BIOLOGICAL INTEGRITY OF STREAMS IN McCONE COUNTY, MONTANA BASED ON THE STRUCTURE AND COMPOSITION OF THE BENTHIC ALGAE COMMUNITY

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and

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Summary

In the summer of 2003, periphyton samples were collected from 11 sites on 5 streams in McCone County, 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 indicate severe impairment from organic loading at the middle site on Horse Creek, Nelson Creek, the upper (Fairgrounds) site on the Redwater River, and the upper site on Sand Creek. Moderate stress from organic loading was indicated at the upper and lower sites on Horse Creek and the Cemetery Road site on the Redwater River. All other sites showed minor impairment from organic loading. Some of this organic loading may be internal and natural in origin.

Severe impairment from sedimentation was noted at the lowest (Highway 13) site on the Redwater River. Moderate sedimentation was indicated at the lower site on Horse Creek and the fairgrounds and airport sites on the Redwater River. All other sites showed minor impairment from sedimentation except the upper site on Horse Creek, where the sedimentation index was normal for a prairie stream.

Diatoms that indicate elevated concentrations of dissolved solids were common at all sites. Salinity, along with elevated organic loading, was the most probable cause of depressed diatom species richness and diversity. Diatom species indicate brackish waters at most sites, but somewhat lower levels of salinity were indicated in Horse Creek near mouth, Redwater River at the airport, and both sites on Sand Creek.

Large percentages of nitrogen-fixing diatoms were recorded in the samples from Nelson Creek and the upper site on Horse Creek. Nitrogen is most likely the limiting nutrient at these sites. Cyanobacteria, many species of which can fix atmospheric nitrogen, were also common in Nelson Creek and the upper reaches of Horse Creek, as well as in Sand Creek and the Redwater River. Cyanobacteria were absent from Prairie Elk Creek and lower Sand Creek.

Algae in the division Euglenophyta (*Euglena* and *Phacus*) are known to be especially tolerant of organic pollution. These algae were found only in samples collected from the Redwater River below the airport and at Highway 13. Conversely, Prairie Elk Creek was the only site where a pollution sensitive species (*Achnanthidium minutissimum*) accounted for more than 10 percent of the diatom cells.

Two abnormal diatom cells were counted at the Fairgrounds site on the Redwater River. This is within the normal range for an unimpaired prairie stream. No abnormal cells were observed at the other 10 sites that were sampled for this project.

Introduction

This report evaluates the biological integrity[1], support of aquatic life uses, and probable causes of stress or impairment to aquatic communities in Horse Creek, Nelson Creek, Sand Creek, Prairie Elk Creek, and the Redwater River in McCone County, northeastern Montana. The purpose of this report is to provide information that will help the State of Montana determine whether these streams 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 eleven sites that were sampled in the summer 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. Horse Creek is a tributary of the Redwater River near Circle (HUC 10060002). Like the Redwater River, Sand Creek and Prairie Elk Creek are south side tributaries of the Missouri River (HUC 10060001). 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. Nelson Creek is a tributary of the Big Dry Arm of Fort Peck Reservoir (HUC 10040104).

The streams are located in the Northwestern Great Plains and Northwestern Glaciated Plains Ecoregions (Woods et al. 1999). The surface geology of the area consists of coal-bearing sedimentary rocks of the Fort Union Formation and sandstones and shales of the Montana Group (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 dry land farming.

Periphyton samples were collected at 4 sites on the Redwater River, 3 sites on Horse Creek, 2 sites on Sand Creek, and 1 site each on Nelson Creek and Prairie Elk Creek (Table 1). Elevations at the sampling sites range from about 2,500 feet to 2,000 feet. The streams are classified C-3 in the Montana Surface Water Quality Standards.

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 3% 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). At least 400 diatom cells (800 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 the Integrated Taxonomic Information System (http://www.itis.usda.gov). For taxa not yet included in ITIS, naming conventions followed those adopted by the Academy of Natural Sciences for USGS NAWQA samples (Morales and Potapova 2000). 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 (Table 6). 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., 2008-02. The first part of this number (2008) designates the sampling site (Redwater River at Fairgrounds) and the second part (02) 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 (Table 6).

Sample Notes

All of the samples in this sample set, except the one collected from Nelson Creek, 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. Diatoms and blue-green algae (cyanobacteria) were more resistant to decay than green algae, which were the most problematic to identify. Most of the samples were silty to extremely silty, except for upper Horse Creek, Nelson Creek, and Redwater River at the Fairgrounds. Fine particulate organic matter (FPOM) was abundant in samples collected from the lower 3 Redwater River sites and from upper Sand Creek. The samples from upper Horse Creek, Nelson Creek, and Redwater River at Fairgrounds contained moss and/or macrophytes.

Non-Diatom Algae (Table 3)

McCone County streams supported 18 genera of non-diatom algae in 4 algal divisions (Table 3). Green algae and cyanobacteria were the most diverse and most abundant groups of non-diatom algae. Each site supported from 2 to 9 genera of non-diatom algae.

Diatoms accounted for most of the biovolume in these samples except for the 3 Horse Creek sites and the lower site on Redwater River (Table 3). Filamentous cyanobacteria (*Lyngbya* and *Oscillatoria*) dominated at the upper 2 Horse Creek sites and the filamentous green alga *Rhizoclonium* was the most abundant alga in samples from lower Horse Creek and the lower site on Redwater River. *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* are excessive in these streams. Also, criteria have not been established for determining when algal growth in prairie streams is excessive.

Cyanobacteria, many species of which can fix atmospheric nitrogen, were most common in Nelson Creek and the upper reaches of Horse Creek, Sand Creek, and the Redwater River. Nitrogen is most likely the limiting nutrient at these sites. Cyanobacteria were absent from Prairie Elk Creek and lower Sand Creek.

Algae in the division Euglenophyta (*Euglena* and *Phacus*) are known to be especially tolerant of organic pollution (Palmer 1969). These algae were found only in samples collected from the Redwater River below the airport and at Highway 13. The filamentous chrysophyte *Tribonema* is known to favor cool water temperatures. *Tribonema* was common in samples collected from upper Horse Creek, Prairie Elk Creek, and lower Sand Creek.

Diatoms (Table 4)

Of the12 major diatom species in McCone County streams, only *Achnanthidium minutissimum* is sensitive to organic pollution (class 3). *A minutissimum* was most abundant in Prairie Elk Creek and lower Sand Creek (Table 4). Eight of the major species are most tolerant of organic pollution (class 1). These species were abundant at all sites except the lower 2 sites on the Redwater River. The remaining 3 major species are somewhat tolerant of organic pollution and these (class 2) species were most abundant in lower Horse Creek and lower Redwater River (Table 4).

Horse Creek. Diatom metrics indicate moderate organic loading at the upper and lower sites and severe organic loading at the middle site. Minor to moderate sedimentation was evident at the lower two sites (Table 4). Some sedimentation and internal organic loading may be natural in prairie streams. Diatom species richness, diversity, and equitability values were moderately low to extremely low at the two downstream sites. The cause of this low diversity is likely a combination of organic loading and excessive salinity. Some of the most common diatom species in Horse Creek tolerate elevated concentrations of dissolved solids. Nitrogen-fixing diatoms were abundant at the upper site on Horse Creek, indicating that nitrogen is likely the limiting nutrient here. The three Horse Creek stations had little in common floristically, indicating that major changes in environmental conditions occurred between the sites.

Nelson Creek. Nelson Creek was dominated by 4 species of diatoms that are very tolerant of elevated organic loading and/or salinity. The pollution index indicates severe impairment from organic loading, which resulted in depressed diatom species richness and diversity. Sedimentation was only a minor problem in Nelson Creek. Nelson Creek supported a large percentage of nitrogen-fixing diatoms (Rhopalodiales), which indicates probable nitrogen limiting conditions.

Prairie Elk Creek. Prairie Elk Creek (and the lower site on Sand Creek) had the best overall biological integrity of all the sites in this sample set. Diatom metrics indicate only minor impairment from organic loading and sedimentation. Diatom species richness and diversity values were somewhat depressed, but still within the range of minor impairment. This was the only site where the pollution sensitive diatom *Achnanthidium minutissimum* was a major species.

Redwater River. Diatom metrics indicate severe organic loading and moderate sedimentation at the upper (Fairgrounds) site on the Redwater River (Table 4). This site was dominated by *Navicula durrenbergiana*, a motile diatom that tolerates elevated concentrations of organic nutrients and dissolved solids. Although diatom species richness and non-diatom genus richness were normal for a prairie stream, diatom diversity and equitability were low and indicate a moderate amount of stress. Two abnormal diatom cells were counted at this site. This is within the normal range for an unimpaired prairie stream. No abnormal cells were observed at the other 10 sites that were sampled for this project.

The Cemetery Road and airport sites showed moderate stress from organic loading and sedimentation, respectively. The salinity tolerant species *Navicula salinarum* dominated the diatom assemblage at Cemetery Road, indicating that elevated dissolved solids were also a stressor here. This site shared about a third of its diatom assemblage with the upstream site, indicating that a moderate amount of environmental change occurred between the two sites. *Nitzschia frustulum* was the dominant diatom species at the airport site. This species is highly motile and tolerates elevated concentrations of both organic and inorganic nutrients. This site

shared about a third of its diatom assemblage with the Cemetery Road site. Both the Cemetery Road and airport sites had normal diatom species richness and diversity for a prairie stream.

At Highway 13, diatom metrics indicate severe impairment from sedimentation but only minor impairment from organic loading. Diatom species richness, diversity, and equitability were very low as a result of dominance by *Nitzschia reversa*. This is a facultative planktonic species and its abundance here indicates probable ponding and very low current velocities. The sedimentation index is very high here because *Nitzschia reversa* belongs to the highly motile genus *Nitzschia*. This site shared only about one-fifth of its diatom assemblage with the next upstream site, indicating that a major environmental change occurred between the two sites.

Sand Creek. Diatom metrics indicate severe impairment from organic loading at the upper site on Sand Creek. Several pollution tolerant species dominated the diatom assemblage at this site. Not all of these species are motile, however, and the sedimentation index indicates only minor impairment, both here and at the downstream site near the mouth. Although depressed, diatom species richness and diversity were within the normal range for a prairie stream.

Along with Prairie Elk Creek, the lower site on Sand Creek had the best biological integrity of all sites in the sample set. Only minor impairment from sedimentation and organic loading was evident. This site supported the second largest percentage of the pollution sensitive species *Achnanthidium minutissimum*. Diatom species richness, diversity, and equitability were excellent and within the normal range for a prairie stream. This site shared less than one-third of its diatom assemblage with the upper site on Sand Creek, which indicates that a moderate amount of environmental change occurred between them.

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 streams of McCone County (Table 5).

Most diatoms at most of the sites were highly motile nitrogen autotrophs that tolerate moderate levels of organics and prefer brackish, 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 in upper Horse Creek, upper Redwater River, and Sand Creek were "moderately motile". At other sites, the modal category was "highly motile". At most sites, the modal category for salinity was "brackish", but it was "brackish-fresh" at the lowest site on Horse Creek, the next to last site on Redwater River (airport), and both sites on Sand Creek.

Modal categories suggest possible inferior water quality conditions at the lower site on Horse Creek and the airport site on the Redwater River. Both sites supported a predominance of obligate nitrogen heterotrophs, as opposed to autotrophs at other sites. The modal category for oxygen demand was "moderate" at these sites, whereas the modal category was "fairly high" at other sites (Table 5).

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Table 1. Location of periphyton sampling stations in McCone County in 2003.

Station	McCone County Station Code	*Hannaea* Sample Number	Latitude	Longitude	Sample Date
Horse Creek below South Fork (HORCK-02)	MCNHORC-02	3407-01	47 28 58	105 46 17	7/11/2003
Horse Creek above Circle (HORCK-04)	MCNHORC-04	3381-01	47 25 30	105 37 24	7/11/2003
Horse Creek near mouth (HORCK-05)	MCNHORC-05	3019-02	47 25 26	105 34 44	7/11/2003
Nelson Creek (NLSN-01)	MCNNLSN-01	3382-01	47 28 15	106 04 35	7/9/2003
Prairie Elk Creek (PRELK-4A)	MCNPREK-4A	3383-01	47 52 06	105 52 16	9/16/2003
Redwater River at Fairgrounds (RW-1)	MCNREDW-01	2008-02	47 24 08	105 35 11	8/27/2003
Redwater River at Cemetery Road (RW-2)	MCNREDW-02	2009-02	47 24 49	105 34 23	8/27/2003
Redwater River below airport (RW-3)	MCNREDW-03	2010-02	47 25 25	105 34 08	8/27/2003
Redwater River at Highway 13 (RW-4)	MCNREDW-04	2011-02	47 26 06	105 33 28	8/27/2003
Sand Creek near headwaters (SAND-03)	MCNSAND-03	3384-01	47 52 07	105 38 26	9/16/2003
Sand Creek near mouth (SAND-2A)	MCNSAND-2A	3385-01	47 58 34	105 39 23	9/16/2003

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 streams in McCone County in 2003.

Taxa	Station										
	HORC02	HORC04	HORC05	NLSN01	PRELK4A	REDW01	REDW02	REDW03	REDW04	SAND03	SAND2a
Cyanophyta											
Anabaena		o/3	o/5			o/5		o/8			
Calothrix						r/7					
Chroococcus										r/5	
Lyngbya	d/1							f/2			
Merismopedia			r/7	c/5		r/9					
Oscillatoria	f/3	d/1	f/4	f/2		c/2	f/2	f/4	o/4	f/3	
Phormidium				c/3							
Chlorophyta											
Closterium						r/6					
Cosmarium						r/8					
Microspora			c/3					c/5	c/3	c/4	
Mougeotia						o/3	o/4				
Oedogonium				o/4				c/6			
Rhizoclonium			d/1		o/4		c/3	c/3	a/1	a/2	c/3
Scenedesmus			o/6	o/6		o/4	o/5	o/9			
Spirogyra					c/3						o/4
Euglenophyta											
Euglena								c/7	r/5		
Phacus								o/10			
Chrysophyta											
Tribonema	c/4				f/2						f/2
Bacillariophyta	a/2	a/2	a/2	a/1	d/1	d/1	a/1	a/1	a/2	d/1	a/1
No. Non-Diatom Genera	3	2	6	5	3	8	4	9	4	4	3

Table 4. Percent abundance of major diatom species[1] and values of selected diatom association metrics for periphyton samples collected from stream sites in McCone County 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]	Station										
		HORC02	HORC04	HORC05	NLSN01	PRELK4A	REDW01	REDW02	REDW03	REDW04	SAND03	SAND2A
Achnanthidium minutissimum	3	0.23				19.98	0.43	3.29	1.13	0.22		6.40
Amphora coffeaeformis	1	0.46	2.52	15.85	0.48			1.59	0.23		4.22	
Cymbella pusilla	1	12.16	29.86		24.31		2.50	2.34	1.02		15.28	0.47
Navicula durrenbergiana	1						59.35	5.84				
Navicula salinarum	1	16.17	1.95	2.5	2.17		2.93	16.24	0.45		12.43	
Navicula veneta	1	6.19	9.15	3.34	9.75	3.19	2.28	4.46	1.47	0.44	10.26	14.20
Nitzschia agnita	1	0.69	2.97	1.19	9.27	19.39	2.83	4.88	3.85	2.42	0.46	1.40
Nitzschia aurariae	1		26.77	2.74	16.25	2.84	0.33	1.49		0.44	0.91	
Nitzschia filiformis	2				0.24	12.17			12.34	0.55	0.11	7.57
Nitzschia frustulum	2	3.67	2.63	69.61	7.58	1.65	1.41	8.81	27.63	0.55	7.41	6.40
Nitzschia pusilla	1		6.75		0.96	0.71	0.87	1.59		0.66	14.25	3.84
Nitzschia reversa	2	0.11				2.84	1.20	6.26	9.85	74.62	0.46	8.27
No. of Species Counted		40	**28**	**17**	**28**	32	43	66	51	**27**	48	52
Shannon Diversity		4.23	3.28	**1.64**	3.55	3.79	**2.93**	4.91	4.08	**1.75**	4.12	4.74
Pollution Index		**1.67**	**1.13**	**1.72**	**1.23**	1.93	**1.24**	**1.60**	1.98	1.94	**1.23**	1.77
Siltation Index		43.12	59.95	**83.79**	56.08	56.62	**85.54**	69.43	**75.99**	**91.54**	64.88	66.47
Disturbance Index		0.23	0.00	0.00	0.00	19.98	0.43	3.29	1.13	0.22	0.00	6.40
% Dominant Species		16.17	29.86	**69.61**	24.31	19.98	**59.35**	16.24	27.63	**74.62**	15.28	14.20
Percent Rhopalodiales		14.91	0.00	0.00	14.08	1.18	0.54	1.27	4.87	0.77	0.80	3.96
Similarity Index[3]			29.22	18.06				37.10	38.49	21.31		30.87

[1]A major diatom species accounts for 10.0% 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 McCone County streams. Categories that represent significant departures in water quality from other sites in the sample set are given in **bold face type**.

Ecological Attribute	Station HORC02	HORC04	HORC05	NLSN01	PRELK4A	REDW01	REDW02	REDW03	REDW04	SAND03	SAND2A
Motility[1]	**Moderately Motile**	Highly Motile	Highly Motile	Highly Motile	Highly Motile	**Moderately Motile**	Highly Motile	Highly Motile	Highly Motile	**Moderately Motile**	**Moderately Motile**
pH[2]	Alkaliphilous	Not Classified	Alkaliphilous	Not Classified	Alkaliphilous	Not Classified	Alkaliphilous	Alkaliphilous	Not Classified	Alkaliphilous	Alkaliphilous
Salinity[2]	Brackish	Brackish	**Brackish-Fresh**	Brackish	Brackish	Brackish	Brackish	**Brackish-Fresh**	Brackish	**Brackish-Fresh**	**Brackish-Fresh**
N Uptake[2]	Autotrophs	Not Classified	**Obligate Heterotroph**	Not Classified	Not Classified	Not Classified	Autotrophs	**Obligate Heterotroph**	Not Classified	Autotrophs	Not Classified
O_2 Demand[2]	Fairly High	Not Classified	**Moderate**	Not Classified	Not Classified	Not Classified	Not Classified	**Moderate**	Not Classified	Fairly High	Not Classified
Saprobity[2]	beta-Mesosaprobous	Not Classified	beta-Mesosaprobous	Not Classified	beta-Mesosaprobous	Not Classified	beta-Mesosaprobous	beta-Mesosaprobous	Not Classified	beta-Mesosaprobous	Not Classified
Trophic State[2]	Eutraphentic	Not Classified	Eutraphentic	Not Classified	Not Classified	Not Classified	Eutraphentic	Eutraphentic	Not Classified	Eutraphentic	Eutraphentic

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

Table 6. Metrics and ecological attributes that are calculated from diatom proportional counts. Source: Van Dam et al. 1994, unless otherwise indicated.

Metric	Category or Reference	Metric	Category or Reference
Valves Counted	Barbour et al. 1999	**Nitrogen Uptake (% by Category)**	Not Classified
Cells Counted	Barbour et al. 1999		Nitrogen Autotroph (low organics)
Total Number of Species	Barbour et al. 1999		Nitrogen Autotroph (high organics)
Total Number of Species	Barbour et al. 1999		Facultative Nitrogen Heterotroph
Percent Dominant Species	Barbour et al. 1999		Obligate Nitrogen Heterotroph
Shannon's Diversity Index	Barbour et al. 1999	**Oxygen Demand (% by Category)**	Not Classified
Pollution Index	Lange-Bertalot 1979		Continuously High
Pollution Tolerance (% by	Most Tolerant		Fairly High
(Lange-Bertalot 1979)	Tolerant		Moderate
	Sensitive		Low
Siltation Index	Bahls 1993		Very Low
Disturbance Index	Bahls 1993	**Saprobity (% by Category)**	alpha-Mesosaprobous/Polysaprobous
Stability Index	Bahls (unpublished)		Polysaprobous
Percent Rhopalodiales	Stevenson & Pan 1999		alpha-Mesosaprobous
Percent Aerophiles	Johansen 1999		Oligosaprobous
Percent Centrics			Not Classified
Heavy Metals Index	Bahls (unpublished)		beta-Mesosaprobous
Motility (% by Category)	Moderately Motile	**Trophic State (% by Category)**	Eutraphentic
(Stevenson, R.J., pers. com.)	Not Motile		Dystrophic
	Variable Motility		Not Classified
	Highly Motile		Hypereutraphentic
pH (% by Category)	Acidophilous		Meso-eutraphentic
	Indifferent		Mesotraphentic
	Alkalibiontic		Oligo-mesotraphentic
	Circumneutral		Oligotraphentic
	Acidobiontic		Variable
	Not Classified	**Moisture (% by Category)**	Not Classified
	Alkaliphilous		Rarely Outside Waterbodies
Salinity (% by Category)	Marine		Mainly in Waterbodies; Sometimes Wet
	Not Classified		Mainly in Waterbodies; Regularly Wet
	Very Fresh		Mainly Wet Places; Sometimes in Water
	Fresh		Exclusively Outside Waterbodies
	Brackish-fresh	**Similarity Index**	Compared to Reference Sample No.
	Brackish	(Whitaker 1952)	XXXX-XX