MICROFLORA OF THE YELLOWSTONE RIVER
III. THE NON-DIATOM ALGAE

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ENVIRONMENTAL QUALITY COUNCIL

HELENA, MONTANA

MARCH, 1976

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Contents

Preface

Prior surveys of Yellowstone River algae (9, 14, 16) addressed only a few stations in the middle and lower river during something less than a full seasonal cycle. The most extensive of these studies was accomplished by the Public Health Service (9) nearly a quarter of a century ago when the river was receiving a much greater organic load than it is today. To the author's knowledge, a seasonal analysis of algae form the entire length of the river in Montana has not been undertaken until this time.

Proceeding with the business of impounding or allocating water from the Yellowstone without knowledge or regard for the river's primary producers--algae--is akin to applying water to an irrigated pasture or field without knowing what kind of crop is being produced or the water and nutrient requirements of that crop. Algae are a significant resource that should not be overlooked. They provide food for invertebrate animals, help keep the water aerated, regulate the water's chemical balance and readily assimilate waste products (ammonia) that may prove toxic to other organisms in the river. In excess they can also be a nuisance, either physically or by causing taste and odor problems. Moreover, algae are valuable indicators of water quality conditions that may impair use of the water by fish or for municipal, industrial or agricultural purposes.

This report on the Yellowstone's non-diatom algae is a first approximation, a crude sketch, of the plant life of one of Montana's finest rivers. It is offered as a small step toward closing an immense knowledge gap in the belief that some awareness of the river's native flora, if heeded, will be beneficial for guiding future management of the river. The Yellowstone remains, following this brief overview and what has been accomplished before, an ecological frontier for serious research in phycology.

A five-part series on the microflora of the Yellowstone River is proposed. Parts I and II preceded this report. Part I (1) reported on three phytoplankton samples taken near the confluence of the Bighorn River early in 1973. The non-diatom algae from those samples are included in the report, along with the correction of a taxonomic error committed in Part I. Part II (3) took an intensive look at the microflora of the middle river between Laurel and Huntley and described its response, in terms of indicator species and species diversity, to a variety of discharges entering the river in that stretch.

Parts IV and V will follow this report. Part IV will deal with the diatoms, unquestionably the most diverse and perhaps functionally the most important group of algae in the river. It is estimated that between 300 and 400 species and varieties of diatoms inhabit the Yellowstone. Because diatoms are the author's specialty and area of primary interest, and because of their apparent importance in the river's trophic structure, the major share of his effort will be spent on Part IV. The final installment, Part V, will attempt to predict the effects of altered flow regimes, including impoundment and dewatering, upon the composition of the river's algal associations and their ecologic and economic implications.

This report would not have been possible without the assistance of four Montana Department of Fish and Game employees who did most of the field collecting: Dennis Schwehr, Missoula; Rod Berg, Livingston; Larry Peterman, Miles City; and Bob Newell, Glendive. The Department of Fish and Game also contributed some essential laboratory supplies. Duane Klarich, Montana Department of Health and Environmental Sciences, Billings, contributed a number of additional samples. Roger Knapton, hydrologist for the Geological Survey, Helena, permitted examination of the most recent National Stream Quality Accounting Network (NASQAN) phytoplankton data. Thanks are also due Marian Higgins, secretary for the Environmental Quality Council, who typed this report, and to my wife, Peggy, who performed all statistical calculations. The writing of this report was supported in part by the Environmental Quality Council. The remaining time and effort involved were contributed by the author and all errors, opinions, etc. are his alone.

Introduction

This report describes the non-diatom algae in 299 periphyton and phytoplankton samples taken at 49 stations in the Yellowstone River and tributaries between April 1973 and November 1975. (Station descriptions and the number of samples analyzed per station are provided in appendices A and B.) The ecological requirements of, and the implications of altered flow regimes on, the Yellowstone's dominant non-diatom taxon--*Cladophora glomerata*--are discussed at length. Prior and ongoing Yellowstone River algae research efforts, which in many cases complement the results reported here, are reviewed. A key to the common algae of the Yellowstone River is provided (Appendix D).

Other than *C. glomerata* and three other species, one of which is unispecific and the other two with distinct and easily recognizable characteristics, only generic indentifications are provided. Although a generic approach forfeits a certain amount of species-related ecological information, it allowed for a much more rapid analysis of the samples in the face of the apporaching expiration of the Yellowstone water moratorium. Moreover, suitable algal material and keys for identifying many species were not available to the author.

In August and September 1952 the Public Health Service (9) surveyed the phytoplankton in the Yellowstone, Clarks Fork, Bighorn and Powder rivers at 11 stations between Laurel and Glendive in response to complaints of taste and odor problems in domestic water supplies. About 10 years later, Williams (16), also with the Public

Health Service, determined the percent occurrence of plankton algae at Sidney over a one year period. More recently, Stadnyk (12) measured biomass standing crop and autotrophic index of the periphyton (attached) community at three stations between Gardiner and Billings. Westinghouse (14) identified and counted plankton (suspended) algae at two stations near the mouth of Armells Creek. Bahls (1) (also reported in Montana Department of Natural Resources and Conservation (6)) identified suspended algae collected in three net samples taken near the mouth of the Bighorn River. An up-to-date review of Yellowstone algae work was presented to the Fort Union Coal Field Symposium in April 1975 (2). Since October 1974, the Geological Survey (5) has been sampling monthly for phytoplankton and quarterly for periphyton and chlorophyll at a total of five stations on the Yellowstone, Tongue, Powder and Bighorn rivers. An intensive study of the microflora of the middle river between Laurel and Huntley, and its response to a variety of waste discharges, was prepared for presentation at the 1976 annual meeting of the Montana Academy of Sciences (3).

The 1952 Public Health Service survey (9) provides opportunity for historical comparison with more recent findings. That survey and the studies by Williams (16) and the Geological Survey (5), all of which apparently sampled for nannoplankton, allow for comparison with the net plankton described in the present study. Additional taxa identitied in these three studies and not in the present study are included in the checklist in Appendix C.

This report is neither exhaustive nor definitive, but it is hoped that it will be a worthy contribution to an expanding fund of ecological knowledge designed to permit informed scientific management of the Yellowstone's aquatic resource.

Methods

Instructions for sampling the periphyton and phytoplankton communities were supplied to field personnel prior to commencement of sampling. Representative samples were obtained in the following manner:

Phytoplankton. Plankton samples were collected by suspending nets of various mesh sizes in the current for a period of 5 minutes or until a few cubic centimeters of drifting material were entrapped. Nine of the 126 "plankton" samples were collected using invertebrate drift nets, mesh size unknown. Twenty-seven more were obtained with a large oceanographic plankton net, mesh size also unknown. For the remaining three-quarters of the plankton samples a Wisconsin-type plankton net with a mesh size of 80 microns was used. No effort was made to collect nannoplankton and for the purpose of this report "plankton" should be considered only as net plankton.

Periphyton. Benthic algal growths were scraped with a carefully cleaned pocket knife from whatever substrates they happened to colonize. Substrates (mud, rocks, logs, etc.) were scraped in proportion to their importance at a given station. Samples were also representative of the amount of pool, riffle and run habitat present at or near each station. No attempt was made to gather a quantitative sample, i.e., to determine the number, weight or volume or organisms per unit of bottom area.

The great majority of samples was collected at monthly intervals between August 1974 and April 1975. All samples were preserved with either formalin or Lugol's solution and shipped to Helena for analysis.

Each sample was vigorously agitated, a few drops pipetted onto a glass microscope slide, and portions of any large filamentous algae not taken up in the pipet added to the subsample on the slide roughly in proportion to their abundance in the sample. The slide therefore contained a miniature of the orginal sample with both micro- and macroscopic algae present in approximately the same proportion as in the original.

The subsample on the slide was then covered with a coverslip and this "wet mount" observed under low (100X) and medium (400X)magnifications. In scanning the subsample, all non-diatom taxa were identified to genus. Where either diatoms or a non-diatom taxon clearly dominated the sample, this was noted, along with the presence of non-algal microorganisms.

Combining all stations on the Yellowstone, the percent frequency of occurrence and percent frequency of dominance were computed for each taxon, separately for the periphyton and plankton communities and collectively for all samples regardless of community origin. Percent frequency of occurrence was also computed for the 19 most common non-diatom taxa at the 19 principal Department of Fish and Game stations on the Yellowstone, thereby describing the longitudinal distribution of these taxa.

Results

General Observations. A large portion of many of the plankton samples consisted of bits of detritus and recognizable pieces of terrestrial plants, indicating that allochthonous organic matter may contribute significantly to the energetics of the river. Non-diatom algae appearing in the plankton, particularly in winter, usually appeared in a senescent and piecemeal condition. This was especially true of the filamentous Chlorophyta, which were apparently detached from their holdfasts, torn to bits by the current and introduced into the floating community as incidental plankton or tychoplankton. This probably occurs when new growth exceeds the plant's ability to maintain itself in the current and represents a built-in mechanism for keeping the growth of large filamentous benthic algae under control. No aquatic macrophytes, i.e., angiosperms or mosses, were found in the samples, however, they may be present in the river. A host of non-algal microscopic creatures was observed, including nematodes, oligochaetes, protozoans, rotifers, ostracods, tardigrades, bacteria, fungi, water mites, the nauplius stage of a copepod and very early instars of midges and mayflies.

Non-diatom Flora. A checklist of algae taxa from the Yellowstone River and tributaries appears in Appendix C. The Yellowstone River was respresented by four divisions, five classes, and 39 genera of non-diatom algae. It is appropriate to note here that identification of the red alga *Audouinella* in Part I(1) was incorrect. This has since been positively identified as senescent *Stigeoclonium*, which responds inconclusively

to a starch test and has lost the long attenuated filament tips typical of the genus. Consequently, no representatives of the Rhodophyta have been identified from the Yellowstone or its tributaries as reported previously.

The frequency at which diatoms and the non-diatom taxa appeared in the Yellowstone River samples is shown in Table 1. Diatoms appeared in all samples while *Cladophora glomerata* occurred in about three-quarters of all samples. Other major taxa, in descending order of frequency, were *Oscillatoria* (59.4%), *Ulothrix* (40.0%), *Stigeoclonium* (26.4%), *Closterium* (25.6%), *Cosmarium* (20.5%), *Scenedesmus* (15.4%), *Phormidium* (13.8%), and *Spirogyra* (13.4%). Most taxa appeared in the plankton at roughly the same frequency they appeared in the periphyton.

The frequency at which diatoms and non-diatom genera dominated Yellowstone River samples appears in Table 2. Diatoms dominated half of all samples collected. Although many non-diatom algae occurred frequently as shown in Table 1, only one--*Cladophora glomerata*--was consistently abundant as well as present in the Yellowstone samples. In fact, *C. glomerata* was more frequently the dominant taxon in periphyton samples than were diatoms. In most cases where diatoms were dominant, *C. glomerata* was a close second, and vice versa. Only five other non-diatom taxa were ever dominant and all were dominant infrequently.

Table 1. Percent frequency of occurrence of algae taxa at all stations in the Yellowstone River.

Taxa	All Samples	Periphyton Samples	Plankton Samp
acillariophyceae (Diatoms)	100.0%	100.0%	100.0%
ladophora glomerata	75.2	75.9	74.3
scillatoria	59.4	56.0	63.7
lothrix	40.0	31.2	48.7
tigeoclonium	26.4	14.2	41.6
losterium	25.6	31.2	18.6
osmarium	20.5	27.0	12.4
cenedesmus	15.4	20.6	8.8
hormidium	13.8	18.4	8.0
pirogyra	13.4	7.8	20.4
ydrurus foetidus	8.3	2.8	15.0
icrospora	7.5	4.3	11.5
ougeotia	7.1	5.0	9.7
nkistrodesmus	5.5	6.4	4.4
yngbya	4.3	2.8	6.2
nteromorpha	3.9	5.0	2.6
edogonium	3.9	3.6	4.4
taurastrum	3.9	1.4	7.1
nabaena	3.5	5.0	1.8
ediastrum	3.5	3.6	3.5
hlorella	2.8	3.6	1.8
hlamydomonas	2.4	0.7	4.4
uglena	2.0	2.8	0.9
erismopedia	1.6	2.1	0.9
pirulina	1.6	0.7	2.6
lanktosphaeria	1.2	1.4	0.9
elenastrum	1.2	2.1	-
hamaesiphon incrustans	0.8	0.7	0.9
ivularia	0.8	0.7	0.9
alothrix	0.4	0.7	-
ylindrocapsa	0.4	0.7	-
omphosphaeria	0.4	0.7	-
oniochloris	0.4	0.7	-
yella	0.4	0.7	-
icrocoleus	0.4	-	0.9
onostroma	0.4	-	0.9
ocystis	0.4	-	0.9
hacus	0.4	0.7	-
etraspora	0.4	0.7	-
ribonema	0.4	-	0.9

Table 2. Percent frequency of dominance of algae taxa at all stations in the Yellowstone River.

Taxa	All Samples*	Periphyton Samples	Plankton Samples*
Bacillariophyceae (Diatoms)	50.0	44.0	56.6
Cladophora glomerata	39.8	47.5	29.2
Enteromorpha	2.4	3.6	0.9
Spirogyra	2.0	2.8	0.9
Hydrurus foetidus	1.2	0.7	1.8
Stigeoclonium	0.8	0.7	0.9
Phormidium	0.4	0.7	-

*These columns will not add to 100 percent because a clearly dominant taxon was not evident in all plankton samples.

Distribution. The frequency of occurrence of the 19 most common non-diatom algae at the 19 Department of Fish and Game Yellowstone River sampling stations is exhibited in Table 3. (A key to these 19 taxa is provided in Appendix D.) Only *Cladophora glomerata* occurred at all 19 stations from Corwin Springs to Cartwright, North Dakota. Most of the other taxa showed a preference for one or two sections of the river. The first six taxa in Table 3--*Enteromorpha*, *Microspora*, *Hydrurus foetidus*, *Ulothrix* and *Oedogonium*--achieved their greatest development in the upper river. Most of these are typically cold water taxa. The next five taxa appeared to be evenly distributed in the upper and middle river with little representation in the lower river. These are followed by seven taxa, including *Cladophora glomerata*, which appeared in all three reaches of the river and did not clearly prefer one reach over the other two. Only one taxon, *Staurastrum*, was exclusively characteristic of the lower Yellowstone River.

Table 3. Percent frequency of occurrence of common non-diatom algae taxa at the principal stations of the Yellowstone River *

	RIVER SECTION AND STATION																		
	Upper Yellowstone								Middle Yellowstone						Lower Yellowstone				
TAXA	1	2	3	4	5	6	7	8	9	10	11	13	14	15	16	17	18	19	20
Enteromorpha	33.3	11.8	5.6												12.5				
Microspora	50.0	17.6	22.2		7.1		6.2												
Mougeotia	22.2	11.8	5.6	11.8	14.3		12.5	12.5	7.1	5.9									
Hydrurus foetidus	5.6	23.5	22.2	23.5	14.3	7.1	6.2	6.2	7.1		6.7								
Ulothrix	77.8	82.4	72.2	58.8	71.4	78.6	56.2	43.8	14.3	23.5	13.3								
Oedogonium	11.1					7.1	6.2	18.8	14.3			12.5							
Anabaena	5.6				7.1	7.1		6.2			6.7			12.5					
Phormidium	16.7	23.5	16.7	17.6	14.3		6.2	43.8	14.3	35.3			14.3	12.5			11.1		
Spirogyra	11.1	5.9	5.6	5.9	7.1	7.1	18.7	12.5	21.4	11.8	40.0	25.0	28.6	12.5					50.0
Oscillatoria	72.2	58.8	72.2	76.5	85.7	71.4	56.2	68.8	85.7	76.5	60.0	62.5	42.9	37.5	37.5		22.2		
Stigeoclonium	22.2	17.6	5.6	17.6	35.7	50.0	62.5	43.8	28.6	29.4	20.0	12.5	42.9	25.0	37.5		11.1		12.5
Closterium	16.7	23.5	27.8	11.8	50.0	50.0	6.2	43.8	21.4	23.5	13.3		28.6	25.0	37.5	25.0	11.1	33.3	12.5
Scenedesmus	5.6	11.8	5.6	5.9	7.1	14.3	12.5	31.2	14.3	17.6		12.5	14.3	12.5	37.5	50.0	33.3	16.7	25.0
Cladophora glomerata	33.3	70.6	72.2	88.2	92.9	92.9	81.2	100.0	85.7	88.2	66.7	75.0	100.0	87.5	37.5	62.5	77.8	16.7	62.5
Cosmarium		11.8	5.6	11.8	21.4	21.4	18.7	37.5	42.9	23.5	13.3	12.5	14.3	25.0	37.5	37.5	22.2	16.7	12.5
Ankistrodesmus		5.9	5.6	11.8				6.2	14.3							12.5	22.2		12.5
Pediastrum			5.6			7.1	6.2	18.8						12.5	12.5				
Lyngbya				5.9	7.1	14.3		12.5		5.9	13.3						11.1		12.5
Staurastrum													14.3	12.5	25.0	25.0	33.3		12.5

*Principal stations correspond to the Montana Department of Fish and Game aquatic invertebrate sampling stations. Refer to Appendix A for locations.

This genus is generally the commonest of desmids in the freshwater plankton, and several species are strictly planktonic in habit (10). Besides Staurastrum, of the 19 most common taxa in the Yellowstone, Hynes (4) mentions Pediastrum, Anabaena, Scenedesmus, Ankistrodesmus and Lyngbya as possible members of the potamoplankton. The most common of these in the Yellowstone was Scenedesmus, which occurred in 15.4 percent of all samples but, curiously, was more than twice as common in the periphyton than in the plankton (Table 1). This is understandable considering Hynes' explanation that many plankters are of benthic origin or are derived from backwaters and side channels. None of these planktonic non-diatom algae ever dominated a Yellowstone sample, which is to be expected when one considers that diatoms almost always dominate the plankton of larger rivers worldwide (4), as they apparently do in the Yellowstone River (Table 2).

Several taxa exhibited seasonal preferences in the Yellowstone, most likely in response to changing light and temperature regimes. Enteromorpha, Closterium, Cosmarium and the planktonic Chlorophyceae mentioned above clearly preferred the warmer and brighter months. This agrees with Hynes' observation that green algae plankters generally occur only in summer or in permanently warm waters (4). Temperature is also known to encourage development of blue-green algae, but none of the Cyanophyta in the Yellowstone appeared to be clearly favored by a rise in temperature concomitant with a change in season. Hydrurus foetidus and Ulothrix (including U. zonata) clearly preferred the cooler months. _Hydrurus_ is essentially a cold-water organism and is found in mountain streams in both the eastern and western U. S. (10).

Discussion

The Yellowstone River net plankton reported here (Tables 1 and 2) and the nannoplankton reported in earlier and ongoing studies (5, 9, 16) differ considerably in composition, except that in all cases diatoms were reported as the dominant group. None of the filamentous Chlorophyceae in Table 1 were reported in the nannoplankton by other workers nor were any of the five dominant non-diatom plankton taxa listed in Table 2, including Cladophora glomerata. The reason is primarily because the net plankton drift method employed here selects for larger (filamentous) forms as opposed to the smaller cells, which may pass through the meshes of the net. On the other hand, a water bottle sample would select for the smaller organisms occurring at higher densities in a given volume of water, and against the occasional detached and drifting filament.

It is evident from all Yellowstone algae studies that suspended algae of benthic origin make up the bulk of both the net plankton and the nannoplankton. Very few of the algae observed in the plankton are typical or "true" plankters, but these may be well concentrated in some reaches (9). However, many of the detached and suspended benthic forms are either dead or dying. The Public Health Service (9) reported more dead than living diatoms in the plankton and much of the suspended filamentous Chlorophyceae appeared degenerate in the present study. (Recently developed staining techniques could be employed to more accurately determine the ratio between synthesizing and decomposing

plankters.) Nevertheless, it is likely that a considerable number of suspended diatoms, green and blue-green algae are viable and capable of synthesis as they drift in the current. Consequently any primary production study on the Yellowstone must take the suspended periphyton into account and should partition plankton synthesis from benthic synthesis.

Not only do benthic forms dominate the plankton, but all the typical plankters were encountered in the periphyton, some more frequently than in the plankton. Two reasons account for this: (i) the net method underestimated the small plankters and (ii) even many true plankters arise from the periphyton (4). This situation illustrates the interconnectivity and indistinct boundaries of these two communities in the Yellowstone River.

In 1952 it was observed that Cladophora and diatoms dominated the periphyton from Laurel to Glendive, with Cladophora most abundant from Laurel to Huntley and diatoms most abundant from Custer to Glendive (9). This was at a time when the river was receiving a much larger organic waste load than it is today. Now, with less organic pollution, it appears that diatoms and Cladophora are evenly matched as co-dominants of the periphyton throughout the length of the river (Table 2).

Among the non-diatom algae, Cladophora glomerata is far and away the most important taxon in the Yellowstone River in terms of frequency and abundance. In other waters, Cladophora often becomes a nuisance, however there is evidence that in quantity this alga may be functionally significant, both in providing substrate and habitat for epiphytes and micro-organisms, and as an energy source via the decomposer → consumer pathway. For these reasons, any water management proposal for the Yellowstone River should take into account the biology and ecological requirements of this green alga. The information that follows was extracted from an extensive review of the genus *Cladophora* conducted by Whitton (15).

Cladophora glomerata appears to be the most abundant alga in streams throughout the world. In temperate waters at this latitude it has two annual growth peaks, the larger in summer (August) and the smaller in spring (May). The temperature range for optimum growth appears to be from 10°-24°C. *C. glomerata* is favored by high light intensities. It is absent from quiet waters; the flow of water past *Cladophora* appears to be required for efficient use of nutrients. Floods may periodically remove the standing crop of *Cladophora* but they are important in removing other algae from rocks to provide a bare substrate for attachment by *Cladophora* zoospores. *Cladophora* is usually abundant only in shallow, rapid water with a rocky substrate or exposed bedrock. It is favored by hard or very hard water with a high pH. Growth responds directly to nitrogen and phosphorous levels and is favored by high P/N ratios. *Cladophora* supports a characteristic epiphytic flora most frequently consisting of *Chamaesiphon*, *Oedogonium*, *Diatoma*, *Cocconeis* and *Rhoicoshpenia*, all of which have been observed in the Yellowstone.

Several invertebrate taxa, including large numbers of chironomids and larvae of *Caenis* sp. and *Leuctra* sp., are harbored by *Cladophora*.

Whitton (15) further describes a generalized seasonal cycle for *C. glomerata* in temperate rivers:

> . . .In spring, the thick-walled overwintering filaments firmly attached to rocks start to produce upright branches. When light intensities are high, and the water temperature reaches about 10°C., upright growth develops rapidly, and by early summer growths are at a maximum. For one or more of the reasons described earlier, the crops usually decrease, and the rate of vegetative growth apparently slows down. In early autumn there is usually another period of rapid growth giving rise to zoospores, which settle on rocks and produce new filaments, and some of these themselves produce zoospores. Much of the autumn crop may be derived from such new filaments. In late autumn the upright parts of the plants become detached leaving the basal fragments attached to rocks. . .

This closely parallels the seasonal cycle of *Cladophora* in the Yellowstone River.

Large growths of *Cladophora*, commonly known as blanket-weed in other parts of the world, can be a nuisance in many ways. Detached masses washed up on shores can interfere with recreational pursuits, particularly when the alga is rotting. Large submerged growths can interfere with boating and swimming and are generally unpopular with anglers because, as they complain, it interferes with their lines, provides poor habitat for fish food and causes fish mortalities. (Fish kills in *Cladophora* infested waters may result more from sewage-derived ammonia toxicity rather than from depressed oxygen levels due to nocturnal respiration.) Algacides have been used for short-term control of *Cladophora* while long-term control has been accomplished by lowering nutrient levels, either by improving sewage treatment or by discharging the effluent elsewhere. Conditions that are likely to enhance the growth of *Cladophora* are: decreasing turbidity; smoothing flows and reducing temperature extremes via flow regulation; and any increase in hardness or in phosphate levels.

Whitton (15) concludes his review as follows:

> It is reasonable to assume that *Cladophora* played a relatively minor role in aquatic communities before the activities of man led to widespread nutrient enrichment. Certainly it is hard to imagine a situation where massive growths could develop in flowing waters without man's activities. . .*Cladophora* as a genus is favored by high light intensities, high water turbulence, high nutrient levels, high pH values, hard waters. Not all species share all these characters, but *C. glomerata*, the species which has increased the most as a response of man's activities, is the organism which combines all these characters within a single species.

Unfortunately, we have no record of the Yellowstone's algal flora before civilization came to the Yellowstone Valley. But we do know that *Cladophora glomerata* now plays a dominant role in the river. And from Whitton's closing remarks it is possible that it came to assume that position through cultural enrichment. If this is so, then the nutrient contributions of man are pervasive throughout the drainage because *C. glomerata* is abundant the length of the river (Table 3).

Nevertheless, there is considerable evidence that naturally high background nutrient levels exist in the upper river above Laurel. Autotrophic index (AI) levels reported by Stadnyk (12) indicate eutrophic conditions from Corwin Springs downriver to Laurel, The maximum average monthly AI at Corwin Springs (296) indicates moderate eutrophication while the equivalent measurement at Laurel (676) indicates gross nutrient enrichment. Diatom species indicators and diversity indexes (Bahls, unpublished data) lend support to Stadnyk's findings. *Stigeoclonium*, a polluted water cohort of *Cladophora* preferring even more enriched situations, is also a common resident of the upper and middle river (Table 3). Phosphate and nitrate have been shown by Thurston *et al*. (13) to be maximum in the upper river.

There is no evidence, however, that *C. glomerata* is or ever was a nuisance in the Yellowstone River. "Dominance" as reported in this paper is totally relative--relative to the other algae in the sample. It says nothing of total biomass or standing crop, measurements of which must await research more sophisticated than that reported here. Even if it does approach nuisance levels, as it does elsewhere in Montana, it is not clear whether on a whole this would be detrimental or beneficial.

Two examples will illustrate this point. Several miles below the Bozeman sewage effluent the East Gallatin River supports a luxuriant bed of *Cladophora*. A similar situation holds below Yellowtail Dam on the Bighorn River. Both waters are culturally enriched; both waters support bank to bank beds of *Cladophora*; and both waters have an enormously productive fishery. The relationship between the enriched, stabilized flows and the *Cladophora* is straightforward, however it is not obvious whether the fish are there because of the *Cladophora* or whether they occur coincidentally with it without being benefited by its presence. Trout do not eat *Cladophora* but they do eat invertebrates this alga is known to harbor.

Cladophora is favored by low turbidity, high nutrient levels and stabilized flows. These conditions prevail below a bottom-withdrawal impoundment. Consequently, it is almost certain that *Cladophora* production would increase below such an impoundment regardless of where it was placed on the Yellowstone. On the other hand, uncoordinated major withdrawals without flow stabilization would result in more divergence in discharge and temperature extremes. These conditions are inimical to *Cladophora* and production would decrease below the zone of greatest diversion. To reduce *Cladophora* to the theoretically minor status it held prior to civilization may require elimination of all point sources and a major share of the non-point source pollution in the drainage. It is suspected, however that naturally high background nutrient levels have always sustained *Cladophora* as a dominant taxon in the river and that no amount of pollution control would ever reduce it to a minor role.

Summary and Conclusions

Allochthonous material apparently plays a significant role in the energetics of the Yellowstone River. A diverse array of aquatic micro-organisms, representing several phyla of plants and animals, were observed. No macrophytes were found in the samples and it is presumed that algae are the only significant primary producers in the river.

The algal flora is primarily Bacillariophycean-Chlorophycean with the blue-greens (Myxophyceae) contributing relatively little in terms of volume. The non-diatom algal flora was represented by four divisions, five classes and 39 genera.

There is little distinction between the non-diatom plankton and periphyton floras of the river; most taxa, and all of the more frequently occurring algae, are common to both communities. The bulk of the net plankton consists of dead or dying benthic algae detached from the periphyton.

Diatoms clearly dominated the net plankton while *Cladophora glomerata* and diatoms fairly evenly co-dominated the phycoperiphyton. Many of the subordinate non-diatom taxa exhibited interesting preferences for a particular river reach and/or season of the year.

The major non-diatom alga of the Yellowstone River is *Cladophora glomerata*, a cosmopolitan green alga that often becomes a nuisance in response to nutrient enrichment. Elsewhere in Montana, luxuriant growths of *C. glomerata* are associated with productive fisheries. An impoundment on the Yellowstone would enhance the production of

Cladophora downstream. Major water withdrawals without flow stabilization would probably decrease production of this alga. With evidence of naturally high background nutrient levels in the upper river, it is speculated that *Cladophora* would continue to play a major role in the Yellowstone, even following the abatement of cultural enrichment.

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Appendix A. Summary of Yellowstone River Algae Samples

Station Number*	Station Description	No. Periphyton Samples	No. Plankton Samples
	Cascade Picnic Area (YNP)	1	
1	Corwin Springs Fishing Access	11	7
2	Mallard's Rest Fishing Access	10	7
3	Above Livingston (9th St. Bridge)	11	7
	Backwater in Livingston @ BN Facility	1	
4	Above Shields River (below Livingston)	11	6
	Below Shields River	1	
5	Grey Bear Fishing Access	8	6
6	Below Greycliff	8	6
	East of Reedpoint @ I90	1	
7	Columbus	9	7
8	Laurel	9	7
9	Duck Creek Bridge (above Billings)	8	6
	South Bridge (Billings)	1	
	Below Corette Discharge	1	
	East Bridge (Billings)	1	
	Below Yegen Drain	1	1
10	Huntley	10	7
11	Custer	7	8
13	Myers		1
	Hysham	4	4
	Above Armells Creek		1
	Below Armells Creek		1
14	Rosebud	4	3
	Above Miles City		2
15	Miles City	4	4
	Above Powder River		1
	Below Powder River		1
16	Terry	4	4
17	Glendive	4	4
18	Intake	4	5
19	Sidney	3	3
20	Cartwright, N.D.	4	4
	Totals	141	113

*Montana Department of Fish and Game aquatic invertebrate sampling stations.

Appendix B. Summary of Algae Samples From Yellowstone River Tributaries

Station Description	No. Periphyton Samples	No. Plankton Samples
Shields River		
Headwaters (Forest Service Boundary)	2	2
North of Wilsall	3	2
North of Clyde Park (Highway 89 Bridge)	3	2
Mouth	4	2
East Boulder		
Jimmy Joe Campground	1	
Boulder River		
Mouth	1	
West Fork Stillwater River		
Above and Below JM Adit	2	
Stillwater River		
Mouth	1	
Clarks Fork River		
Mouth	2	
Yegen Drain		
Mouth	1	
Bighorn River		
*Mouth	4	5
Decker Mine Discharge	1	
Hanging Woman Creek		
Mouth	1	
Tongue River		
Reservoir Discharge	1	
Birney	2	
Brandenberg	2	
Mouth	1	
Totals	32	13

*Montana Department of Fish and Game aquatic invertebrate sampling station no. 12.

Appendix C. Checklist of Algae from Yellowstone River and Tributaries. Asterisks indicate additional taxa reported by the Public Health Service (9) (*), Williams (16) (**) and the U. S. Geological Survey (5) (***).

YELLOWSTONE RIVER

Division: Chlorophyta (Green Algae)
Class: Chlorophyceae
Genera: _Actinastrum hantzschii fluviatile_ *
Actinastrum sp. **, ***
Ankistrodesmus sp.
Chlamydomonas sp.
Chlorella sp.
Chodatella (_Lagerheimia_) sp. *
Cladophora glomerata
Closteriopsis longissima tropica *
Closterium sp.
Cosmarium sp.
Cylindrocapsa sp.
Enteromorpha sp.
Gloeocystis sp. *, **
Kirchneriella sp. ***
Microspora sp.
Monostroma sp.
Mougeotia sp.
Oedogonium sp.
Oocystis sp.
Pediastrum sp.
Planktosphaeria sp.
Scenedesmus sp.
Schroederia setigera *
Schroederia sp. ***
Selenastrum sp.
Sphaerocystis sp. *
Spirogyra spp.
Staurastrum sp.
Stigeoclonium spp.
Tetradesmus sp. **
Tetraedron sp. ***
Tetraspora sp.
Tetrastrum staurogeniaeforme *
Ulothrix zonata
Ulothrix sp.

Division: Euglenophyta (Euglenoid Algae)
Class: Euglenophyceae
Genera: _Euglena_ sp.
Phacus sp.
Trachelomonas sp. *, **

Division: Chrysophyta (Yellow-green Algae)
    Class: Xanthophyceae
        Genera: _Goniochloris_ sp.
            Tribonema sp.
    Class: Chrysophyceae
        Genera: _Hydrurus foetidus_
    Class: Bacillariophyceae (Diatoms)

Division: Pyrrophyta (Golden-brown Algae)
    Class: Dinophyceae
        Genera: _Ceratium hirudinella_ *

Division: Cyanophyta (Blue-green Algae)
    Class: Myxophyceae
        Genera: _Agmenellum_ sp. ***
            Anabaena sp.
            Anacystis sp. **
            Calothrix sp.
            Chamaesiphon incrustans
            Chroococcus sp. *
            Gomphosphaeria sp.
            Hyella sp.
            Lyngbya sp.
            Merismopedia sp.
            Microcoleus sp.
            Oscillatoria spp.
            Phormidium spp.
            Rivularia sp.
            Spirulina sp.

SHIELDS RIVER

Division: Chlorophyta (Green Algae)
    Class: Chlorophyceae
        Genera: _Ankistrodesmus_ sp.
            Cladophora glomerata
            Closterium sp.
            Cosmarium sp.
            Mougeotia sp.
            Oedogonium sp.
            Scenedesmus sp.
            Stigeoclonium sp.
            Tetraspora sp.
            Ulothrix sp.

SHIFLDS RIVER (cont.)

Division: Chrysophyta (Yellow-green Algae)
  Class: Chrysophyceae
    Genera: *Hydrurus foetidus*
  Class: Bacillariophyceae (Diatoms)

Division: Cyanophyta (Blue-green Algae)
  Class: Myxophyceae
    Genera: *Lyngbya* sp.
      Oscillatoria sp.
      Phormidium sp.
      Synechocystis sp.

EAST BOULDER RIVER

Division: Chlorophyta (Green Algae)
  Class: Chlorophyceae
    Genera: *Ulothrix* sp.

Division: Chrysophyta (Yellow-green Algae)
  Class: Bacillariophyceae (Diatoms)

Division: Cyanophyta (Blue-green Algae)
  Class: Myxophyceae
    Genera: *Oscillatoria* sp.
      Phormidium sp.
      Synechocystis sp.

BOULDER RIVER

Division: Chrysophyta (Yellow-green Algae)
  Class: Bacillariophyceae (Diatoms)

WEST FORK STILLWATER RIVER

Division: Chrysophyta (Yellow-green Algae)
  Class: Bacillariophyceae (Diatoms)

Division: Cyanophyta (Blue-green Algae)
  Class: Myxophyceae
    Genera: *Phormidium* sp.
      Synechocystis sp.

STILLWATER RIVER

Division: Chrysophyta (Yellow-green Algae)
    Class: Bacillariophyceae (Diatoms)

CLARKS FORK RIVER

Division: Chlorophyta (Green Algae)
    Class: Chlorophyceae
        Genera: _Ankistrodesmus_ sp.
            Chlamydomonas sp. *
            Cladophora glomerata
            Closteriopsis longissima tropica *
            Closterium sp. *
            Cosmarium sp.
            Scenedesmus bijuga *
            Stigeoclonium sp.

Division: Euglenophyta (Euglenoid Algae)
    Class: Euglenophyceae
        Genera: _Euglena_ sp.
            Trachelomonas sp. *

Division: Chrysophyta (Yellow-green Algae)
    Class: Bacillariophyceae (Diatoms)

Division: Pyrrophyta (Golden-brown Algae)
    Class: Dinophyceae
        Genera: _Ceratium hirudinella_ *

Division: Cyanophyta (Blue-green Algae)
    Class: Myxophyceae
        Genera: _Aphanizomenon flos-aquae_ *
            Chroococcus sp. *
            Nostoc sp. *
            Oscillatoria so. *

YEGEN DRAIN

Division: Chlorophyta (Green Algae)
    Class: Chlorophyceae
        Genera: _Cosmarium_ sp.

Division: Euglenophyta (Euglenoid Algae)
    Class: Euglenophyceae
        Genera: _Euglena_ sp.

Division: Chrysophyta (Yellow-green Algae)
Class: Bacillariophyceae (Diatoms)

Division: Cyanophyta (Blue-green Algae)
Class: Myxophyceae
Genera: Oscillatoria sp.

BIGHORN RIVER[1]

Division: Chlorophyta (Green Algae)
Class: Chlorophyceae
Genera: Actinastrum hantzschii fluviatile *
Chlamydonomas sp. *
Cladophora glomerata
Closterium sp.
Cosmarium sp. *
Oedogonium sp.
Palmella sp.
Pediastrum sp.
Scenedesmus dimorphus *
Scenedesmus sp. ***
Schroederia setigera *
Spirogyra sp.
Staurastrum sp.
Stigeoclonium sp.
Ulothrix sp.

Division: Euglenophyta (Euglenoid Algae)
Class: Euglenophyceae
Genera: Euglena acus *
Trachelomonas sp. *, ***

Division: Chrysophyta (Yellow-green Algae)
Class: Bacillariophyceae (Diatoms)

Division: Pyrrophyta (Golden-brown Algae)
Class: Dinophyceae
Genera: Ceratium hirudinella *

Division: Cyanophyta (Blue-green Algae)
Class: Myxophyceae
Genera: Coelosphaerium sp. *
Gomphosphaeria sp. *
Oscillatoria sp.
Phormidium sp.
Spirulina sp.

[1] Soltero (11) or Wright and Soltero (17) may be consulted for the algae of Yellowtail Reservoir.

DECKER MINE DISCHARGE

Division: Chlorophyta (Green Algae)
Class: Chlorophyceae
Genera: _Mougeotia_ sp.
Stigeoclonium sp.

Division: Chrysophyta (Yellow-green Algae)
Class: Bacillariophyceae (Diatoms)

Division: Cyanophyta (Blue-green Algae)
Class: Myxophyceae
Genera: _Phormidium_ sp.

HANGING WOMAN CREEK

Division: Chlorophyta (Green Algae)
Class: Chlorophyceae
Genera: _Spirogyra_ sp.

Division: Chrysophyta (Yellow-green Algae)
Class: Xanthophyceae
Genera: _Vaucheria_ sp.
Class: Bacillariophyceae (Diatoms)

Division: Cyanophyta (Blue-green Algae)
Class: Myxophyceae
Genera: _Oscillatoria_ sp.

TONGUE RIVER

Division: Chlorophyta (Green Algae)
Class: Chlorophyceae
Genera: _Ankistrodesmus_ sp. ***
Cladophora glomerata
Closteriopsis sp.
Closterium sp.
Cosmarium sp.
Mougeotia sp.
Oedogonium sp.
Oocystis sp. ***
Pediastrum sp.
Phacotus sp. ***
Planktosphaeria sp.
Scenedesmus sp.
Schroederia sp. ***
Spirogyra sp.
Stigeoclonium sp.
Ulothrix sp.

Division: Euglenophyta (Euglenoid Algae)
Class: Euglenophyceae
Genera: *Trachelomonas* sp. ***

Division: Chrysophyta (Yellow-green Algae)
Class: Bacillariophyceae (Diatoms)

Division: Cyanophyta (Blue-green Algae)
Class: Myxophyceae
Genera: *Anabaena* sp.
Lyngbya sp.
Oscillatoria sp.

POWDER RIVER

Division: Chlorophyta (Green Algae)
Class: Chlorophyceae
Genera: *Actinastrum hantzschii fluviatile* *
Ankistrodesmus sp. *, ***
Chlamydomonas sp. *
Gloeocystis sp. *
Scenedesmus quadricauda *
Scenedesmus sp. ***
Schroederia sp. ***

Division: Euglenophyta (Euglenoid Algae)
Class: Euglenophyceae
Genera: *Euglena* spp. *

Division: Pyrrophyta (Golden-brown Algae)
Class: Dinophyceae
Genera: *Ceratium hirudinella* *

Division: Cyanophyta (Blue-green Algae)
Class: Myxophyceae
Genera: *Dactylococcopsis acicularis* *
Oscillatoria sp. *, ***

Appendix D. Key to the Common Algae of the Yellowstone River*

1a Cells encased in a rigid glass shell having radial or bilateral symmetry and distinct ornamentation . . Bacillariophyceae (Diatoms)
1b Cells not as above 2

2a Cells arranged uniseriately (end-to-end) in branched or unbranched filaments 3
2b Cells solitary or in colonies with two to hundreds of cells; not end-to-end in filaments 14

3a Filaments branched 4
3b Filaments unbranched 5

4a Filaments macroscopic, conspicuous; cells robust, usually greater than 50 microns wide; tips of branches rounded . . Cladophora glomerata
4b Filaments microscopic, inconspicuous; cells delicate, usually less than 10 microns wide; tips of branches usually (but not always) attenuated . . . . Stigeoclonium

5a Pigments localized in chromatophores (chloroplasts); cells grass-green, contain starch, i.e., turn blue-black with addition of iodine . . . . . (Chlorophyceae) 6
5b Pigments not localized in chromatophores; cells blue-green, do not contain starch (Myxophyceae) 11

6a Chloroplast a band, not completely filling the cell; may be axial, transverse or twisted in a spiral 7
6b Chloroplast not a band; completely fills cell in healthy specimens . 10

7a Chloroplast a transverse band, ring-shaped and sometimes open on one side; cells usually wider than long 8
7b Chloroplast an axial or spial band; cells always longer than broad . . 9

8a Cell walls greatly thickened; cells wider than long; chloroplast a closed ring . . . . Ulothrix zonata
8b Cell walls thin; cells about as long as broad; chloroplast an open ring . . . . Ulothrix sp.

9a Chloroplast an axial band; cells several times longer than broad . . . . Mougeotia
9b Chloroplast a spiral band (the common Yellowstone species has a very tight spiral); cells only about two or three times longer than broad . . . . Spirogyra

*This key includes only those taxa found in more than 3 percent of all plankton and periphyton samples. Prescott (7,8) or Smith (10) may be consulted for descriptions and illustrations.

10a Cell walls thickened, forming H-pieces (cell at end of filament has two projections); cells same diameter throughout . . . . Microspora
10b Cell walls thin, no H-pieces; ends of some cells with transverse bands; cells usually wider at one end . . . . Oedogonium

11a Filament (trichome) with a sheath 12
11b Filament (trichome) without a sheath 13

12a Sheath firm, extending well beyond end of trichome; cells wider than long . . . . Lyngbya
12b Sheath watery, barely discernable; cells usually longer than broad . . . . Phormidium

13a Cells rounded, trichome appearing as a string of beads; heterocyst (a differentiated, empty-appearing, thick-walled cell) present . . . . . Anabaena
13b Cells disc-shaped, wider than long, trichome appearing as a stack of frisbees; heterocyst absent . . . . Oscillatoria

14a Cells solitary or in small colonies of up to 128 cells; microscopic 16
14b Cells in colonies of hundreds of cells; macroscopic 15

15a Cells touching, mutually compressed; chloroplasts grass-green, contain starch (turn blue-black with addition of iodine); colony assumes the shape of a hollow tube . . . . Enteromorpha
15b Cells distant from one another in a gelantinous matrix; chromatophores yellow-green, do not contain starch; colony solid, many branched, slimy to the touch and of a tough consistency, sometimes with a disagreeable odor . . . . Hydrurus foetidus

16a Cells in colonies of four or multiples of four 17
16b Cells usually solitary 18

17a Cells arranged in a linear series; usually four cells in a colony . . . . Scenedesmus
17b Cells arranged radially in a stellate plate one cell in thickness; usually 16 to 32 cells in a colony . . . . Pediastrum

18a Cell wall thick and rigid; cell divided into two semicells formed by a median constriction; cells at the most only 3 or 4 times longer than broad (Desmidiaceae) 19
18b Cell wall thin; cell not divided into two semicells; cells many times longer than broad, pointed at the ends . . . . Ankistrodesmus

19a Cells not conspicuously divided into semicells, lunate in shape . . . . Closterium
19b Cells conspicuously divided into semicells, shape variable 20

20a Semicells rounded . . . . Cosmarium
20b Semicells with three rigid projections on each of the outer ends . . . . Staurastrum