Biological Integrity of Prairie Elk Creek and Sand Creek Based on the Structure and Composition the Benthic Algae Community

By L. L. Bahls

2004

BIOLOGICAL INTEGRITY OF PRAIRIE ELK CREEK AND SAND CREEK BASED ON THE STRUCTURE AND COMPOSITION OF THE BENTHIC ALGAE COMMUNITY

Prepared for:

State of Montana
Department of Environmental Quality
P.O. Box 200901
Helena, Montana 59620-0901

Project Officer: Rebecca Ridenour
DEQ Contract No. 200012-10

Prepared by:

Loren L. Bahls, Ph.D.
Hannaea
1032 Twelfth Avenue
Helena, Montana 59601

March 8, 2004

Summary

In June and July of 2003, periphyton samples were collected from five sites on Prairie Elk Creek and one site on Sand Creek in northeastern Montana for the purpose of assessing whether these streams are water-quality limited and in need of TMDLs. The samples were collected following MDEQ standard operating procedures, processed and analyzed using standard methods for periphyton, and evaluated following modified USEPA rapid bioassessment protocols for wadeable streams.

Diatom metrics suggest **moderate impairment from sedimentation** at Garoutte's and Wright's on Prairie Elk Creek, and in Sand Creek. Diatom metrics also suggest **moderate impairment from organic loading** at Garoutte's and in Sand Creek. All other sites had minor organic loading, and the two sites near the mouth of Prairie Elk Creek had minor sedimentation.

Diatom salinity preferences indicate a downstream freshening of the water in Prairie Elk Creek toward the mouth. Diatom floras at the two sites near the mouth of Prairie Elk Creek were virtually identical, even though these two sites were sampled over a month apart. A longitudinal downstream decrease in organic loading was also noted in Prairie Elk Creek. The sample collected at Taylor's contained the largest percentage of nitrogen-fixing diatoms, which suggests that nitrogen was the limiting nutrient at this site.

Sand Creek shared many of the same diatom species with Prairie Elk Creek and diatom metrics indicate that environmental conditions in Sand Creek site were very similar to those at Garoutte's. Both sites suffered moderate impairment from organic loading and sedimentation, and the majority of diatoms at both sites indicate alkaline, eutrophic, and brackish-fresh waters. The sample from Sand Creek also contained nitrogen-fixing diatoms, but a smaller percentage than measured at Taylor's on Prairie Elk Creek.

Introduction

This report evaluates the biological integrity[1], support of aquatic life uses, and probable causes of stress or impairment to aquatic communities in Sand Creek and Prairie Elk Creek in northeastern Montana. The purpose of this report is to provide information that will help the State of Montana determine whether Sand Creek and Prairie Elk Creek are water-quality limited and in need of TMDLs.

The federal Clean Water Act directs states to develop water pollution control plans (Total Maximum Daily Loads or TMDLs) that set limits on pollution loading to water-quality limited waters. Water-quality limited waters are lakes and stream segments that do not meet water-quality standards, that is, that do not fully support their beneficial uses. The Clean Water Act and USEPA regulations require each state to (1) identify waters that are water-quality limited, (2) prioritize and target waters for TMDLs, and (3) develop TMDL plans to attain and maintain water-quality standards for all water-quality limited waters.

Evaluation of aquatic life use support in this report is based on the species composition and structure of periphyton (benthic algae, phytobenthos) communities at six sites that were sampled in June and July of 2003. Periphyton is a diverse assortment of simple photosynthetic organisms called algae that live attached to or in close proximity of the stream bottom. Some algae form long filaments or large colonies that are conspicuous to the unaided eye. But most algae, including the ubiquitous diatoms, can be seen and identified only with the aid of a microscope. The periphyton community is a basic biological component of all aquatic ecosystems. Periphyton accounts for much of the primary production and biological diversity in Montana streams (Bahls et al. 1992). Plafkin et al. (1989) and Barbour et al. (1999) list several advantages of using periphyton in biological assessments.

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[1] *Biological integrity* is defined as "the ability of an aquatic ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats within a region" (Karr and Dudley 1981).

Project Area and Sampling Sites

The project area is located in McCone County in northeastern Montana. Both Sand Creek and Prairie Elk Creek are south side tributaries of the Missouri River. Prairie Elk Creek heads northwest of Circle in central McCone County and flows north to meet the Missouri River just south of Wolf Point. Sand Creek, the next drainage to the east of Prairie Elk Creek, heads north of Circle and enters the Missouri River a few miles downstream.

The headwaters of Prairie Elk Creek are in the Northwestern Great Plains Ecoregion and the lower reaches are in the Northwestern Glaciated Plains Ecoregion (Woods et al. 1999). The Sand Creek drainage is entirely within the Northwestern Glaciated Plains. The surface geology of the area consists of coal-bearing sedimentary rocks of the Fort Union Formation in the headwaters of both streams and sandstones and shales of the Montana Group in the lower reaches (Renfro and Feray 1972). The climate is semiarid and continental, with cold winters and hot, dry summers. Upland vegetation is predominantly mixed grassland steppe (USDA 1976). The main land uses are livestock grazing and dryland farming.

Periphyton samples were collected at five sites on Prairie Elk Creek and one site on Sand Creek (Table 1). Elevations at the sampling sites range from 2,300 feet at Garoutte's to 2,000 feet near the mouths of Sand Creek and Prairie Elk Creek

Methods

Periphyton samples were collected following standard operating procedures of the MDEQ Planning, Prevention, and Assistance Division. Using appropriate tools, microalgae were scraped, brushed, or sucked from natural substrates in proportion to the importance of those substrates at each study site. Macroalgae were picked by hand in proportion to their abundance at the site. All collections of microalgae and macroalgae were pooled into a common container and preserved with Lugol's (IKI) solution.

The samples were examined to estimate the relative abundance and rank by biovolume of diatoms and genera of soft (non-diatom) algae according to the method described in Bahls (1993). Soft algae were identified using Smith (1950), Prescott (1962, 1978), John et al. (2002), and Wehr and Sheath (2003). These books also served as references on the ecology of the soft algae, along with Palmer (1969, 1977).

After the identification of soft algae, the raw periphyton samples were cleaned of organic matter using sulfuric acid, potassium dichromate, and 30% hydrogen peroxide. Then, permanent diatom slides were prepared using Naphrax™, a high refractive index mounting medium, following *Standard Methods for the Examination of Water and Wastewater* (APHA 1998). Approximately 300-350 diatom cells (600-700 valves) were counted at random and identified to species. The following were the main taxonomic references for the diatoms: Krammer and Lange-Bertalot 1986, 1988, 1991a, 1991b; Lange-Bertalot 2001; Krammer 2002. Diatom naming conventions followed those adopted by the Integrated Taxonomic Information System (http://www.itis.usda.gov). Van Dam et al. (1994) was the main ecological reference for the diatoms.

The diatom proportional counts were used to generate an array of diatom association metrics. A metric is a characteristic of the biota that changes in some predictable way with increased human influence (Barbour et al. 1999). Diatoms are particularly useful in generating metrics because there is a wealth of information available in the literature regarding the pollution tolerances and water quality preferences of common diatom species (e.g., Lowe 1974, Beaver 1981, Lange-Bertalot 1979, 1996, Van Dam et al. 1994).

Values for selected diatom metrics were compared to biocriteria (numeric thresholds) developed for streams in the Great Plains ecoregions of Montana (Table 2). These criteria are based on the distribution of metric values measured in least-impaired reference streams (Bahls et al. 1992) and metric values measured in streams that are known to be impaired by various sources and causes of pollution (Bahls 1993). The biocriteria in Table 2 are valid only for samples collected during the summer field season (June 21-September 21).

The criteria in Table 2 distinguish among four levels of stress or impairment and three levels of aquatic life use support: (1) no impairment or only minor impairment (full support); (2) moderate impairment (partial support); and (3) severe impairment (nonsupport). These impairment levels correspond to excellent, good, fair, and poor biological integrity, respectively.

Quality Assurance

Several steps were taken to assure that the study results are accurate and reproducible. Upon receipt of the samples, station and sample attribute data were recorded in the Montana Diatom Database and the samples were assigned a unique number, e.g., 3015-01. The first part of this number (3015) designates the sampling site (Prairie Elk Creek at Garoutte's) and the second part (01) designates the number of periphyton samples that that have been collected at this site for which data have been entered into the Montana Diatom Database.

Sample observations and analyses of soft (non-diatom) algae were recorded in a lab notebook along with information on the sample label. A portion of the raw sample was used to make duplicate diatom slides. The slide used for the diatom proportional count will be deposited in the Montana Diatom Collection at the University of Montana Herbarium (MONTU) in Missoula. The duplicate slide will be retained in Helena at the offices of *Hannaea*. Diatom proportional counts have been entered into the Montana Diatom Database.

Results and Discussion

Results are presented in Tables 3, 4, and 5, which are located near the end of this report following the references section. Appendix A consists of a series of diatom reports, one for each sample. Each diatom report contains an alphabetical list of diatom species and their percent abundances, and values for 65 different diatom metrics and ecological attributes.

Sample Notes

All of the samples in this sample set, except the one from near the mouth of Prairie Elk Creek (3014-01), were septic, black in color, and smelled of rotten eggs (H_2S). Decomposition of soft algae was not complete, however, allowing for identification of most specimens. All of the samples were silty to extremely silty. The samples from Garoutte's and Taylor's contained macrophytes.

Non-Diatom Algae (Table 3)

Filamentous green algae dominated the samples from all sites except Taylor's on Prairie Elk Creek and Sand Creek near mouth. *Spirogyra* ('pond scum') was the dominant alga at Garoutte's and *Rhizoclonium* was most abundant at the other 3 sites where filamentous greens dominated. Diatoms ranked first in biovolume at Taylor's, where filamentous green algae (*Rhizoclonium* and *Oedogonium*) were common. Diatoms were the only algae present in the sample from Sand Creek.

Rhizoclonium has been reported to cause problems in standing and slowly flowing waters across the western United States (Wehr and Sheath 2003). Algae interfere with water uses—e.g., fishing, swimming, boating, and irrigation—only when standing crops are excessive. Mat-forming filamentous algae are normal components of many aquatic ecosystems, including prairie streams, and there is no evidence from this study that standing crops of *Rhizoclonium* or *Spirogyra* in Prairie Elk Creek are excessive. Also, criteria have not been established for determining when algal growth in prairie streams is excessive.

Cyanobacteria (mainly *Oscillatoria*) were found only in samples collected from Prairie Elk Creek at Garoutte's and near its mouth. The red alga *Audouinella* was also present in the sample collected from Prairie Elk Creek near its mouth.

Diatoms (Table 4)

Of the18 major diatom species in Sand Creek and Prairie Elk Creek, only *Achnanthidium minutissimum* is sensitive to organic pollution (class 3). *A minutissimum* was most abundant in the lower reaches of Prairie Elk Creek. Seven of the major species are most tolerant of organic pollution (class 1). These species tended to be most abundant in the upper and middle reaches of Prairie Elk Creek and in Sand Creek. The remaining 10 major species are somewhat tolerant of organic pollution and these (class 2) species were abundant at all sites (Table 4).

Garoutte's. This site was dominated by highly motile and pollution tolerant species of *Navicula* and *Nitzschia*. As a result, diatom metrics indicate moderate impairment from organic loading and sedimentation at this site (Table 4).

Wright's. This site was also dominated by highly motile species, which indicated higher than usual levels of sedimentation for a prairie stream. The siltation index at this site was near the threshold between minor impairment and moderate impairment. The pollution index at this site suggests minor impairment from organic loading. Although this is an improvement from the moderate rating upstream at Garoutte's, the Wright site supported a larger percentage brackish water species (*Nitzschia agnita, Nitzschia filiformis, Tabularia fasciculate*), indicating that this site had saltier water than upstream. The Wright and Garoutte sites shared only about a third of their diatom assemblages, which suggests that a moderate change in environmental conditions occurred between the two sites.

Taylor's. Diatom metrics showed improved conditions at this site compared to the upstream sites. Sedimentation levels were normal for a prairie stream and the pollution index was higher, indicating only minor impairment from organic loading. However, like the Wright site, this site supported a large percentage of brackish-water diatoms, which indicates higher levels of dissolved solids. The higher salinities at this site may be responsible for the smaller diatom species richness and diversity values observed here. The Taylor site supported the largest percentage of nitrogen fixing diatoms (5.40%), which may indicate that this site is nitrogen limited. The Taylor and Wright sites shared slightly less than half of their diatom assemblages, which suggest that minor environmental change occurred between them.

Near Mouth. An increase in the percentage of freshwater species (e.g., *Fragilaria vaucheriae*) indicates a decrease in salinity at this site and at the Hutterite Colony. However both of these sites were dominated by *Nitzschia amphibioides*, which prefers waters that are "rich in electrolytes" (Krammer & Lange-Bertalot 1988). Diatom metrics indicate minor impairment from sedimentation and organic loading. This site had somewhat depressed species richness, diversity, and equitability values, each of which indicates minor stress. This site shared only 24% of its diatom assemblage with the Taylor site, which indicates a major difference in environmental conditions between the two sites.

Hutterite Colony. This site is just downstream from the preceding site. Although this site was sampled over a month later than the other site, they shared almost two thirds of their diatom assemblages and were virtually identical in terms of diatom species composition and metric values (Table 4). Both sites had pollution index and siltation index values that suggest minor impairment, and both sites had slightly depressed species richness, diversity, and equitability values that suggest minor stress.

Sand Creek. This site shared several major taxa with Prairie Elk Creek and had metric values very similar to those at Garoutte's. Diatom metrics for Sand Creek suggest moderate impairment from sedimentation and organic loading. Other metrics were normal for a prairie stream. This site had a higher percentage of nitrogen-fixing diatoms than all of the sites on Prairie Elk Creek except Taylor's, which suggests that Sand Creek is nitrogen-limited.

Modal Categories (Table 5)

Several ecological attributes were selected from the diatom reports in the appendix and modal categories of these attributes were extracted to characterize water quality tendencies in Sand Creek and Prairie Elk Creek (Table 5).

Most diatoms at most of the sites were highly motile nitrogen autotrophs that tolerate high levels of organics and prefer brackish or brackish-fresh eutrophic and alkaline waters. The modal category for some of the attributes and sites was "not classified", which means that the ecological preferences of the diatoms that comprise the largest group have yet to be determined.

Modal categories at some sites represent a significant improvement in water quality compared to other sites. For example, most diatoms at Taylor's were "not motile" and most diatoms in Sand Creek were "moderately motile". At other sites, the modal category was "highly motile". At Wright's and Taylor's, the modal category was "brackish", but it was "brackish-fresh" at Garoutte's and in Sand Creek and "fresh" at both sites near the mouth of Prairie Elk Creek.

Modal categories suggest possible inferior conditions at one or both of the upstream sites on Prairie Elk Creek. At Garoutte's, the modal category for oxygen demand was "low", whereas it was "not classified" at the remaining sites. At Wright's, the modal category for saprobity was "alpha-mesosaprobous", while it was "beta-mesosaprobous" at Garoutte's and "not classified" at the remaining stations.

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Table 1 Location of MDEQ periphyton sampling stations in the Prairie Elk/Wolf Creek TMDL Planning Area in 2003

Station	Montana DEQ Station Code	*Hannaea* Sample Number	Latitude	Longitude	Sample Date
Prairie Elk Creek at Garoutte's	M49PREKC03	3015-01	47 43 23	105 50 17	7/12/03
Prairie Elk Creek at Wright's	M49PREKC02	3364-01	47 45 45	105 50 51	6/3/03
Prairie Elk Creek at Taylor's	M49PREKC04	3016-01	47 48 34	105 52 09	7/12/03
Prairie Elk Creek near mouth	M49PREKC01	3014-01	47 57 01	105 53 41	6/3/03
Prairie Elk Creek at Hutterite Colony	M49PREKC05	3017-01	48 00 05	105 51 52	7/12/03
Sand Creek near mouth at Pipals	M49SANDC02	3018-01	48 00 58	105 42 52	7/12/03

Table 2. Diatom association metrics used by the State of Montana to evaluate biological integrity in **prairie** streams: references, range of values, expected response to increasing impairment or natural stress, and criteria for rating levels of biological integrity. The lowest rating for any one metric is the rating for that site.

Biological Integrity/ Impairment or Stress/ Use Support	No. of Species Counted[1]	Diversity Index[2] (Shannon)	Pollution Index[3]	Siltation Index[4]	Disturbance Index[5]	% Dominant Species[6]	Similarity Index[7]
Excellent/None Full Support	>39	>3.99	>2.25	<50.0	<25.0	<25.0	>59.9
Good/Minor Full Support	30-39	3.00-3.99	1.76-2.25	50.0-69.9	25.0-49.9	25.0-49.9	40.0-59.9
Fair/Moderate Partial Support	20-29	2.00-2.99	1.25-1.75	70.0-89.9	50.0-74.9	50.0-74.9	20.0-39.9
Poor/Severe Nonsupport	<20	<2.00	<1.25	>89.9	>74.9	>74.9	<20.0
References	Bahls 1979 Bahls 1993	Bahls 1979	Bahls 1993	Bahls 1993	Barbour et al. 1999	Barbour et al. 1999	Whittaker 1952
Range of Values	0-100+	0.00-5.00+	1.00-3.00	0.0-90.0+	0.0-100.0	~5.0-100.0	0.0-100.0
Expected Response	Decrease	Decrease	Decrease	Increase	Increase	Increase	Decrease

[1]Based on a proportional count of 400 cells (800 valves)
[2]Base 2 [bits] (Weber 1973)
[3]Composite numeric expression of the pollution tolerances assigned by Lange-Bertalot (1979) to the common diatom species
[4]Sum of the percent abundances of all species in the genera *Navicula*, *Nitzschia*, and *Surirella*
[5]Percent abundance of *Achnanthidium minutissimum* (synonym: *Achnanthes minutissima*)
[6]Percent abundance of the species with the largest number of cells in the proportional count
[7]Percent Community Similarity (Whittaker 1952)

Table 3 Relative abundance of cells and ordinal rank by biovolume of diatoms (Division Bacillariophyta) and genera of non-diatom algae in periphyton samples collected from the Prairie Elk/Wolf Creek TMDL Planning Area in 2003.

Taxa	Prairie Elk Creek at Garoutte's	Prairie Elk Creek at Wright's	Prairie Elk Creek at Taylor's	Prairie Elk Creek near mouth	Prairie Elk Creek Hutterite Colony	Sand Creek near mouth
Cyanophyta						
Hydrocoleum				rare/6th		
Oscillatoria	occasional/3rd			occasional/5th		
Rhodophyta						
Audouinella				frequent/3rd		
Chlorophyta						
Cladophora					occasional/3rd	
Mougeotia			rare/4th			
Oedogonium			common/3rd	common/4th		
Rhizoclonium		dominant/1st	common/2nd	dominant/1st	dominant/1st	
Spirogyra	dominant/1st					
Bacillariophyta	common/2nd	frequent/2nd	frequent/1st	abundant/2nd	common/2nd	occasional/1st
No. Non-Diatom Genera	2	1	3	5	2	0

Table 4. Percent abundance of major diatom species[1] and values of selected diatom association metrics for periphyton samples collected from Prairie Elk Creek and Sand Creek in 2003. Underlined values indicate minor stress; **bold values** indicate moderate stress; **underlined and bold** values indicate severe stress; all other values indicate no stress and full support of aquatic life uses when compared to criteria for plains streams in Table 2.

Species/Metric	PTC[2]	Prairie Elk Cr. at Garoutte's	Prairie Elk Cr. at Wright's	Prairie Elk Cr. at Taylor's	Prairie Elk Cr. near mouth	Prairie Elk Cr. Hutterite Colony	Sand Creek near mouth
Achnanthidium minutissimum	3		8.03	11.09	11.82	9.22	
Cymbella pusilla	1	5.31	0.68		0.31		0.76
Entomoneis paludosa	2	5.97	2.59	0.73	5.91	0.94	2.65
Fragilaria vaucheriae	2				17.57	6.88	1.52
Gomphonema parvulum	1		0.27	0.58	0.62	5.00	
Navicula caterva	2		5.58				
Navicula cincta	1	2.79	0.41	0.88	5.91	3.12	10.98
Navicula cincta v. rostrata	1	17.77	3.40	2.48	4.20	3.12	15.53
Navicula erifuga	2	0.27	1.36	0.15	0.93	0.94	10.98
Navicula recens	2	0.66	6.67			0.62	0.76
Nitzschia agnita	1	2.12	17.41	25.99		0.31	3.03
Nitzschia amphibioides	2			0.44	30.64	32.19	1.52
Nitzschia filiformis	2	1.19	13.47	0.73	0.47		0.76
Nitzschia frustulum	2	14.46	2.45	6.86	1.24	12.97	4.55
Nitzschia palea	1	11.01	5.17	0.58	1.56	0.78	2.27
Nitzschia pusilla	1	10.61	0.27		0.93	0.94	0.76
Synedra delicatissima	2			7.15	0.47	0.62	
Tabularia fasciculata	2		7.89	19.71			
Number of Species Counted		49	50	44	34	38	49
Shannon Species Diversity		4.25	4.41	3.72	3.56	3.76	4.80
Pollution Index		**1.45**	1.76	1.83	2.03	2.00	**1.68**
Siltation Index		**77.72**	**70.48**	44.96	50.86	64.06	**73.11**
Disturbance Index		0.00	8.03	11.09	11.82	9.22	0.00
Percent Dominant Species		17.77	17.41	25.99	30.64	32.19	15.53
Percent Rhopalodiales		1.59	0.27	5.40	0.00	0.00	3.41
Similarity Index[3]			**33.64**	47.30	**23.71**	66.07	

[1]A major diatom species accounts for 5.0% or more of the cells at one or more stations in a sample set.

[2](Organic) Pollution Tolerance Class (Lange-Bertalot 1979): 1 = most tolerant; 2 = tolerant; 3 = sensitive.

[3]Percent Community Similarity (Whittaker 1952) when compared to the diatom assemblage at the adjacent upstream station.

Table 5. Modal categories for selected ecological attributes of diatom species in Prairie Elk Creek and Sand Creek. Categories that represent significant departures in water quality from other sites are given in **bold face type**.

Ecological Attribute	Prairie Elk Creek at Garoutte's	Prairie Elk Creek at Wright's	Prairie Elk Creek at Taylor's	Prairie Elk Creek near mouth	Prairie Elk Creek Hutterite Colony	Sand Creek near mouth
Motility[1]	Highly Motile	Highly Motile	**Not Motile**	Highly Motile	Highly Motile	**Moderately Motile**
pH[2]	Alkaliphilous	Alkaliphilous	Alkaliphilous	Alkaliphilous	Alkaliphilous	Alkaliphilous
Salinity[2]	**Brackish-Fresh**	Brackish	Brackish	**Fresh**	**Fresh**	**Brackish-Fresh**
Nitrogen Uptake[2]	Nitrogen Autotrophs (high organics)	Not Classified	Nitrogen Autotrophs (high organics)	Nitrogen Autotrophs (high organics)	Not Classified	Not Classified
Oxygen Demand[2]	**Low**	Not Classified	Not Classified	Not Classified	Not Classified	Not Classified
Saprobity[2]	beta-Meso-saprobous	**alpha-Meso-saprobous**	Not Classified	Not Classified	Not Classified	Not Classified
Trophic State[2]	Eutraphentic	Eutraphentic	Eutraphentic	Not Classified	Eutraphentic	Eutraphentic

[1]Dr. R. Jan Stevenson, Michigan State University, digital communication.
[2]Van Dam et al. 1994