depth from several centimeters in the riffles to more than 2 m (7 ft.) in some pools. The substrate of the river consists mainly of cobbles and coarse to fine gravel. The river water is of the calcium-magnesium-bicarbonate type (Soltero, 1969).

Following the completion of this study the new Bozeman Waste Water Treatment Plant was built at the site indicated on the map (Figure 1) to replace the overloaded primary plant. This plant went into operation in December, 1970 and now provides secondary (aeration and clarification) as well as primary treatment to the Bozeman sewage.

Six sampling stations were established on the river, one above and five below the effluent of the original treatment plant. Each station encompassed both pool and riffle situations.

The upstream station was located 9 m (30 ft.) above the sewage effluent and shall henceforth be designated as station -9 m.

The first downstream station was located 0.3 km (0.2 mi.) below the effluent at a point where the discharged waste was thoroughly mixed with the river water. This station is about 0.7 km (0.4 mi.) above the mouth of Bridger Creek.

The second downstream station was located 2.2 km (1.4 mi) below the effluent. This station is 1.2 km (0.7 mi.) below the mouth of Bridger Creek.

The third downstream station was located 5.3 km (3.3 mi.) below the effluent and just above the effluent of the new treatment plant.

The fourth downstream station was located 17.4 km (10.8 mi.) below the effluent.

The fifth and last downstream station was located 23.5 km (14.6 mi.) below the effluent.

METHODS

Water samples for chemical and physical analyses and diatom collections from natural substrates were made monthly at all six stations according to the schedule in Table I.

Table I. Sampling schedule of water chemistry and diatom collections from natural substrates.

MONTH	CHEMISTRY (Day)	DIATOMS (Day)
July, 1968		18
August, 1968		15
September, 1968	9	16
October, 1968		16
November, 1968	11	18
December, 1968	16	16
January, 1969	13	13
February, 1969	10	10
March, 1969	10	25
April, 1969	13	
May, 1969	17	
June, 1969	16	
July, 1969	13	
August, 1969	11	

Chemical and Physical Determinations

Water was collected in twice-rinsed standard 2.5 l (0.7 gal.) glass acid jugs with plastic caps. The jug was completely immersed in the river and filled slowly to maximum capacity, capped and immediately returned to the laboratory for analyses.

Temperature and Conductivity

Water temperature (C) was measured with a pocket thermometer at the time of collection of each water and diatom sample. In addition, maximum and minimum water temperatures at -9 m and 23.5 km were measured with Taylor self-registering thermometers for a month and a half period through the midsummer high temperature peak in 1969.

The electrical resistance of each sample was measured with a YSI Conductivity Bridge (Model 31) coupled with an Industrial Instruments (Model CEL 4) dipping cell. The specific conductance at 25 C was then computed from the observed resistance, correcting for temperature and cell resistance.

Water Chemistry

The pH values of the samples were measured with a Beckman Expanded Scale pH Meter (Model 76).

Calcium, magnesium, total alkalinity, sulfate, ortho-phosphate, fluoride, chloride, nitrite, nitrate, ammonia, silica and turbidity determinations were made as described by the American Public Health Association (1965). The colorimetric apparatus used in the various