Blackfoot Watershed Water Quality Status and Trends
Periphyton Monitoring
2004

Prepared for:

Land and Water Consulting, Inc./PBS&J
Helena, Montana
Gary Ingman, Project Manager

Prepared by:

Erich E. Weber
*Phyco*Logic
East Helena, Montana

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Introduction

In late August of 2004, biological and water quality samples were collected at twelve core stations (6 on the main stem and 6 on major tributaries) in the Blackfoot River drainage of western Montana, as part of the *Blackfoot Watershed Water Quality Status and Trends Monitoring Program* (Land and Water 2004). A composite periphyton sample was collected at each of the twelve stations as a component of the biological monitoring effort.

Periphyton is the assemblage of small, often microscopic organisms (micro-invertebrates, bacteria, fungi, and benthic algae) that occur in aquatic habitats as a biofilm of varying thickness attached to or in close association with the surfaces of submerged substrates. Benthic algae typically dominate the periphyton community in freshwater streams. These algae can be divided into two major groups: the diatom algae which possess a rigid siliceous cell wall called a "frustule," and the non-diatom or soft-bodied algae which lack a siliceous cell wall. The taxonomy of both groups has been well established. Because the shape and ornamentation of diatom frustules are unique to each individual taxon, diatoms are readily identifiable to species. It is generally impractical to identify soft-bodied algae below the genus level.

Algae, and particularly the diatoms, are useful as water quality biomonitors because they occur in very large numbers, are highly sensitive to physical and chemical factors, and have known environmental requirements and pollution tolerances unique to individual species (Bahls 1993). Plafkin et al. (1989) lists several other advantages of using algae for bioassessment purposes:

- Algae generally have rapid reproduction rates and very short life cycles, making them valuable indicators of short-term impacts. (Perennial and fossil algae, including expired but recognizable algae within the periphyton matrix, reflect longer term impacts).

- As primary producers, algae are most directly affected by physical and chemical factors.

- Sampling is easy, inexpensive, requires few people, and creates minimal impact to resident biota.

- Relatively standard methods exist for evaluation of functional and non-taxonomic structural characteristics (e.g., biomass and chlorophyll) of algal communities.

- Algal communities are sensitive to some pollutants which may not visibly affect other aquatic communities, or may only affect other communities at higher concentrations (e.g., copper, herbicides and inorganic nutrients) (Palmer 1977).

Generally, periphyton collected from a particular stream location will reflect the environmental conditions that existed there for up to several weeks prior to sample collection. However, many factors in addition to water quality can affect the types and amount of algae present at a given time. These include but are not necessarily limited to: streamflow extremes, substrate scour, variable recolonization rates, normal seasonal succession, and sloughing of algal biomass late in the season. Bias introduced by factors not directly related to water quality can be minimized by sampling at the same time each year, well after the spring spate but before major sloughing of algal biomass occurs in late summer and early autumn (Peterson and Stevenson 1992). Monitoring conducted during the months of August and September likely satisfies the aforementioned criteria. Additionally, late summer likely encompasses the period with the poorest seasonal water quality and maximum environmental stress on stream biota due to low stream flow, elevated water temperature, and minimum instream dilution of pollutants and wastewater discharges (Hynes 1970).

Methods

Composite (qualitative) periphyton samples were collected from natural substrates at the twelve core sites in the Blackfoot River watershed of western Montana by personnel of Land and Water Consulting, Inc., following procedures in Section 6.1.1 of *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers* (Barbour et al. 1999). Sampling sites are listed in Table 1. Sampling was conducted during the last two weeks of August 2004.

In the laboratory, the raw sample was manually homogenized and a sub-sample of algal material was prepared as a wet mount. Soft-bodied (non-diatom) algae were identified to genus at 200X and 400X under an Olympus BHT compound microscope. The relative abundance of each algal genus (and of all diatom genera collectively) was estimated for comparative purposes, according to the following system:

- Rare (r): represented by a single occurrence in the sub-sample
- Occasional (o): multiple occurrences, but infrequently seen
- Common (c): multiple occurrences, regularly seen
- Frequent (f): present in nearly every field of view
- Abundant (a): multiple occurrences in every field of view, but well within limits of enumeration
- Dominant (d): multiple occurrences in every field of view, but generally beyond practical limits of enumeration

Soft-bodied genera (and the diatom component) also were ranked according to their estimated contribution to the total algal biovolume present in the sample.

A second sub-sample was chemically oxidized to remove organic matter, and a fixed mount of the siliceous diatom frustules was prepared according to “Standard Methods” (APHA *et al*. 1980). Diatoms present in each sample were identified to species under a 1000X oil immersion objective with a numerical aperture of 1.25. A proportional count of at

Table 1. Periphyton sampling locations on the Blackfoot River and tributaries, during August 2004.

SITE	STREAM NAME / SITE LOCATION	DATE
B-1	Blackfoot River below Alice Creek	8/23/2004
B-2	Landers Fork near Lincoln	8/24/2004
B-3	Blackfoot River at Dalton Mtn. Rd. near Lincoln	8/24/2004
B-4	Blackfoot River above Nevada Cr. Near Helmville	8/25/2004
B-5	Nevada Creek below Nevada Cr. Reservoir	8/25/2004
B-6	Nevada Creek near mouth	8/25/2004
B-7	Blackfoot River at Raymond Bridge	8/26/2004
B-8	North Fork Blackfoot River above Dry Gulch	8/26/2004
B-9	Monture Creek near Ovando	8/27/2004
B-10	Blackfoot River at Scotty Brown Bridge	8/27/2004
B-11	Clearwater River at Clearwater	8/27/2004
B-12	Blackfoot River near Bonner	8/27/2004

least 300 diatom cells (600 valves) was conducted on each sample, and the percent relative abundance of each species calculated.

A suite of metrics based on diatom community structure and composition, as well as environmental requirements and preferences of the diatom taxa, was calculated for each sample. The metrics of primary interest include diatom **species richness, diversity index** (Shannon), **pollution index**, **siltation index**, **disturbance index**, **percent dominant species**, **stability index, heavy metals index** and **percent community similarity.** Additionally, seven ecological attributes for diatom species were applied to each sample, based on those identified by Van Dam et al. 1994. Of these, only the diatom **trophic state** will be considered in the discussion.

Diatom **species richness,** the number of species counted, is considered a measure of biological integrity. High species richness is assumed to indicate unimpaired conditions, and a decrease in species richness is predicted with increasing pollution levels due to elevated stress on many diatom species (Barbour et al. 1999). Species richness may increase in headwater and naturally unproductive, nutrient-poor streams in response to slight to moderate increase in nutrients or sediment (Bahls et al. 1992).

The **Shannon diversity index** (Weber 1973) incorporates elements of species richness with equitability, the evenness of distribution of individuals among the species present. High diversity values occur in diatom communities where no taxa are strongly dominant in numbers, generally the case in healthy, unimpaired streams. In diatom communities under environmental stress, the majority of individuals present belong to a relatively small number of taxa, resulting in lower diversity index values. Diatom species diversity values of between 2.16 and 4.50 (mean 3.58) were found in nine least-impaired mountain reference streams in Montana (Bahls 1993). As with species richness, Shannon diversity may increase somewhat in naturally nutrient-poor mountain streams in response to slight to moderate increase in nutrients or sediment (Bahls et al. 1992).

The **pollution index** was proposed by Bahls (1993) as a shorthand method of summarizing the information contained in the pollution tolerance (PT) groups originally defined by Lange-Bertalot (1979) based on the species response to organic (biogenic) pollution. Each diatom species is assigned to one of three groups: pollution tolerance (PT) group 1 taxa are most tolerant of pollution, PT group 2 taxa are less tolerant, and PT group 3 are intolerant of (or most sensitive to) pollution. Additional diatom taxa are assigned to PT groups as autecological information becomes available in the literature. The pollution index is calculated as the sum of three products: the decimal fraction of the total PRA of diatom taxa in each PT group, multiplied by the respective group number. The index will range from 1.00 (all most tolerant taxa) to 3.00 (all most sensitive taxa). Pollution index values of between 2.45 and 2.94 (mean 2.72) were determined by Bahls (1993) for diatom communities from least-impaired mountain reference streams in Montana.

The **siltation index** is defined as the total percent relative abundance of diatom species belonging to the genus *Navicula* (plus approximately 13 allied genera recently split off form *Navicula*), the genus *Nitzschia* (and 2 recent allies) and the genus *Surirella* present in a sample. These genera are comprised largely of highly motile, biraphidean diatoms that are better adapted to existence on unstable, shifting substrates. Values can range from 0 to over 90; in mountain reference streams in Montana the index ranged from 0 to 50.3 (mean 14.5) (Bahls 1993). Diatom genera included in the siltation index are listed in Appendix C.

The **disturbance index** is simply the percent abundance of the diatom *Achnanthidium minutissimum* (synonym: *Achnanthes minutissima*). This cosmopolitan species is an attached form that often pioneers and dominates recently disturbed sites. While somewhat sensitive to organic pollution, *A. minutissimum* resists chemical and physical disturbances such as heavy metals toxicity and substrate scour. Disturbance index values can range from 0 to 100. A value of less than 25 indicates a relatively stable undisturbed community, while a value in excess of 50 suggests a relatively recent disturbance of moderate to severe intensity (Barbour et al. 1999).

The **percent dominant species** considers just that: the single diatom species having the highest percent relative abundance. In healthy, unimpaired streams, no single species is responsible for a high percentage of the total diatom cells present. The greater the percentage contributed by a single dominant species, the greater the degree impairment indicated at that site. Values in excess of 50% indicate moderate to severe impairment or stress (Bahls 1993 revised).

The **stability index** is defined as the percent of araphid, or non-motile pennate diatom species present. Species belonging to the dozen or so genera of freshwater araphid diatoms generally are attached forms and are poorly equipped to survive on unstable substrates such as sediment. Higher numbers of araphid species at a site would suggest a higher degree of substrate stability.

A presumptive **heavy metals index,** proposed by Bahls (2004 personal communication), is defined as the total percent abundance of 18 diatom species that apparently tolerate elevated concentrations of heavy metals. Included are three diatom species that, when present in large numbers, appear to confirm elevated heavy metals concentrations. The diatom species included in the proposed heavy metals index are listed in Appendix C.

The **similarity index**, or percent community similarity (Whittaker 1952) considers the diatom species that are in common between two samples, and is calculated as the sum of the lower of the percent relative abundance values of all shared species. The similarity index can be used to gauge change between adjacent stream sites, particularly above and below a tributary, point source or other potential impact, or between streams of similar size in the same vicinity. Similarity index values range from 0 (completely dissimilar diatom assemblages) to 100 (identical assemblages), with a value of 60% or greater indicating very similar diatom floras.

The **trophic state** of a stream site is estimated by the percent abundance of species in each of eight diatom classes defined by their nutrient preferences or tolerances, and is a general indicator of inorganic nutrient levels. Of the eight nutrient classes, one (dystrophic) does not apply to streams, while another includes diatom species with highly variable or generally indifferent nutrient preferences. The remaining six trophic classes denote inorganic nutrient preferences that range from very low (oligotraphentic) to moderate (mesotraphentic) to very high (hypereutraphentic), with three additional categories that represent preferences intermediate to these. For the sake of simplicity and clarity, these six trophic classes are paired into three, and are plotted along with the variable or indifferent segment and the remaining segment of unknown classification.

Results and Discussion

The genera of soft-bodied algae identified at each Blackfoot River and tributary site in August 2004, along with the estimated abundance and biovolume ranking of each genus, are included in Appendix A. A summary of the total number of soft-bodied genera at each site is included in Table 2a, and is plotted in Figure 1. The soft-bodied genera are grouped into three major types: the green algae (Division Chlorophyta), the cyanobacteria (blue-green algae: Division Cyanobacteria) and other (brown algae: Division Phaeophyta; red algae: Division Rhodophyta; and yellow-green algae: Division Chrysophyta, Class Tribophyceae).

The species of diatom algae identified at each Blackfoot River and tributary site in August 2004, along with cell counts and percent abundance values for each taxon, are presented in Appendix A. The number of diatom species counted at each site, or species richness, is also presented in Table 2b.

The full suite of diatom metrics calculated for each of the twelve Blackfoot River and tributary sites are presented in Appendix B. Metrics selected for more detailed examination and for bioassessment purposes are presented in Table 2b. Values for Shannon diversity index, pollution index and siltation index are also illustrated in Figures 2, 3 and 4, respectively. The trophic state of the diatom assemblages at the six mainstem Blackfoot River sites are plotted in Figure 5a-f, and for the six tributary sites in Figure 6 a-f. The percent similarity of diatom assemblages between adjacent Blackfoot River sites, between selected tributary and mainstem sites, and between selected tributary sites are presented in Figure 7.

Table 2. Abundance values for soft-bodied algae and diatoms, and values for selected diatom metrics at 12 mainstem and tributary sites in the Blackfoot River basin during August 2004. See Table 1 for site descriptions.

SITE:	B-1	B-2	B-3	B-4	B-5	B-6	B-7	B-8	B-9	B-10	B-11	B-12
2a. SOFT-BODIED ALGAE												
Total number of genera	16	5	10	18	5	16	16	12	13	18	15	22
Number of genera common or greater	15	5	8	12	3	10	10	8	7	11	8	15
Green algae	11	1	5	11	3	11	9	11	11	11	8	15
Cyanobacteria	4	3	3	6	1	4	5	1	1	5	5	4
Other (brown, red, or yellow-green algae)	1	1	2	1	1	1	2	0	1	2	2	3
2b. DIATOM ALGAE												
Species Richness (no. of species counted)	56	43	76	83	46	59	79	68	59	68	61	63
Shannon Diversity Index	4.60	2.10	5.01	5.44	4.20	4.46	4.83	4.43	3.96	4.56	4.75	4.55
Pollution Index	2.40	2.92	2.64	2.61	2.52	2.52	2.56	2.79	2.43	2.69	2.75	2.58
Siltation Index	30.46	5.72	23.93	30.85	29.63	26.26	31.60	11.80	9.03	14.13	17.00	10.02
Disturbance Index	17.22	72.66	16.01	6.82	0.64	10.37	3.48	34.93	16.82	26.37	5.77	9.23
Percent Dominant Species	17.22	72.66	16.01	10.23	15.94	25.77	24.49	34.93	33.33	26.37	15.29	24.73
Stability Index	30.62	1.11	28.21	23.10	3.38	3.89	9.64	24.40	13.08	22.45	7.96	34.43
Heavy Metals Index	31.58	4.61	11.73	8.53	4.67	15.72	12.95	11.00	50.78	10.52	8.11	6.73

Table 3. Diatom association metrics used by the State of Montana to evaluate biological integrity in mountain streams. The lowest rating for any one metric is considered to be the rating for that site (after Bahls 1993, revised 2004).

BIOASSESSMENT	**METRICS**						
Biological Integrity/ Impairment or Stress/ Use Support	**Species Richness[1] (no. of species counted)**	**Diversity Index[2] (Shannon)**	**Pollution Index[3]**	**Siltation Index[4]**	**Disturbance Index[5]**	**% Dominant Species[6]**	**Score**
Excellent/ None/ Full Support	>29	>2.99	>2.50	<20.0	<25.0	<25.0	3
Good/ Minor/ Full Support	20-29	2.00-2.99	2.01-2.50	20.0-39.9	25.0-49.9	25.0-49.9	2
Fair/ Moderate/ Partial Support	10-19	1.00-1.99	1.50-2.00	40.0-59.9	50.0-74.9	50.0-74.9	1
Poor/ Severe/ Nonsupport	<10	<1.00	<1.50	>59.9	>74.9	>74.9	0
Expected Response to Increasing Impairment or Natural Stress	Decrease[7]	Decrease[7]	Decrease	Increase	Increase	Increase	
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	
References	Bahls 1979 Bahls 1993	Bahls 1979	Bahls 1993	Bahls 1993	Barbour et al. 1999	Barbour et al. 1999	

[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* (and 13 allies), *Nitzschia* (and 2 allies) and *Surirella*
[5] Percent abundance of *Achnanthidium minutissimum*
[6] Percent abundance of the species with the largest number of valves in the proportional count
[7] Species richness and diversity may increase somewhat in mountain streams in response to slight to moderate increases in nutrients or sediment

Table 4. Metric scores for diatom metric values included in Table 2b, and bioassessment results for biological integrity, impairment and beneficial use support at 12 mainstem and tributary sites in the Blackfoot River basin during August 2004. See Table 1 for site descriptions and Table 3 for metric scoring criteria. (mod.= moderate; part.= partial; excel.= excellent)

SITE:	B-1	B-2	B-3	B-4	B-5	B-6	B-7	B-8	B-9	B-10	B-11	B-12
DIATOM METRICS	**METRIC SCORES**											
Species Richness	3	3	3	3	3	3	3	3	3	3	3	3
Shannon Diversity Index	3	2	3	3	3	3	3	3	3	3	3	3
Pollution Index	2	3	3	3	3	3	3	3	2	3	3	3
Siltation Index	2	3	2	2	2	2	2	3	3	3	3	3
Disturbance Index	3	1	3	3	3	3	3	2	3	2	3	3
Percent Dominant Species	3	1	3	3	3	2	3	2	2	2	3	3
	BIOASSESSMENT											
MINIMUM SCORE	**2**	**1**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**3**	**3**
BIOLOGICAL INTEGRITY	**good**	**fair**	**good**	**good**	**good**	**good**	**good**	**good**	**good**	**good**	**excel.**	**excel.**
IMPAIRMENT	**minor**	**mod.**	**minor**	**minor**	**minor**	**minor**	**minor**	**minor**	**minor**	**minor**	**none**	**none**
USE SUPPORT	**full**	**part.**	**full**	**full**	**full**	**full**	**full**	**full**	**full**	**full**	**full**	**full**

Bioassessments

Criteria for assessment of biological integrity, and the degree of impairment and use support that utilize selected diatom metrics as developed by the State of Montana, are presented in Table 3. Diatom metric scores for the twelve Blackfoot River and tributary sites monitored in August 2004, and assessments of biological integrity and degree of impairment and support of beneficial uses, based on the criteria in Table 3, are presented in Table 4.

Blackfoot River sites B-1, B-3 and B-4, located within the mainstem segment between the headwaters and Nevada Creek, were rated as having good biological integrity with only minor levels of impairment, and fully supported beneficial uses based on diatom association metrics. Slightly elevated values for the siltation index were responsible for the minor impairment rating. Mainstem Blackfoot River sites B-7 and B-10 located in the segment between Nevada Creek and the Clearwater River were also rated as having good biological integrity with minor impairment of aquatic life, but fully supporting beneficial uses. A slightly elevated siltation index value at site B-7, and slightly elevated disturbance index and % dominant species values at site B-10 were the only reasons for the minor impairment ratings. Blackfoot River site B-12, near Bonner, was rated as unimpaired with excellent biological integrity fully supporting beneficial uses.

Tributary site B-2, Landers Fork near Lincoln, was rated as having fair biological integrity with moderate impairment of the aquatic biota, and only partially supporting beneficial uses due to elevated disturbance index and % dominant species values. The same diatom taxon, *Achnanthidium minutissimum*, was responsible for the elevated values of both metrics. It is possible that impacts of the severe forest fires that occurred over large areas of this drainage in 2003 contributed to the elevated disturbance index, likely through substrate scour caused by abnormally severe runoff events.

The two sites on Nevada Creek, B-5 below Nevada Cr. Reservoir and B-6 near the mouth, were rated as having good biological integrity with only minor impairment of the biota and fully supporting beneficial uses due to somewhat elevated siltation index values, as well as elevated % dominant species value at site B-6.

The North Fork of the Blackfoot River (site B-8) and Monture Creek (site B-9) were rated as having good biological integrity with only minor impairment of aquatic lie due to elevated % dominant species values at both sites, and a correspondingly high disturbance index value at B-8. Both sites were rated as fully supporting beneficial uses.

The Clearwater River at Clearwater (site B-11) was rated as unimpaired with excellent biological integrity and full support of beneficial uses, based on the diatom metrics in Table 2.

Figure 1. Genera of soft-bodied algae identified at Blackfoot River and tributary sites during August 2004.

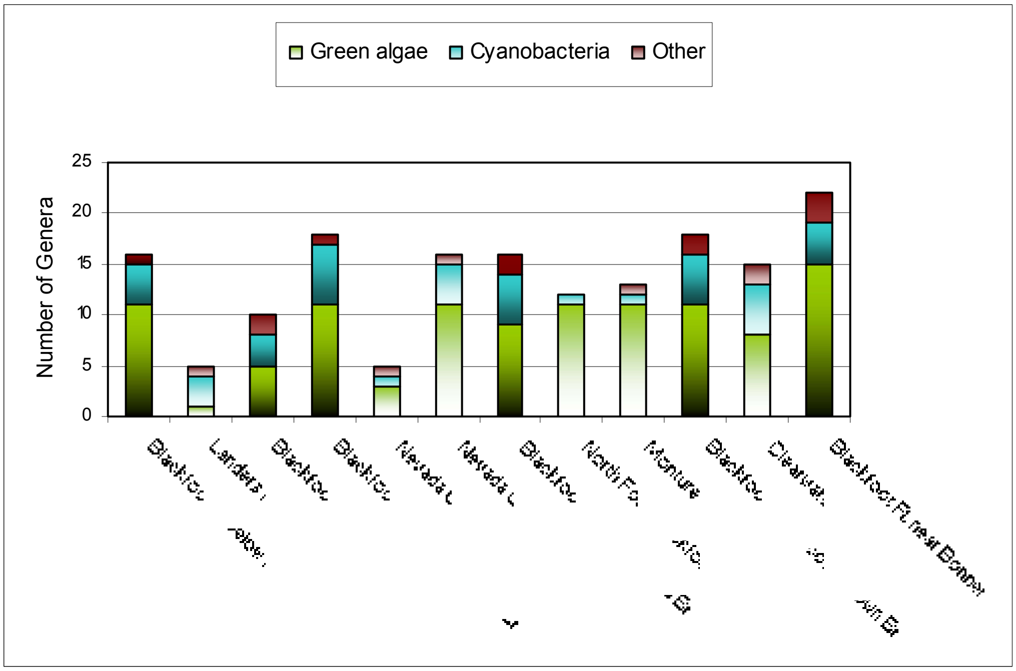


Figure 2. Shannon divesity index values for diatom associations at Blackfoot River and tributary sites during August 2004.

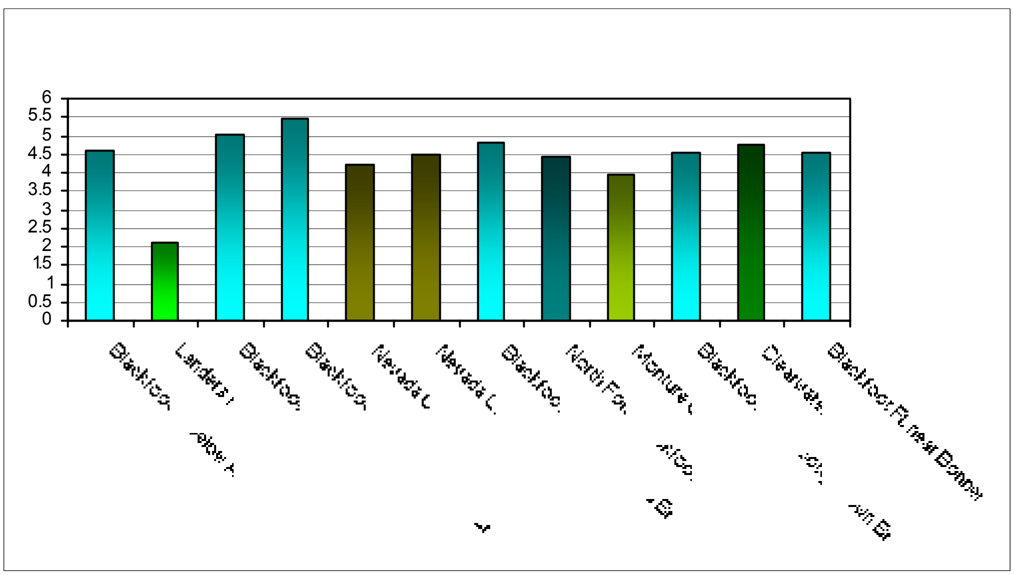


Figure 3. Pollution index values for diatom assemblages from Blackfoot River and tributary sites during August 2004.

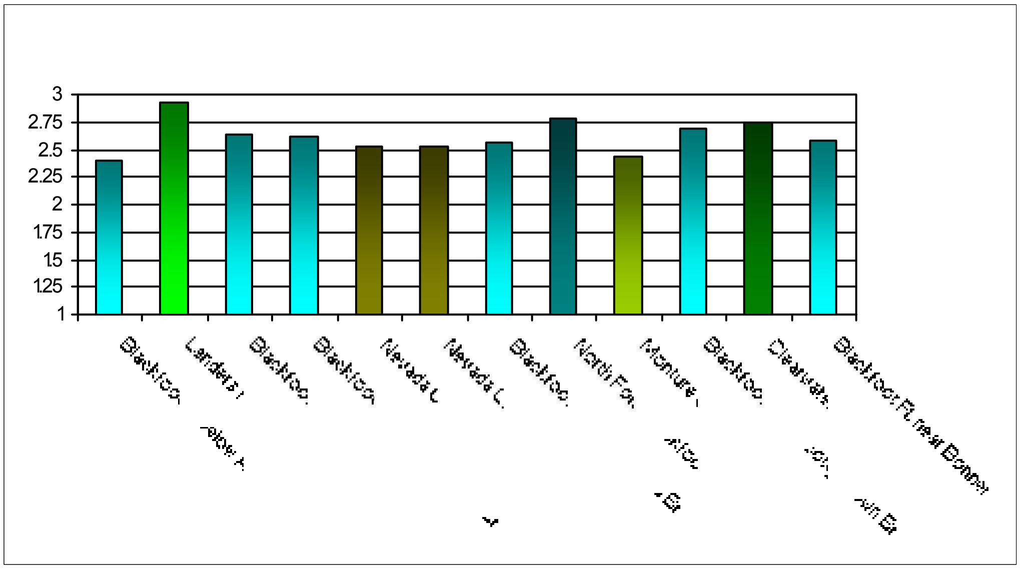


Figure 4. Siltation index values for diatom assemblages at Blackfoot River and tributary sites during August 2004.

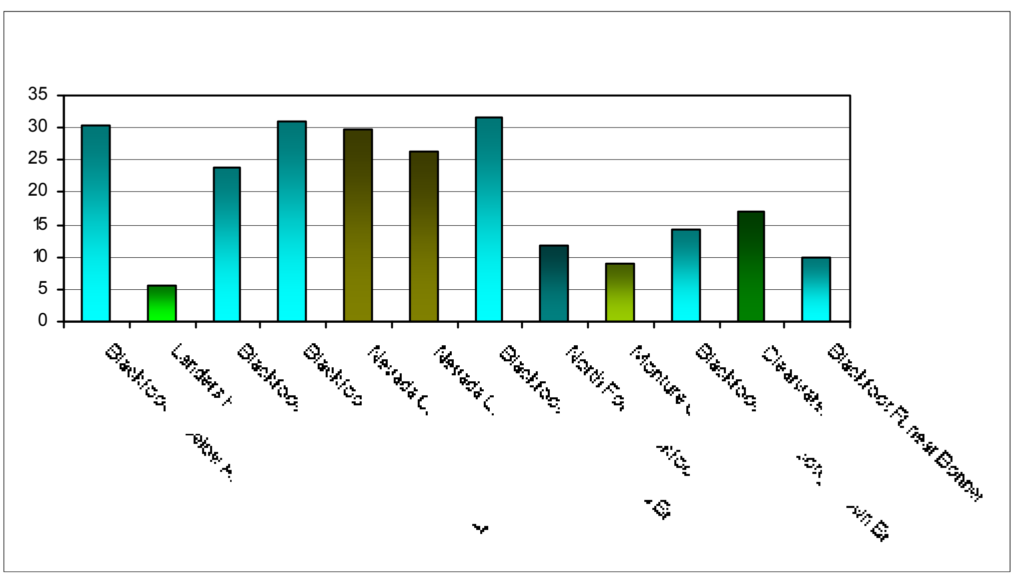
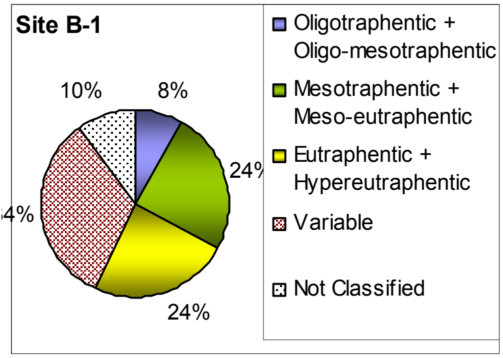
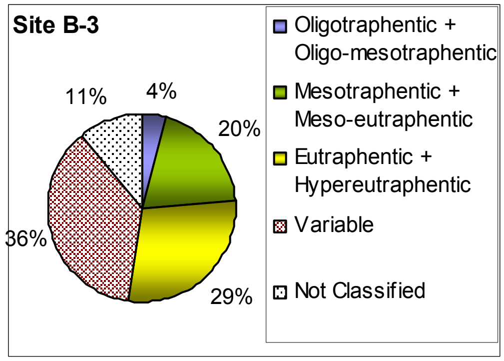


Figure 5. Trophic state of the diatoms present at each of the six **mainstem** Blackfoot River sites monitored during August 2004, as percent by category.

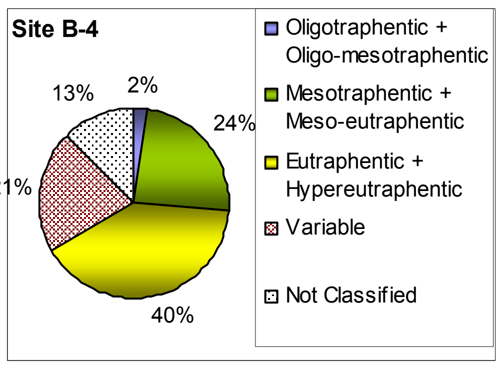
5a.
Blackfoot River below Alice Creek



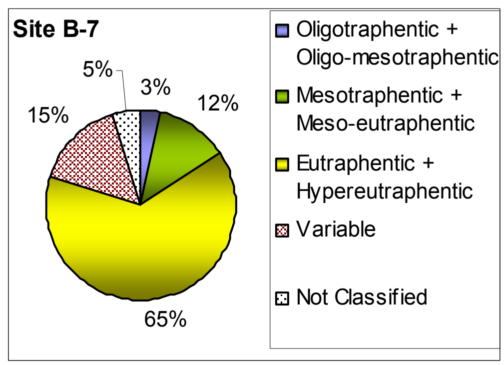
5b.
Blackfoot River at Dalton Mtn. Road



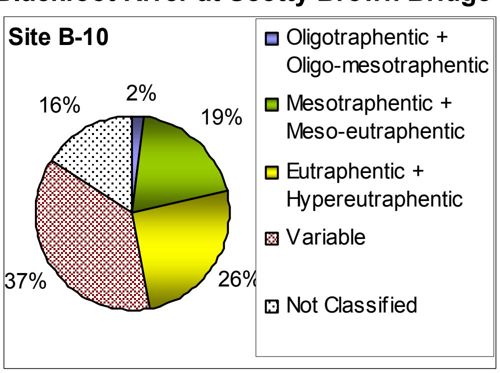
5c.
Blackfoot River above Nevada Creek



5d.
Blackfoot River at Raymond Bridge



5e.
Blackfoot River at Scotty Brown Bridge



5f.
Blackfoot River near Bonner

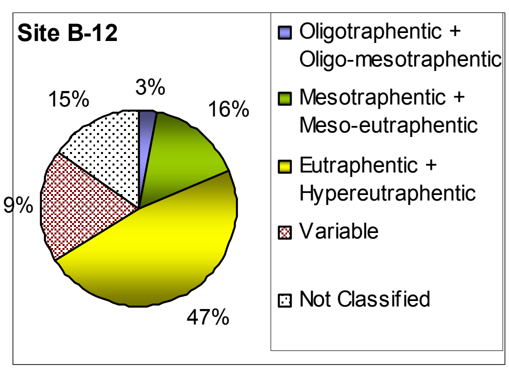
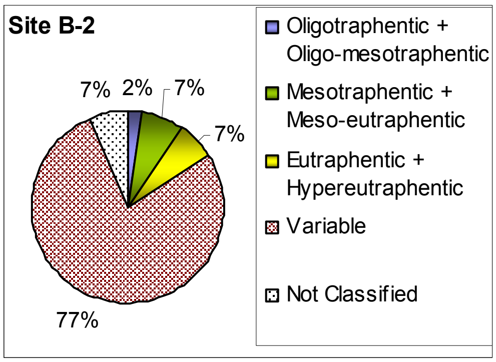
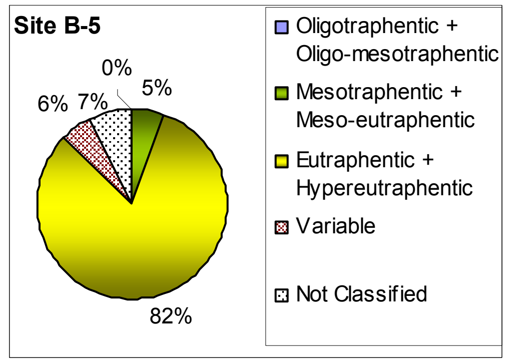


Figure 6. Trophic state of the diatoms present at each of six **tributary** sites monitored in the Blackfoot River watershed during August 2004, as percent by category.

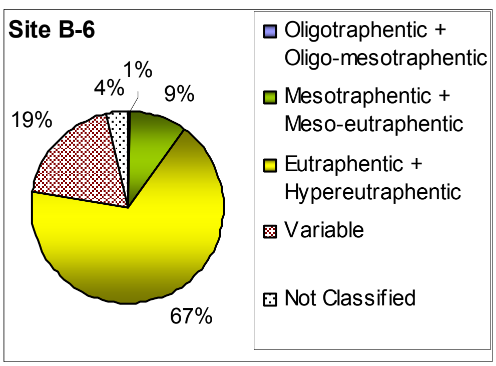
6a.
Landers Fork near Lincoln



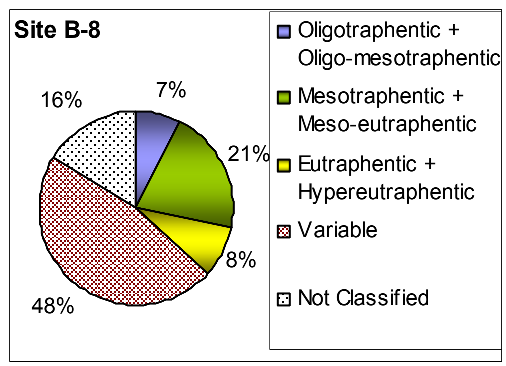
6b.
Nevada Creek below Nevada Cr. Reservoir



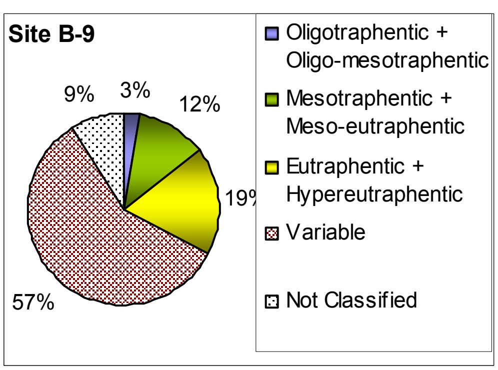
6c.
Nevada Creek near mouth



6d.
North Fork Blackfoot R. above Dry Gulch



6e.
Monture Creek near Ovando



6f.
Clearwater River at Clearwater

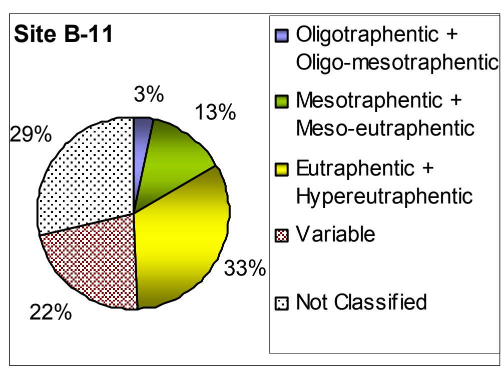


Figure 7. Schematic diagram of the Blackfoot River and tributaries with percent similarity of diatom communities between sites monitored during August 2004.
Percent similarity after Whitaker (1952).

Taxonomic Assessments

A diverse assemblage of soft-bodied algae was present at the **Blackfoot River below Alice Creek**, site B-1, with 15 genera identified (Figure 1). Several genera of both green algae and cyanobacteria dominated the soft-bodied flora (Appendix A), and were indicative of a nutrient rich, low gradient headwaters stream. The diatom assemblage at B-1 was slightly less diverse than other mainstem stations (Figure 2) and had the lowest pollution index value of the twelve sites monitored in 2004 (Figure 3) suggesting at least minor impairment at this site. The siltation index value was also relatively high, possibly indicating some sediment deposition at site B-1. The presumptive heavy metals index value was considerably higher at site B-1 than at downstream mainstem stations (Table 2). This suggests that some degree of heavy metals impact was present in the reach below the historic Mike Horse Mine tailings, although this can not be quantified. The trophic state of diatoms at site B-1 (Figure 5a) suggests a flora that prefers moderate to high levels of inorganic nutrients, with nearly 50% of diatom cells counted belonging to species in those categories.

Landers Fork site B-2 had only 5 genera soft-bodied algae present in August 2004 (Figure 1, Appendix A.3), suggesting relatively nutrient-poor conditions in this major tributary to the upper Blackfoot River. Diatom algae were much less important relative to the soft-bodied algae at this site, ranking 5th in estimated biovolume. The three dominant genera of soft-bodied algae belonged to different algal divisions and suggest unimpaired conditions at site B-2 (Appendix A.3). Diatom species diversity at B-2 was by far the lowest of any of the twelve mainstem or tributary stations, suggesting some degree of impairment. However, the pollution index at site B-2 was the highest, and the siltation index the lowest of any site monitored in August 2004 (Figures 3 and 4), both of which strongly indicate low levels of stress or impairment. This contradicts the bioassessment result presented in the previous section that, based on the low score returned by a very high disturbance index value, indicated moderate impairment in the Landers Fork (Table 4). The heavy metals index at site B-2 also was the lowest of any site monitored in August 2004 (Table 2). It is likely that the low diatom species richness and diversity values at B-2 were related to naturally unproductive conditions, and not impairment, although major disturbances did occur in the Lander Fork watershed during the summer of 2003. Over 75% of the diatoms counted at site B-2 were considered to have variable or indifferent nutrient preferences under the trophic state classifications (Figure 6a). The percent similarity of the diatom floras at sites B-1 and B-2 was only about 25% (Figure 7), indicating somewhat dissimilar diatom communities between the Landers Fork and the mainstem upstream of their confluence.

The **Blackfoot River at Dalton Mountain Road**, site B-3, had 10 genera of soft-bodied algae present in August 2004, considerably fewer than at site B-1 and possibly reflecting the influence of upstream tributaries (Figure 1). The soft-bodied algae at B-3 contained 9 filamentous genera from four algal divisions (Appendix A.5), including *Vaucheria*, *Chaetophora*, *Spirogyra*, *Ulothrix*, *Audouinella* and *Nostoc*. These diverse genera indicate rich, relatively unimpaired conditions in the Blackfoot River downstream of the Lincoln valley. Diatom algae were also relatively important at B-3, ranking 3rd in estimated biovolume. The Shannon diversity index at site B-3 was the second highest of all twelve sites monitored in August 2004 (Figure 2), while the pollution index was the second highest of the Blackfoot mainstem sites (Figure 3). The siltation index value at site B-3 was less than the relatively high value seen at mainstem site B-1 some 15 river miles upstream (Figure 4), as was the presumptive heavy metals index value (Table 2). This suggests a positive influence by the Landers Fork on the Blackfoot mainstem. Together, these metrics indicate relatively unimpaired conditions at site B-3 in August 2004. The trophic state of the diatom assemblage at site B-3 was very similar to that at upstream mainstem site B-1 (Figure 5b). The diatom floras at Blackfoot River sites B-1 and B-3 had a similarity index value of 45.5% (Figure 7), indicating somewhat similar floras between these sites.

The **Blackfoot River above Nevada Creek**, site B-4, had a diverse assemblage of soft-bodied algae with 18 genera identified (Figure 1). Several genera of filamentous green algae were present, with the robust form *Cladophora* occurring for the first time in this monitoring (Appendix A.7). Cyanobacteria (blue-green algae) were also well represented at site B-4, with the colonial filamentous genus *Nostoc* accounting for the greatest estimated abundance and biovolume. Diatoms were also relatively important at site B-4, ranking 2nd overall compared to non-diatom algae (Appendix A.7). The diatom species richness and diversity index values at the Blackfoot River above Nevada Creek were the highest of the twelve sites sampled in August 2004 (Table 2, Figure 2). The pollution index value at B-4 was little changed from upstream site B-3 (Figure 3), while the siltation index value increased to a level slightly greater than seen at B-3 (Figure 4). These metrics suggest an increase in inorganic nutrients and sediment at mainstem site B-4, although the level of impairment appears to be about the same. The trophic state at B-4 indicates an increase in the percentage of diatom species preferring moderate to high levels of inorganic nutrients (Figure 5c). The percent similarity of diatom floras between mainstem sites B-4 and B-3 was 51.8, again indicating somewhat similar communities (Figure 7).

Nevada Creek below Nevada Cr. Reservoir, site B-5, had only 5 genera of soft-bodied algae present in August 2004 (Figure 1), with the filamentous green alga *Cladophora* and the filamentous cyanobacteria *Oscillatoria* ranked 1st and 3rd in estimated biovolume, respectively (Appendix A.10). Diatoms were ranked 2nd in estimated biovolume relative to soft-bodied algae at site B-5. Diversity index and pollution index values for diatoms, while somewhat depressed compared to Blackfoot River sites, indicate no impairment of the biota at site B-5 (Figures 2 and 3, Table 4). However, the somewhat elevated siltation index value does indicate minor impairment of the biota in Nevada Creek below Nevada Creek Reservoir in August 2004 (Figure 4). The trophic state at site B-5 was dominated by diatom species clearly preferring highly elevated levels of inorganic nutrients (82%), while diatom species preferring nutrient poor conditions were entirely absent (0%).

Site B-6, **Nevada Creek near mouth** had 16 genera of soft-bodied algae present in August 2004, the most at any tributary site sampled (Figure 1). Several genera of filamentous green algae including *Cladophora* and *Oedogonium*, and the cyanobacteria *Nostoc* and *Phormidium* were dominant taxa at site B-6 (Appendix A.12). The assemblage of soft-bodied algae at site B-6 indicates highly productive conditions with elevated levels of algal nutrients. Diatoms were ranked 3rd in estimated biovolume relative to soft-bodied algae at site B-6. The Shannon diversity index value at site B-6 was slightly higher than at the upper Nevada Creek site (Figure 2), while the pollution index was essentially unchanged (Figure 3). The siltation index value decreased slightly at site B-6 compared to site B-5, but still indicated slight impairment of the biota (Figure 4, Table 4). The presumptive heavy metals index of 15.7 at site B-6 was the third highest of sites monitored in August 2004 (Table 2). Still it was only about 50% of the value seen at the headwater mainstem site B-1. The trophic state at Nevada Creek site B-6 continued to be dominated by diatom species preferring highly elevated inorganic nutrients, although slightly less so than at site B-5 (Figure 6c). The percent similarity of the diatom assemblages between Nevada Creek sites B-5 and B-6 was only 25.9, indicating somewhat dissimilar floras at the two sites (Figure 7).

The **Blackfoot River at Raymond Bridge**, site B-7, had 16 genera of soft-bodied algae present in August 2004 (Figure 1). This site is located downstream of the mouth of Nevada Creek, and the biota might be expected to display some influence from the tributary. Many of the same genera of soft-bodied algae occurred at Blackfoot River site B-7 as at Nevada Creek site B-6, although the dominant forms differed between the sites. The filamentous green alga *Spirogyra* and the cyanobacteria *Nostoc* and *Tolypothrix* were all strongly dominant at site B-7, occupying the top three ranks for estimated biovolume (Appendix A.14). Diatoms were ranked 4th in estimated biovolume at site B-7. Diatom species richness at site B-7 was 79, the second highest of the twelve sites behind only Blackfoot River site B-4 (Table 2). Shannon diversity at site B-7 was slightly lower than at upstream mainstem sites (Figure 2), and the pollution index value decreased very slightly, indicating a small worsening of water quality (Figure 3). The siltation index value at site B-7 was the highest determined for any of the twelve sites, but only slightly greater than values at upstream mainstem sites B-1 and B-4 (Figure 4). The trophic state at Site B-7 (Figure 5d) indicates an increase in numbers of diatoms preferring high levels of inorganic nutrients over those seen at Blackfoot River site B-4, above Nevada Creek. The percentages of diatoms in the 5 trophic state categories for Blackfoot River site B-7 (Figure 5d) are very similar to those at Nevada Creek site B-6 (Figure 6c). The percent similarity of the diatom floras at Nevada Creek site B-6 and Blackfoot River site B-7 was 61.4, indicating very similar diatom assemblages between the tributary and mainstem sites (Figure 7). The Blackfoot River mainstem sites B-4 and B-7 above and below Nevada Creek, respectively, had a similarity index value 49.4, indicating somewhat similar diatom communities (Figure 7).

The **North Fork Blackfoot River above Dry Gulch**, site B-8, had 12 genera of soft-bodied algae present in August 2004 (Figure 1). Several genera of filamentous green algae were strongly dominant at site B-8, including *Zygnema*, *Mougeotia, Spirogyra* and *Oedogonium,* although diatoms actually ranked 1st in estimated biovolume relative to the soft-bodied genera in the North Fork (Appendix A.17). Site B-8 had a moderately high Shannon diversity value, the 2nd highest pollution index value overall, and a relatively low siltation index value, all of which indicate largely unimpaired conditions in this large tributary to the Blackfoot River (Figures 2, 3 and 4). Nearly 50% of diatoms counted at site B-8 were classified as variable/indifferent in nutrient preference, while about 30% preferred moderate to high levels of inorganic nutrients (Figure 6d). This suggests moderate levels of inorganic nutrients in the lower North Fork. The percent similarity of diatom species at site

B-8 and mainstem site B-7 was only 16.8, indicating there was little in common between the diatom communities at these sites in August 2004 (Figure 7).

Monture Creek near Ovando, site B-9, had 13 genera of soft-bodied algae present in August 2004 (Figure 1). These were dominated by filamentous green algae including *Oedogonium, Mougeotia* and *Spirogyra*, although *Oscillatoria*, the lone genus of cyanobacteria at site B-9 actually ranked 1st in estimated biovolume contribution (Appendix A.19). Diatoms were strongly dominant at site B-9, and ranked 3rd in estimated biovolume relative to soft-bodied algae. The Shannon diversity index at Monture Creek site B-9 was slightly lower than at other tributary sites along the middle reach of the Blackfoot River (Figure 2), as was the pollution index value (Figure 3). The later was indicative of minor impairment under the bioassessment criteria (Table 4). The siltation index at site B-9 was the second lowest of the twelve sites monitored, suggesting only minor sediment impacts in this major tributary. The trophic state of the diatom flora in Monture Creek indicates somewat elevated levels of inorganic nutrients, although over 50% of diatom numbers at site B-9 belong to the variable/nutrient indifferent category (Figure 6e). The presumptive heavy metals index value at site B-9 was the highest determined for any of the twelve sites, do largely to the high percent abundance of a single diatom species, *Encyonema silesiacum* (Table 2, Appendix A.19). While *E. silesiacum* is included on the list of proposed heavy metals indicators, it is not one the handful of species considered likely to confirm metals pollution when present in high numbers (Appendix C), and is considered to be intolerant of other forms of pollution. The percent similarity of diatom species between Monture Creek and the North Fork Blackfoot River was 41.2, indicating somewhat similar diatom communities (Figure 7).

The **Blackfoot River at Scotty Brown Bridge** (site B-10) had 18 genera of soft-bodied algae present in August 2004 (Figure 1). The cyanobacteria genus *Oscillatoria* ranked 1st in relative biovolume soft-bodied algae, followed by at least half a dozen genera of green algae including filamentous forms *Ulothrix* and *Chaetophora*, and the desmid *Cosmarium* (Appendix A.21). Diatoms were ranked 2nd in biovolume relative to the other forms of algae at Site B-10. Shannon diversity and pollution index values were relatively high and siltation index moderately low, indicating no impairment at Blackfoot River site B-10. However, a slightly elevated disturbance index value was indicative of minor impairment at site B-10 under the bioassessment criteria (Tables 2 and 4). The trophic state at site B-10 was quite different from the closest mainstem site (site B-7), but had much in common with the upper Blackfoot River sites B-1 and B-3 (Figures 5a, b, d and e), indicating somewhat lower levels of inorganic nutrients at site B-10. The percent similarity between Blackfoot River site B-10 and upstream site B-7 was only 28.6, indicating somewhat dissimilar diatom floras. However, Monture Creek site B-9 and site B-10 had somewhat similar diatom communities, with a percent similarity of 48.0 (Figure 7). This suggests a strong tributary influence on the middle Blackfoot River mainstem.

At the **Clearwater River at Clearwater** (site B-11), 15 genera of soft-bodied algae were identified in August 2004 (Figure 1). These included a diverse assemblage of green algae and cyanobacteria, plus the relatively uncommon brown alga *Heribaudiella*, none of which were strongly dominant (Appendix A.23). Diatoms were considered abundant and ranked 3rd in estimated biovolume contribution relative to soft-bodied algae. Shannon diversity index for diatom species at site B-11 was the highest of any tributary monitored in August 2004 (Figure 2). The pollution index value at site B-11 exceeded all Blackfoot River mainstem sites, and was the third highest overall behind the North Fork Blackfoot River and the Landers Fork (Figure 3). The siltation index at site B-11, while slightly elevated compared to the other three 'north side' tributaries, was low enough (along with the five other diatom metrics) for site B-11 to be rated as unimpaired under the bioassessment criteria (Figure 4, Tables 2 and 4). The trophic state indicates nearly 50% of diatoms at site B-11 preferred moderate to high levels of inorganic nutrients, although nearly 30% were not classified by nutrient preference (Figure 6c). The Clearwater River and upstream Blackfoot River site B-10 had a percent similarity index value of 31.7, indicating somewhat dissimilar diatom floras at these sites (Figure 7).

The **Blackfoot River near Bonner**, site B-12, is over 25 miles downstream of the Clearwater River, and over 35 river miles downstream of Blackfoot River site B-10. A very diverse assemblage of 23 genera of soft-bodied algae was present at site B-12 (Figure 1). Several genera of filamentous green algae, including *Mougeotia*, *Ulothrix*, *Oedogonium*, and *Chaetophora,* as well as the cyanobacteria *Oscillatoria* and the brown alga *Heribaudiella* were important at site B-12 (Appendix A.25). These taxa indicate a healthy, nutrient-rich unimpaired environment. Diatoms were dominant forms at Blackfoot River site B-12, and were ranked 4th in biovolume relative to soft-bodied algae. Values for Shannon diversity index and pollution index were slightly lower but similar to the middle Blackfoot River sites (Figures 2 and 3), while the siltation index at site B-12 was the lowest of the six mainstem sites (Figure 3). The Blackfoot River near Bonner was determined to be unimpaired, based on the bioassessment criteria in Table 3. The trophic state at site B-12 indicates that over 60% of diatoms present preferred moderate to high levels of inorganic nutrients (Figure 5f).

Conclusions

- Minor impairment of the biota was indicated at the Blackfoot River below Alice Creek (site B-1), probably due to sediment impacts, and possibly the result of low levels of heavy metals pollution. A very diverse assemblage of soft-bodied and diatom algae suggested elevated levels of algal nutrients.

- Landers Fork near Lincoln (site B-2) was moderately impaired due to environmental stress related to substrate disturbance, although sediment impacts were not indicated. Both soft-bodied and diatom algae were much less diverse than in the Blackfoot mainstem due to relatively nutrient-poor conditions at site B-2.

- Sediment impacts were responsible for minor impairment at Blackfoot River at Dalton Mountain Road near Lincoln (site B-3). Biological integrity was good, and a diverse assemblage of soft-bodied and diatom algae indicated abundant inorganic nutrients.

- Minor impairment of the biota related to sediment was indicated at site B-4, Blackfoot River above Nevada Creek. A highly diverse community of soft-bodied and diatom algae was present, apparently in response to low levels of environmental stress and nutrient-rich conditions.

- Nevada Creek below Nevada Cr. Reservoir (site B-5) had only minor impairment indicated by diatom metrics that apparently was due to sediment impacts. The very low number of soft-bodied genera and the predominance of diatoms with a strong affinity for elevated nutrients suggest site B-5 was adversely impacted by the upstream impoundment.

- Elevated sediment was responsible for minor impairment at Nevada Creek near mouth (site B-6), and highly productive conditions were indicated by the predominance of diatom species preferring elevated levels of inorganic nutrients.

- Sediment was indicated as the cause of minor impairment of the Blackfoot River at Raymond Bridge (site B-7). Elevated inorganic nutrients influenced the diverse assemblage of soft-bodied and diatom algae at this site, which strongly mirrored the flora of lower Nevada Creek.

- At the North Fork Blackfoot River above Dry Gulch (site B-8) biological integrity was good with only minor impairment, apparently related to substrate disturbance. Moderately low levels of inorganic nutrients were indicated, based on the lower diversity of soft-bodied genera and diatom species at site B-8.

- Minor impairment was indicated by a slightly depressed pollution index value at site B-9, Monture Creek near Ovando, although a cause was not apparent. Soft-bodied algae and the diatom assemblage suggested at least slight enrichment by inorganic nutrients at site B-9.

- Biological integrity was good at the Blackfoot River at Scotty Brown Bridge (site B-10), with only minor impairment due substrate disturbance. Monture Creek and the North Fork likely had significant positive impacts on site B-10, as suggested by diatom nutrient preferences.

- The Clearwater River at Clearwater (site B-11) was rated as unimpaired with excellent biological integrity. The diatom flora, which had relatively little in common with the Blackfoot River, indicated moderately high levels of inorganic nutrient enrichment at site B-11.

- Excellent biological integrity with no impairment of aquatic life was indicated at the Blackfoot River near Bonner (site B-12), the only mainstem site so rated in August 2004. The very diverse algal assemblage indicated highly productive, nutrient-rich conditions at site B-12.

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