An Assessment of the Ecological Conditions of the Streams and Rivers of Montana using the Environmental Monitoring and Assessment Program (EMAP) Method

Prepared For:

The Montana Department of Environmental Quality. Rosie Sada, Project Manager. 1520 E 6th Avenue, Helena, MT 59620

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Wease A Bollman and Jennifer A Bowman. *Rhitron* Associates, Inc. Missoula, MT.

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SUMMARY

Obtaining useful information about the statewide extent of biological impairment and chemical stressors is an elusive goal for managers of the State's streams and rivers. State agencies may lack the resources to design a study that adequately represents the population of streams, which is extensive and complex. Furthermore, credible analysis of a linear network like streams and rivers requires innovative tools. US EPA's EMAP has provided a dataset built from a probability-based sampling design, in which each of the sites chosen has a known probability of selection, and collectively are representative of the population of streams and rivers in the State. EMAP has also produced analytical tools that offer a new approach to questions about whether impairment to streams and rivers is general and widespread, or local and confined to a small extent of the State's streams. EPA's tools may offer insight into whether specific stressors are associated with increased risk of impairment to biological health.

In this report, statewide results are based on the probability design model of the EMAP study of Montana streams and rivers. A total of 80 sites were sampled in the State. The model used in this report includes assessment and/or geospatial data from 69 of those sites for the statewide analysis. Six of the 7 Level III ecoregions in the State were represented in the sampling design.

The statewide results reported here suggest that about 70% of the stream and river length in Montana can be classified as unimpaired, when Montana Department of Environmental Quality's (MDEQ) macroinvertebrate assessment tools are used. About 7% of total stream length was not assessed in the present model. Of the 2 macroinvertebrate assessment methods used by MDEQ, only the O/E gives a statistically significant result for the estimation of increased risk of impairment when phosphorus levels exceed thresholds. Risk of biological impairment did not show a statistically significant increase from either nitrogen or phosphorus stress.

The nutrient analysis indicates that ammonia[1] is the most widespread stressor statewide, affecting 28% of stream length, whereas total nitrogen and total phosphorus affected 10% and 20% of stream length respectively.

The analysis of individual ecoregions includes additional EMAP data not incorporated in the statewide assessment, and the EPA model was manipulated to accommodate extent estimates for these data. Estimates of biological impairment extent and stressor extent in several instances were statistically insignificant because of small sample sizes. The analysis indicates that the extent of biological impairment is greater in the montane ecoregions than in the plains regions, when MDEQ macroinvertebrate assessment tools are used. Impairment was most extensive in the streams of the Middle Rockies ecoregion,

[1] Ammonia concentrations were elevated above concentrations derived from regional reference streams, but they did not exceed toxicity ammonia thresholds in DEQ-7 (DEQ 2006).

and least extensive in the Northwestern Great Plains. Results of relative risk estimates for individual ecoregions were generally statistically insignificant.

Ecological interpretation of the biological data for individual sites resulted in a third impairment classification based on taxonomic and functional composition and other attributes of the macroinvertebrate assemblages. Compared to the MMI and O/E results, the narrative interpretation approach estimated more widespread biological impairment in the plains ecoregions and less extent of impairment in the Middle Rockies.

Periphyton assessments were limited to sediment impairment classifications for the Middle Rockies ecoregion, based on the diatom assemblages. Periphyton tools indicated that 12% of stream length in the Middle Rockies could be classified as impaired.

SCOPE AND PURPOSE

This report presents the results of analyses of data collected in Montana as part of the United States Environmental Protection Agency (US EPA) Environmental Monitoring and Assessment Program (EMAP). The report is organized into 4 parts: First, a summary of the physical characteristics of the study area is given; attention is paid to the probable variation in stream resources defined by geographic settings. The development of biological assessment tools in current use by MDEQ are described; these involved the definition of reference condition, and the establishment of the methods by which test sites would be compared with reference condition. A review of how thresholds were set for chemical nutrient stressors in the various ecoregions of the State and in the various seasons is given. These introductory materials set the stage for the analysis of the extent of impairment and stressors and the relative risk to biota from individual stressors.

Second, using methods designed by US EPA, the relative extent of impairment for biological and chemical parameters is explored, and the relative risk of biological impairment given impairment by chemical stressors is calculated. Third, specific information sought by the Montana Department of Environmental Quality (MDEQ) relative to the extent of impairment in individual ecoregions of the State is presented. Although EPA's tools were designed for a state- or region-wide assessment, MDEQ has further goals; there is interest in investigating the location, on an ecoregional basis, of impairment associated with stressors and biota. Since EMAP samples in Montana streams were collected using multiple sampling methods, a comparison of the results of these various methods is presented. Fourth, to address interest in finding out whether ecological interpretations of the aquatic assemblages agree with the results of assessment tools, narrative assessments, independent of the results of MDEQ tools, are given based on the taxonomic composition of biological samples.

PART 1. THE STUDY AREA AND THE ASSESSMENT TOOLS

Physical Setting

The State of Montana covers approximately 380,803 square kilometers (147,029 square miles). Three major river basins dominate the landscape of Montana: the Missouri, the Yellowstone, and the Columbia River basins. Tributaries of the Columbia River, principally the Clark Fork River and the Kootenai River, flow west of the Continental Divide to the Pacific Ocean. East of the Continental Divide, the Yellowstone and Missouri Rivers and their tributaries drain the State's waters toward the Mississippi River and on to the Gulf of Mexico. Smaller areas of the State are drained by tributaries of the St. Mary River, which flows northward to Hudson Bay. Parts of 7 Level III ecoregions (Woods et al. 1999) are located in the State. These are the Northern Rockies (15), Idaho Batholith (16), Middle Rockies (17), Wyoming Basin (18), Canadian Rockies (41), Northwestern Glaciated Plains (42), and Northwestern Great Plains (43).

The Northern Rockies ecoregion (15) varies from high, rugged, glaciated mountains with dense coniferous forests to low elevation, essentially treeless valleys. Mountains range from the wet and rugged Cabinet Range to the gentler, drier Salish Mountains. Valleys are also varied, with the most striking comparison between the forested Swan Valley with its gravelly soils and the dry treeless grasslands of the Camas Prairie Basin, with its lacustrine clays. Flathead Lake, with its moderating climate, is a prominent feature of the ecoregion. Precipitation in the Northern Rockies ecoregion may range from 100 or more inches in the high mountains to 12 or fewer inches in the drier, rain shadowed valleys. The climate is influenced by maritime weather patterns, which are a stronger influence in the north and west than in the east and south.

The Idaho Batholith ecoregion (16) is characterized by low alkalinity waters; granitic rocks underlie the erodable soils. The glacier-gouged canyons and high peaks of the Bitterroot Range are a prominent feature of the ecoregion; these form the southwestern border of Montana. The eastern part of the Idaho Batholith ecoregion is characterized by forested mountains. Much of the region remains in wilderness.

The Middle Rockies ecoregion (17) is a diverse mosaic of landscapes that lie both east and west of the Continental Divide. Rugged, high mountains are treeless in the higher elevations, and forested on lower slopes. Partly-wooded or shrub-and-grass covered foothills, and intermountain valleys dominated by grasslands and pastures cover large areas of the region. The high mountains, particularly the Absaroka, Madison, and Gallatin ranges are much wetter than low elevation areas. Carbonate rocks occur throughout the ecoregion, influencing water quality and productivity. A large number and many kilometers of perennial streams, fed by mountain runoff, flow through the Middle Rockies ecoregion. High concentrations of heavy metals contaminate parts of the Clark Fork River in this ecoregion, a legacy of the Anaconda Smelter. Parts of the ecoregion are isolated mountain areas lying in the midst of the Northwestern Glaciated Plains; these include the Little Rockies, Sweetgrass Hills, Highwood Mountains and other ranges.

A small part of the Wyoming Basin ecoregion (18) extends into south central Montana. This region is dry, lying in the rain shadow of the Beartooth Plateau to the west; only a few inches of precipitation fall annually. Alkaline soils, arid rolling plains, and sagebrush steppes characterize the region. Aquatic resources are few, but include reaches of the Clarks Fork of the Yellowstone River.

The Canadian Rockies ecoregion (41) encompasses the high elevation mountains of Glacier National Park, and the Bob Marshall, Great Bear, and Scapegoat wilderness areas. West of the Continental Divide, these mountains are influenced by maritime air masses, and receive heavy precipitation. Portions of the ecoregion that lie east of the Divide, however, are in the rain shadow of the mountains, and are influenced by continental weather patterns. Rugged, forested lower slopes and unforested high alpine country characterize the region. Much remains in wilderness. Carbonaceous rocks underlie the southern part of the Canadian Rockies ecoregion both west of the Continental Divide and on the Front Range to the east, influencing water quality and aquatic productivity.

The Northwestern Glaciated Plains ecoregion (42) extends over the northern part of the State, from the base of the Rocky Mountain Front to the North Dakota state line. In its western expanse, grassy hills and buttes are dissected by tree-lined streams, and there is more precipitation than in the areas to the east. Broad, nearly-level, treeless plains characterize the areas eastward; native vegetation in these areas were short-stemmed grasses. Today, this is an important cereal crop production area. Dissected, rolling plains farther east are drier, and cattle grazing is more common there. The Milk River drains the central part of the Northwestern Glaciated Plains.

The Northwestern Great Plains ecoregion (43) is an immense expanse of semi-arid, rolling plains, dissected by many intermittent and ephemeral stream channels. Open-forested or savannah-covered buttes also occur in the vast region. Some areas of badlands, treeless rolling hills and benches, and a few perennial rivers and streams are present. Low precipitation precludes cropland, except in a few areas such as the Judith River basin. Most of the ecoregion is rangeland, much remains in native grasslands. Soils are highly erodable in many parts of the area. The Yellowstone River is a prominent feature of this region.

Human Influence

The extent of urban development and cropland plotted on the map in Figure 1 only hints at the extent of human influence in the State. Many human activities in the State affect, or have the potential to affect water quality and aquatic habitats. The contrasting physical environments in the eastern and western parts of the State influence the characteristics of human activity as well as the intensity and nature of their influence on aquatic resources.

Figure 1 clearly shows that grasslands and croplands dominate the eastern parts of the State, while forests dominate the western areas. Grasslands are common in the southwestern corner.

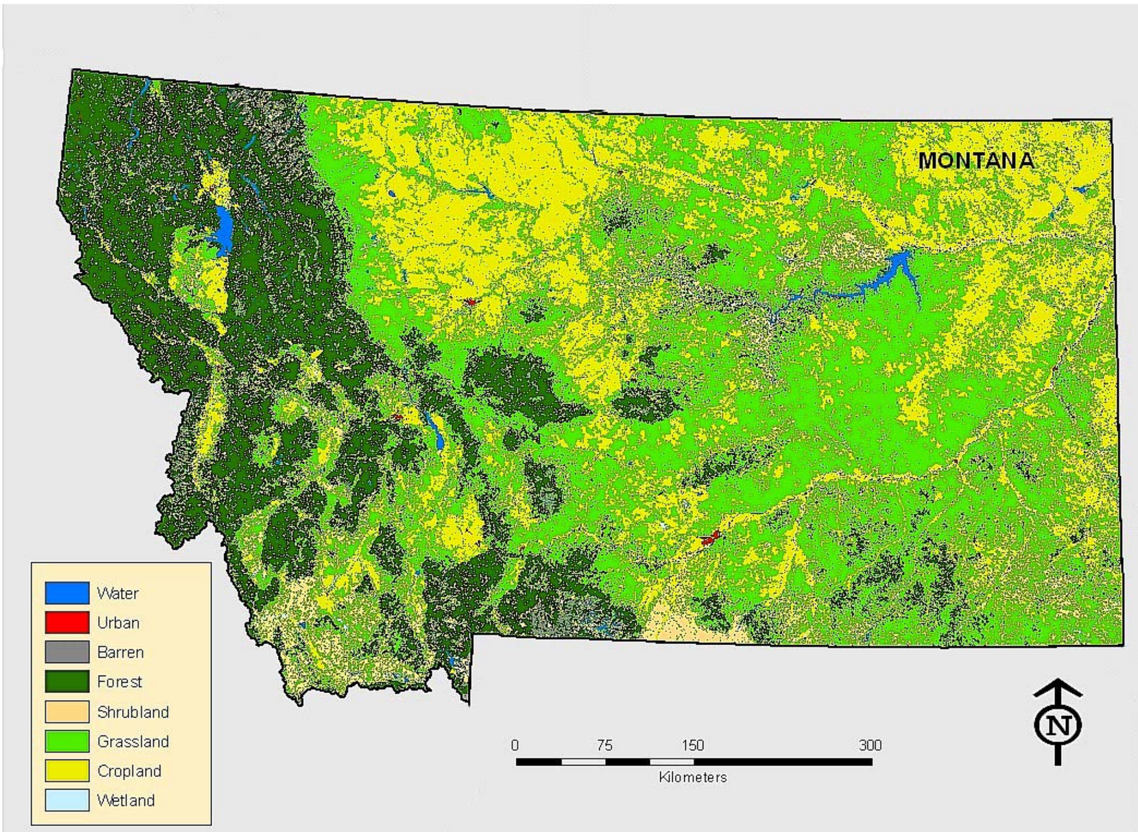

Figure 1. Montana Land Cover

Human-caused impacts to aquatic resources in the Northern Rockies ecoregion (15) include those attributable to logging and mining in the mountains, and grazing, residential development, irrigated and non-irrigated cropland, lumber mills, and gravel and sand mining in the valleys. Recreational activities may also affect water quality in this ecoregion.

Logging, mining, and the roads associated with these activities are major sources of impact to streams and rivers in the Idaho Batholith ecoregion (16). Soils in this region are highly erodable, and sediment deposition is often a consequence of human activity here. Grazing and recreation are also potential sources of disruption to aquatic habitats.

Forestry and mining activities potentially impact aquatic resources in the Canadian Rockies (41). Recreation may also threaten streams and rivers here.

The arid Wyoming Basin ecoregion (18) supports some livestock grazing, and irrigated agriculture may be found along the Clarks Fork of the Yellowstone River. These are the major threats to aquatic resources in the region.

Industrial activities have had immense and long-lived impacts on the aquatic resources of the Middle Rockies ecoregion (17). In addition, logging, mining, and grazing are potential sources of habitat and water quality degradation. The effects of historic large-scale mining activities, especially in Butte, but also in other areas of the region are a grave concern. Periodic dewatering of streams and rivers is not uncommon in the region. Residential development and recreation are also potential sources of impact.

Cattle grazing and cropland impacts are potential sources of degradation to habitat and water quality for the aquatic resources of the Northwestern Glaciated Plains ecoregion (42).

Grazing, especially where soils are erodable, has the potential to degrade streams and rivers in the Northwestern Great Plains ecoregion (43). Where cropland exists, impacts associated with it are of concern. Recent development of coalbed methane resources in the Powder River area has great potential for degradation of water quality due to salinization.

Extent of Stream Resources

Estimation of the total length of Montana streams in this study is based on information about the perennial stream network contained in US EPA's River Reach file, which is a model based on an interpretation of 1:100,000 scale USGS topographic maps. Only perennial streams and rivers were included. There are an estimated 48,195 kilometers (29,947 miles) of perennial streams in the State.

According to the EPA model, first order streams account for approximately 29% of the total length of perennial streams in Montana (Figure 2). The model does not include the Missouri River. By far, the greatest extent of stream length is located in the Middle Rockies ecoregion (Figure 3), with 49% of total State stream length located there.

Table 1 quantifies the estimated extent of kilometers of perennial streams in the State, and indicates the number of sites in each ecoregion/stream order category used in the statewide analysis.

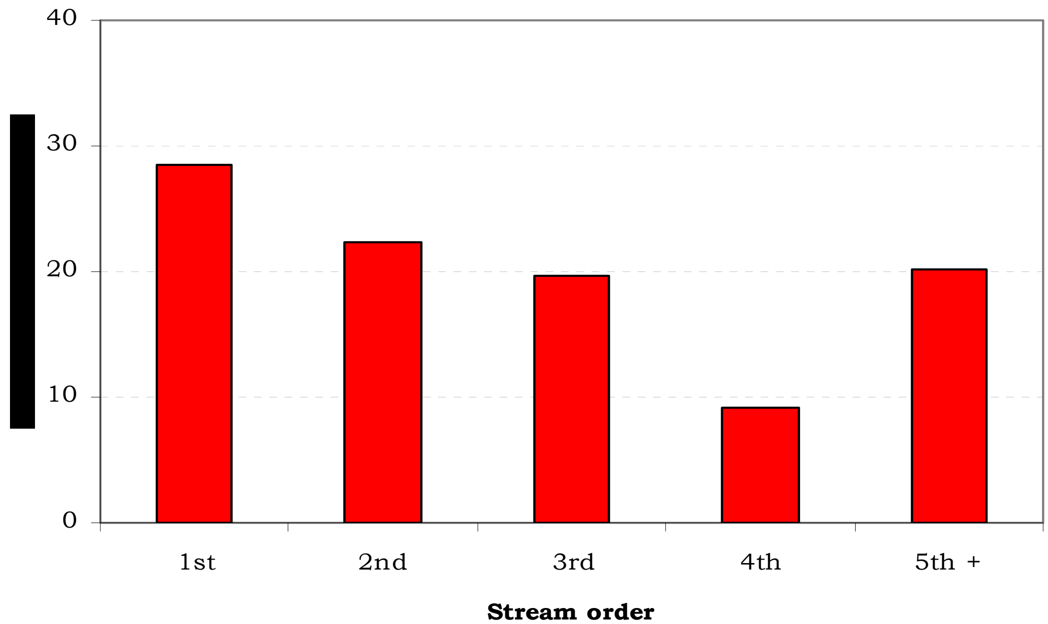

Figure 2. Statewide extent of Montana stream length by Strahler stream order, as represented in the EMAP design.

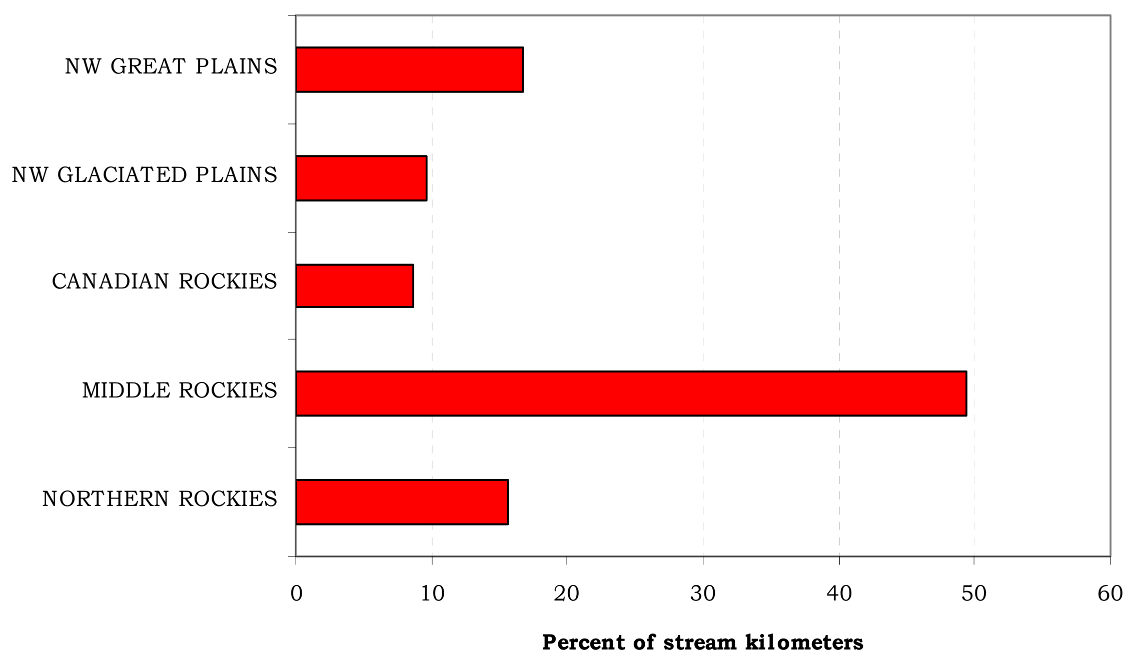

Figure 3. Statewide extent of Montana stream length, estimated by the EPA model, in Level III ecoregions. Only 5 of the 7 ecoregions in the State are shown; about 1% of statewide stream extent is estimated to lie in the Idaho Batholith ecoregion (16), and streams in the Wyoming Basin (18) ecoregion were not represented in the EPA model.

Table 1. Stream kilometers statewide within each ecoregion by stream order as represented in the EMAP design.

Ecoregion	Stream order	Stream length (km)	Representative sites
15 Northern Rockies	1st	2009.8	1
	2nd	2009.8	2
	3rd	0	0
	4th	0	0
	5th +	3433.4	3
16 Idaho Batholith	1st	0	0
	2nd	513.0	1
	3rd	0	0
	4th	0	0
	5th +	0	0
17 Middle Rockies	1st	8596.8	7
	2nd	5600.5	9
	3rd	5301.2	11
	4th	683.9	1
	5th +	3363.7	3
41 Canadian Rockies	1st	1025.9	1
	2nd	1517.9	2
	3rd	1607.8	2
	4th	0	0
	5th +	0	0
Mountain total		35663.7	43
42 NW Glaciated Plains	1st	1025.9	1
	2nd	0	0
	3rd	1308.1	4
	4th	1846.7	3
	5th +	384.7	1
43 NW Great Plains	1st	947.0	2
	2nd	1538.9	3
	3rd	1179.8	4
	4th	1846.7	3
	5th +	2453.7	5
Plains total		12531.5	26

Data Sources

Sampled sites

Statewide results are based on the probability design model of the EMAP study of Montana streams and rivers. A total of 80 unequal probability sites (Fig. 4) were sampled in the State. However, the model used in this report includes assessment and/or geospatial data from only 69 of those sites. Sites on the Yellowstone, Flathead, and Kootenai Rivers were excluded from the statewide assessment data, but geospatial data from these sites, including their total in-state stream length, is included in estimates. The stream length represented by these sites appears as “not assessed” in graphs of impairment class extent.

There were a total of 64 sites with biological, chemical, and geospatial data; many of these sites are represented by both reachwide (64 sites) and targeted riffle (45 sites) macroinvertebrate sampling methods. Reachwide and targeted riffle samples are analyzed separately in this report, for purposes of comparing statewide results from each sampling method. Although shore-collection methods for non-wadeable streams were necessarily different from either reachwide or targeted riffle sampling, samples collected this way were grouped with the more-similar reachwide samples. Periphyton samples were collected at a total of 78 EMAP sites. Samples from sites in the Middle Rockies ecoregion (32 sites) were analyzed for sediment impairment.

The EMAP research strategy assigned weights to ecoregions, stream orders, and other physical or geographic variables, based on their extent within the study area, so that randomly selected sites within a stratified framework would produce data that fully represents the wide variety of flowing waters in the State. Each sampled site is then considered to represent a calculated proportion of total stream kilometers within a stratum. The design thus allows for an estimate of stream length within each of a number of geographic, hydrologic, and assessment classifications. The biological or chemical condition of a site is extrapolated to the length of stream represented by the site.

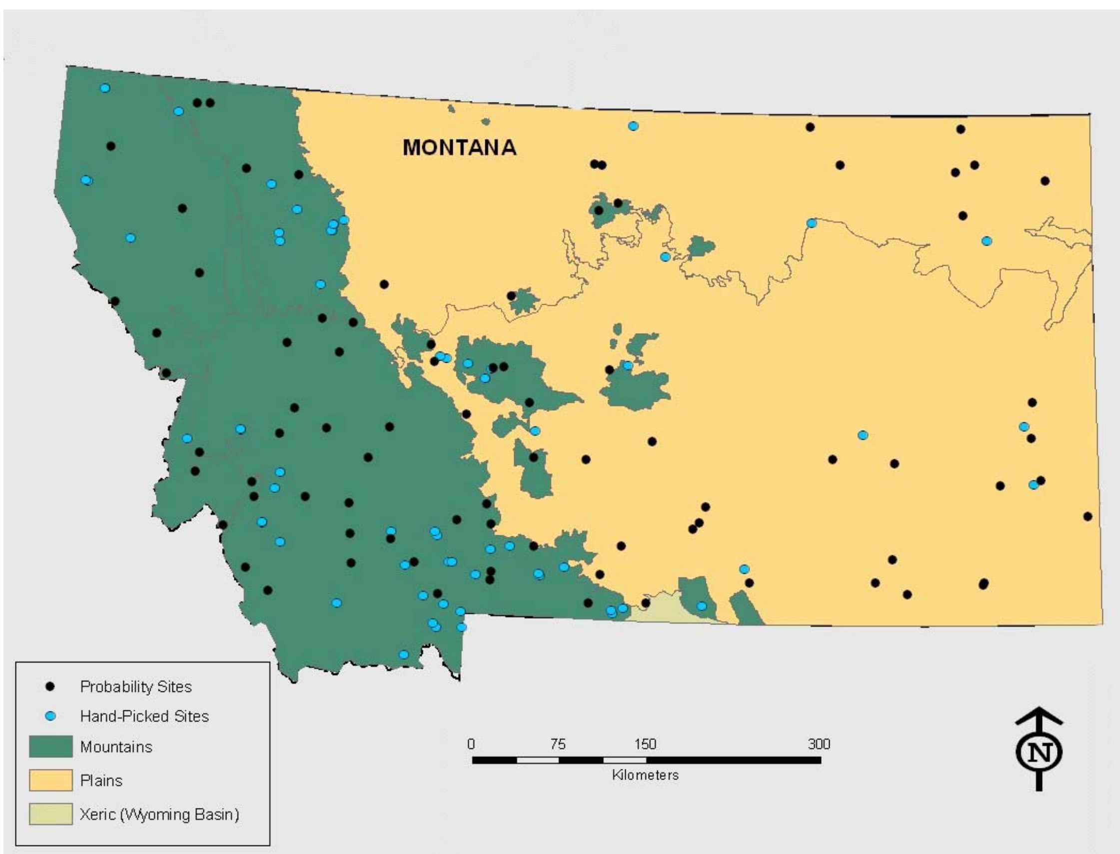

Figure 4. EMAP Sampling Sites

Assessment

In this study, impairment classifications are assigned to stream sites based on evaluation of macroinvertebrate communities, periphyton assemblages, and nutrients. Evaluations were made using multimetric index and predictive model tools for macroinvertebrates, and a discriminant function tool for periphyton; development of these assessment tools is summarized in the next chapters. Biological tools were developed based on the characterization of reference condition, and comparison of site characteristics with reference site characteristics. Nutrient concentrations were evaluated against draft criteria (Suplee et al. 2007) which are proposed for ecoregions in various seasons.

Reference site determination

Biological impairment at a site cannot be adequately assessed without a determination of the potential of the site. Reference sites are those sites that are considered to be at their biological potential, or as near to that condition as possible. Given the scarcity of sites that are not influenced in some way by human activities, usually to the detriment of biological integrity, the use of minimally impaired sites to represent attainable potential is often the only recourse. Since aquatic environments in the surface waters of the State vary greatly, from the cold, cobble-bottom streams of the mountainous regions to the warm, near-lentic, soft-bottom streams of the plains regions, reference condition must be determined for a wide range of environmental conditions. In general, Level III ecoregions have been demonstrated to be a useful model for the initial partitioning of environmental conditions. At a finer scale, certain geospatial characteristics, such as elevation and watershed area, also influence biology. To address these issues, the Montana Department of Environmental Quality (MDEQ) developed an evaluation process for assessing candidate reference sites in order to establish benchmark conditions for the aquatic biology of each of the various ecoregions of the State (Suplee et al. 2005). Quantitative watershed and water quality analyses are conducted for each candidate site. In addition, qualitative assessments of stream health and habitat condition are performed, using specific criteria as well as best professional judgment.

The quantitative watershed analysis includes study of land-cover types; in particular, the proportion of agricultural use is determined at the 5th code HUC level. Road density upstream of the candidate site is evaluated. Where available, water quality data are assessed, particularly for heavy metals.

Qualitative assessments are composed of a series of 7 tests or “screens” that use both best professional judgment as well as other criteria. Sites are screened for impairment that exceeds a minimal level, generally reflecting cumulative impacts from multiple causes. Sites lacking sufficient site-specific data collected in the field are screened out. Using quantitative measures and best professional judgment, cold water streams in forested areas are eliminated from consideration if either road density or timber harvest intensity in the watershed is judged to be influential. Sites are screened for the intensity of agricultural land use. Sites that show a clear tendency to exceed numeric water quality standards, and sites that may be influenced by abandoned mines are removed. Sites that pass all 7 screens are considered reference sites.

Reference sites identified by MDEQ's process were used to develop the biological assessment tools that assigned impairment classifications to the sites in this study. Determination of ecoregion-specific reference condition that incorporates influential geospatial characteristics by assessing and screening candidate sites is an on-going process at MDEQ.

Biological indicators

MDEQ uses 2 indicators of biological health for macroinvertebrate assemblages: a multimetric index (MMI) and a predictive model (O/E). Both tools rely on comparison of assemblages with reference assemblages, but the methods differ on the assignment of sites to an appropriate group for which reference conditions have been determined, and in how the comparisons are made. In practice, MDEQ uses both the MMI and O/E tools and assigns impairment classifications based on a decision tree, when the tools give different results.

To date, assessment of periphyton community health is limited to a single tool, developed specifically for a single ecoregion (Middle Rockies) and for a specific stressor (sediment). In this report, impairment classifications based on periphyton assessment are assigned and reported only for Middle Rockies sites. In spite of its limitation to the assessment of sediment stress, this tool is used in calculations of relative risk of impairment given impairment of chemical stressors in this study.

Development of biological assessment tools

1. The multimetric index (MMI) (Jessup et al. 2006)

Development of the MMI approach began with a classification of reference sites, based on an ordination of the taxonomic components of their macroinvertebrate assemblages. For Montana, the recommended classification model uses 3 site classes: Mountains, Low Valleys, and Plains. Mountains are distinguished from Low Valleys by site elevation, annual mean of daily maximum air temperature, and the annual precipitation. Biological metrics expressing attributes of the communities such as richness, composition, function, habit, voltinism, and pollution tolerance were calculated for both reference assemblages and assemblages from sites known to be impaired. Within each site class, metrics that predictably and efficiently discriminated between reference sites and impaired sites were selected. Metrics were further screened to identify those with low variability for reference condition, ecological interpretability, and contribution of unique information. Metrics that were redundant with other metrics were eliminated. The work resulted in 3 site class-specific indices. Scoring criteria for metrics were based on the 95^{th} percentile of metric performance for all data within a given site class. Table 2 lists the metrics selected for each site classification, and gives the expected response of each metric to increasing stress. Impairment classifications were assigned to sites using the criteria given in Table 3.

2. O/E (Hawkins 2005, and Jessup et al. 2006)

Similar to the multimetric assessment tool, development of the O/E approach began with a classification of reference sites, based on analysis of an ordination of the taxonomic components of macroinvertebrate assemblages. Reference site classes were analyzed to determine variables that could reliably predict the probability of class membership. For Montana, these predictor variables were: latitude, longitude, annual mean of daily maximum temperature, and watershed area. A discriminant function model was derived for estimating the probability of class membership of a site based on the predictor variables.

Taxonomic composition of reference samples was analyzed to determine the frequency of occurrence of each taxon in each site class. Each frequency of occurrence, when weighted by the probability of a site belonging to a class, represented the probability of capture for a particular taxon. The sum of the probabilities of capture for each taxon is interpreted as a prediction of the expected number of taxa at a site. Only taxa with a probability of capture greater than or equal to 0.5 are used. Sites are evaluated by comparing the observed number of taxa (O) with the expected number of taxa (E). The proportion of O/E is interpreted as the degree to which a site is attaining its potential in biological diversity. Impairment classifications were assigned to sites using the criteria given in Table 3.

Table 2. Metrics and expected responses. MMI indices for Montana site classifications.

Site class	**Metric**	**Expected response to increasing stress**
Mountain	Ephemeroptera taxa	Decrease
	Plecoptera taxa	Decrease
	% EPT	Decrease
	% Non-insect	Increase
	% Predator	Decrease
	Burrower taxa %	Increase
	Hilsenhoff Biotic Index	Increase
Low Valley	% EPT excluding Hydropsychidae and Baetidae	Decrease
	% Chironomidae	Decrease
	% Crustacea and Mollusca	Increase
	Shredder Taxa	Increase
	% Predator	Decrease
Plains	EPT taxa	Decrease
	% Tanypodinae	Decrease
	% Orthocladiinae of Chironomidae	Increase
	Predator taxa	Decrease
	% Filterers and Collectors	Increase

Table 3. Criteria for the assignment of impairment classifications using MMI and O/E.

Site class	MMI	O/E	Impairment class
Mountain	≥ 63	≥ 0.8	Not impaired
	< 63	< 0.8	Impaired
Low Valley	≥ 48	≥ 0.8	Not impaired
	< 48	< 0.8	Impaired
Plains	≥ 37	≥ 0.8	Not impaired
	< 37	< 0.8	Impaired

3. Periphyton assessment (Teply and Bahls 2005, and Teply and Bahls 2007)

Periphyton bioassessment methods developed for MDEQ use an empirically-derived list of diatom taxa ("increaser taxa") that respond in a measurable way to stress from sediment. Further, these are taxa that exist in detectable abundances in samples from both impaired and unimpaired streams. Model development was restricted to data from the Middle Rockies ecoregion.

Discriminant analysis was used to determine the probability of impairment by sediment for a dataset of randomly chosen samples collected since 1995 from both impaired and unimpaired streams in the Middle Rockies ecoregion (Teply and Bahls 2006). The percent abundance of "increaser" taxa was used to derive a discriminant function that can be used to predict the probability that a site is impaired by sediment stress.

Table 4 gives the probability of impairment by sediment for values of abundance of "increaser taxa". Development of discriminant functions for other stressors and other ecoregions is an on-going effort at MDEQ. For this particular report, the threshold for impairment was considered if the probability of sediment impairment was above 56%.

Table 4. Probability of sediment impairment for Middle Rockies sites based on the percent relative abundance of Middle Rockies Sediment Increasers.

Percent Relative Abundance	Probability of Sediment Impairment
5	5.31%
10	11.56%
15	21.80%
20	35.92%
25	52.30%
30	68.30%
35	81.45%
40	90.54%
45	95.83%
50	98.42%

Evaluation of Stressors (Suplee et al. 2007)

Reference condition for nutrient concentrations (nitrogen, phosphorus, and ammonia) were defined by MDEQ by establishing the frequency distributions of nutrient values from least impaired streams throughout the State. Streams were stratified according to ecoregion and data were further stratified according to seasonality, since the seasonal differences in median nutrient concentrations in the general population of samples is significant. Regional scientific studies were reviewed; the studies identified nutrient concentrations at which impacts to beneficial uses appeared. These nutrient concentrations matched, on average, the 86th percentile of reference condition concentrations. Based on these findings, draft criteria for assessment of stress due to nutrients were set at the 85th percentile of reference condition. It should be noted that these draft ammonia criteria represent much lower concentrations than concentrations shown to have a toxic effect on aquatic life (DEQ 2006). Therefore, these are nutrient-enrichment values, not toxicity values.

Seasonal draft criteria for nutrients in Montana ecoregions is presented in Table 5 (A-C). For most of the extent of the Clark Fork River, separate nutrient numeric criteria apply. These thresholds are presented in Table 5 (D). Clark Fork River standards apply from June 21 to September 21.

Table 5. Seasonal nutrient thresholds for Montana ecoregions. Dashes in the tables indicate that there were too few observations in the data to generate valid distributions.

A. Winter season

	Middle Rockies (17)	Northwestern Glaciated Plains (42)	Northwestern Great Plains (43)
Total N mg/l	-	0.089	1.670
Total P mg/l	0.020	2.825	0.179
Ammonia mg/l	0.010	0.173	0.046

B. Runoff season

	Middle Rockies (17)
Total N mg/l	-
Total P mg/l	0.040
Ammonia mg/l	0.010

C. Growing season

	Northern Rockies (15)	Middle Rockies (17)	Canadian Rockies (41)	Northwestern Glaciated Plains (42)	Northwestern Great Plains (43)
Total N mg/l	-	0.320	0.158	1.399	2.980
Total P mg/l	0.003	0.020	0.003	0.178	0.327
Ammonia mg/l	-	0.010	0.005	0.101	0.073

D. Nutrient criteria for the Clark Fork River

	Clark Fork River near Tarkio, MT
Total N mg/l	0.300
Total P mg/l	0.039
Ammonia mg/l	-

PART 2. STATEWIDE ANALYSIS

A. Reachwide and Shore Sampling Methods Results

Biological condition

Figure 5 summarizes the extent of impaired and unimpaired biological condition in the State, based on the analysis of 69 sites in the EPA probability model, and using the data generated by the reachwide and shore sampling methods. These analyses suggest that about 60% of stream length (about 28,900 kilometers) in the State is classified as unimpaired. About 33 % of stream length fell into the impaired category. About 7% of Montana stream length was not represented in this analysis. The MMI and O/E assessment tools gave similar estimations of the kilometer extent of biological condition. A site-by-site comparison indicates that MMI and O/E assessments agreed in 78% of cases (54 of 69 samples). Confidence intervals do not overlap, indicating statistically significant results.

Figure 6 plots the statewide percent of stream kilometers in each Strahler stream order class classified as impaired by the biological assessment tools. The wide extent of impairment of first order stream length is an unexpected result; the MMI indicates impairment in more than 75% of first order stream kilometers statewide and the O/E tool indicates impairment in more than 60% of first order stream extent. MMI results suggest that third order streams have the lowest extent of impairment, while the O/E suggests that fifth order streams have the lowest extent of impairment.

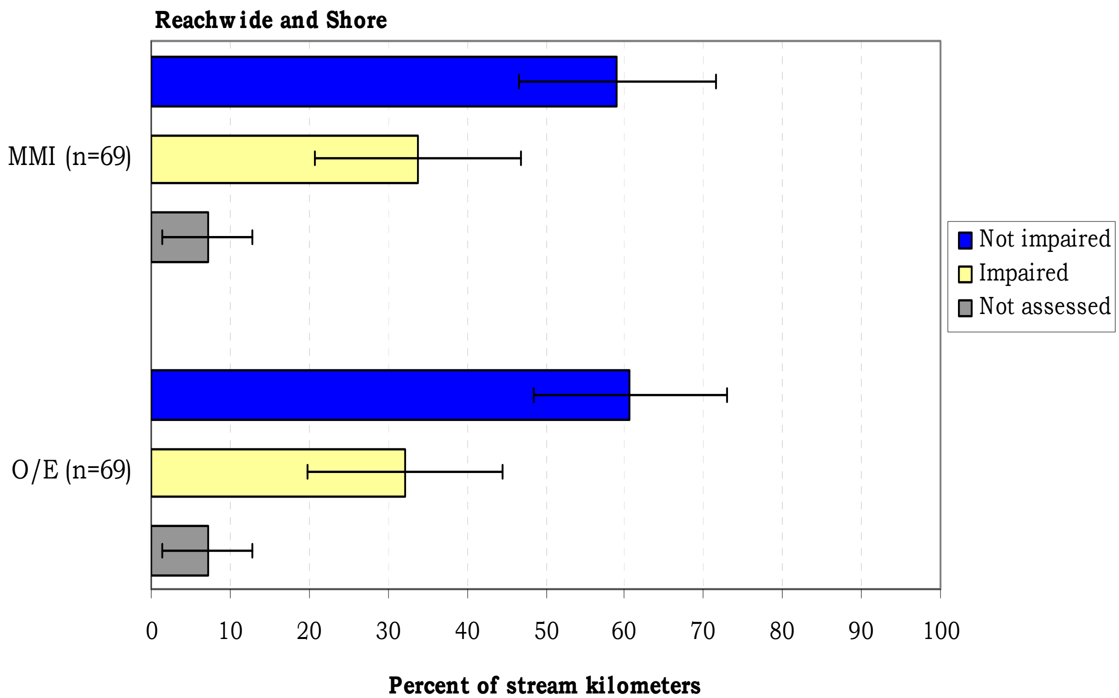

Figure 5. Biological condition evaluated for reachwide and shore samples using macroinvertebrate assessment tools. The percentage of total statewide stream length in each biological impairment classification along with 95% confidence intervals is plotted. Data for 69 sites sampled with the reachwide or shore protocol are depicted.

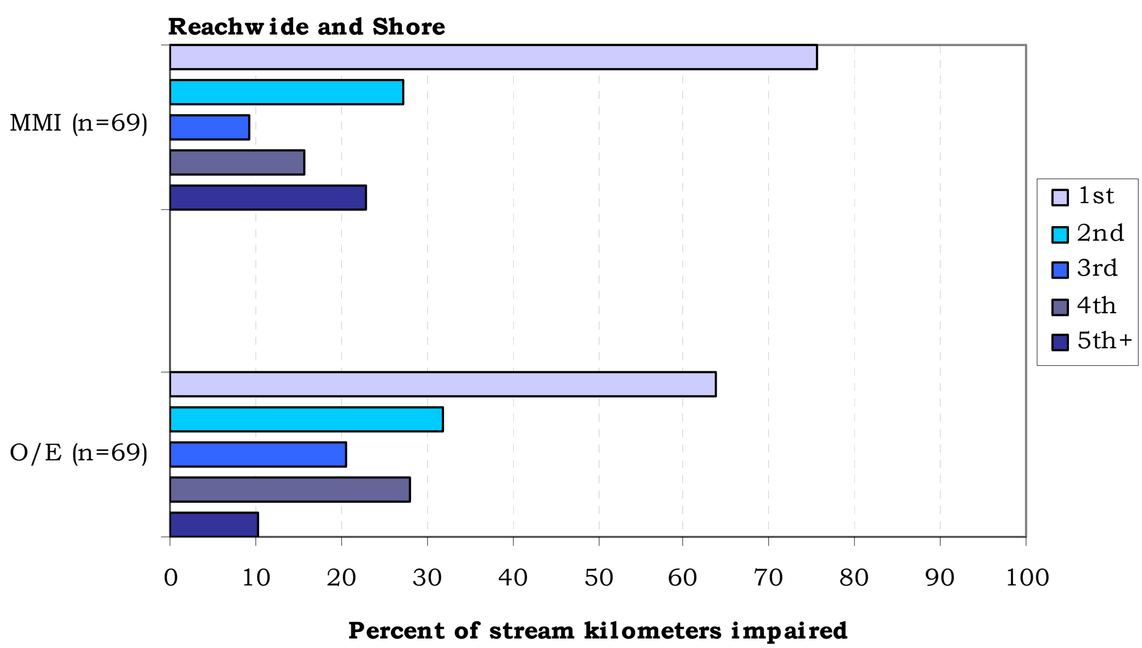

Figure 6. Statewide extent of impairment of total stream kilometers in each Strahler stream order. Data for 69 sites sampled with the reachwide or shore protocol are depicted.

Stressor extent

Figure 7 graphs the model's approximation of impaired stream length for chemical stressors. Appropriate criteria, as in Table 5, for nutrients were applied, and impairment classifications based on exceedances of the criteria.

The model suggests that about 20% of stream length (about 9,640 kilometers) statewide was in impaired condition using thresholds for total phosphorus. Sixty-nine percent (about 33,255 kilometers) of total stream length was not impaired, and about 10% of stream length was not assessed for total phosphorus.

The analysis suggests that impaired conditions for total nitrogen were present in 10% of stream length (about 4,820 kilometers) in the state. Sixty-seven percent (about 32,290 kilometers) were not impaired. Twenty-three percent of stream length was not assessed for total nitrogen. Impaired conditions for ammonia[2] were the most widely extensive of any chemical impairment; 28% of statewide stream length (about 13,500 kilometers) exhibited impairment. Non-impaired conditions were assessed for 53% of stream length (about 25,540 kilometers). Nineteen percent of stream length was not assessed for ammonia.

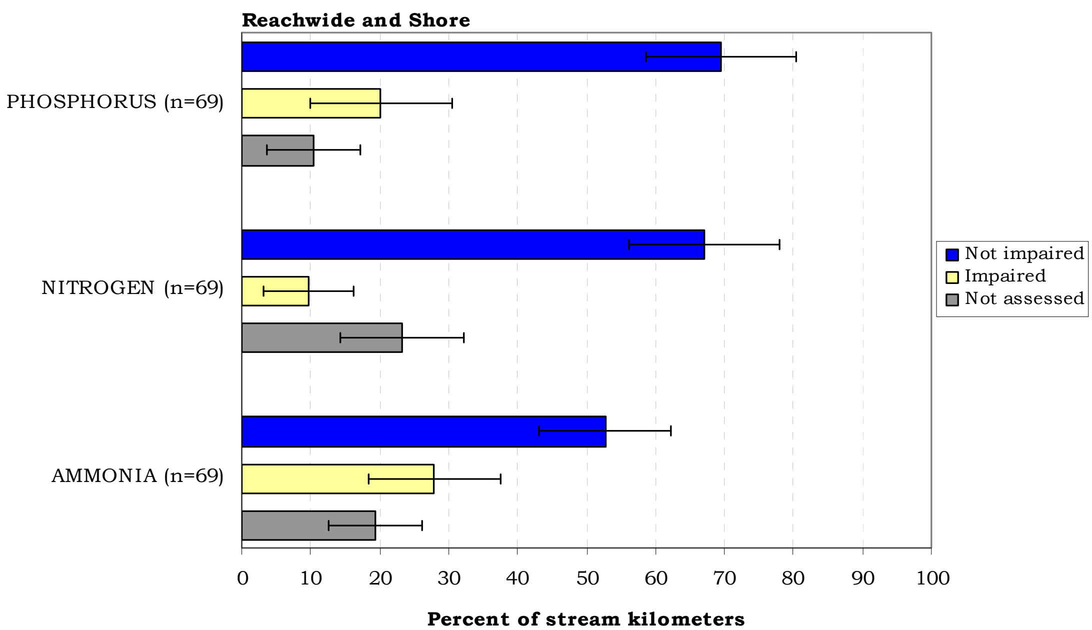

Figure 7. The statewide extent of impairment classifications for 3 chemical stressors. The percentage of total statewide stream length in each impairment classification along with 95% confidence intervals is plotted. Data for 69 sites sampled with the reachwide or shore protocols are depicted.

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[2] Ammonia concentrations were elevated above concentrations derived from regional reference streams, but they did not exceed toxicity ammonia thresholds in DEQ-7 (DEQ 2006),

Figure 8 plots the statewide percent of impaired stream kilometers, as assessed with appropriate criteria for each chemical stressor, in each Strahler stream order class. Compared to higher stream orders, first order streams have greater extent of impairment for phosphorus and nitrogen. However, impairment by ammonia has greater extent in second and third order streams.

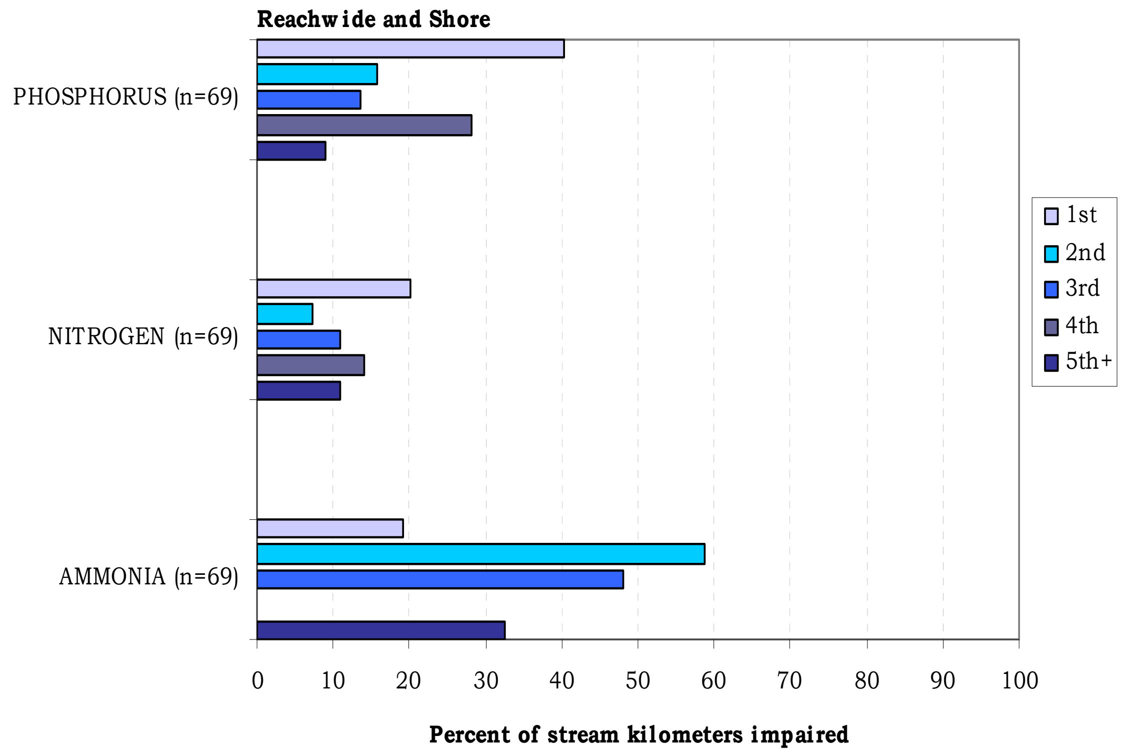

Figure 8. Statewide extent of impaired stream length for each chemical stressor in each Strahler stream order. Data for 69 sites sampled with the reachwide or shore protocols are indicated

Relative risk

The relative risk of biological impairment given impairment by each of the chemical stressors is plotted in Figure 9. Relative risk is a ratio of conditional probabilities (Van Sickle et al. 2006). It is calculated as the probability of impaired biological condition given impaired stressor condition divided by the probability of impaired biological condition given unimpaired stressor condition. A relative risk value of 1 or less indicates that impairment for a given stressor is not associated with increased risk of impairment for a given biological measure. Among the tested stressors, the only increased risk that is statistically significant is the effect of phosphorus on O/E assessment; impairment by phosphorus pollution almost doubles the risk of biological impairment indicated by the O/E score.

Neither nitrogen nor ammonia impairment increases the risk of biological impairment as measured by the MMI. Impairment for phosphorus somewhat increases the risk that the MMI score will indicate impairment, but the increased risk is not statistically significant. Impairment for total nitrogen is associated with only a mildly, and statistically insignificant increased risk for impairment indicated by the O/E score. Impairment for ammonia is associated with a moderately increased risk for impairment assessed with the O/E tool; this increased risk is also statistically insignificant.

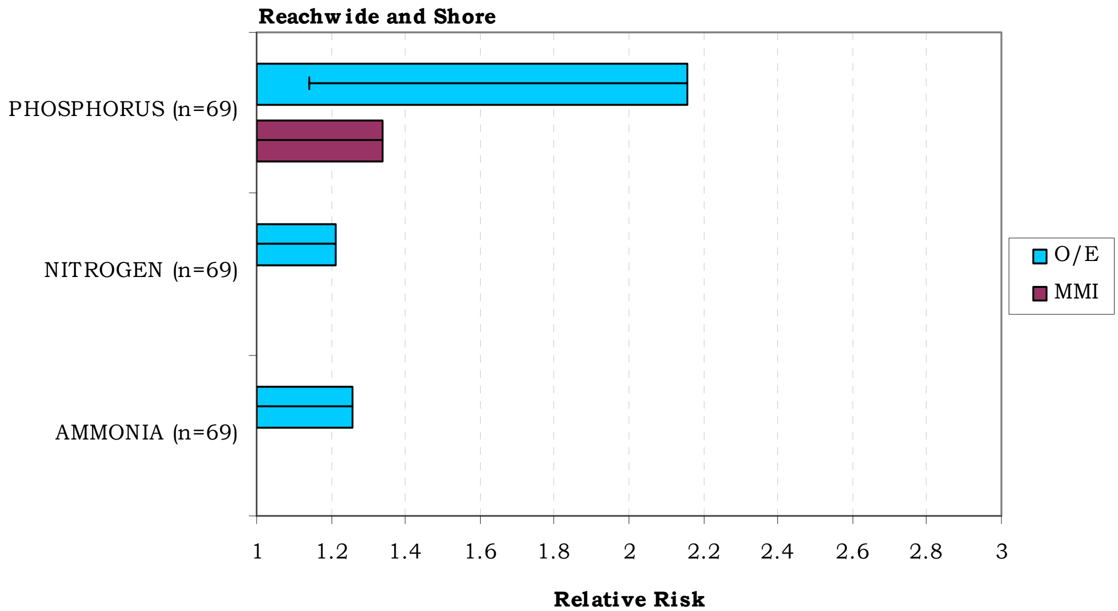

Figure 9. The relative risk of impairment to macroinvertebrates from stressors statewide. Bars indicate 95% confidence intervals. Data for 69 sites sampled with the reachwide or shore protocols are depicted.

This analysis suggests that among the 3 nutrient stressors, ammonia is the stressor with the widest extent in the State (Figure 7) but ammonia pollution is not associated with increased risk of biological impairment. Phosphorus pollution is associated with increased risk for impairment to macroinvertebrates, but only when impairment is measured by the O/E. No other stressor shows great enough impact for a statistically significant increase in risk of impairment to macroinvertebrates.

Calculations for confidence intervals for relative risk estimates result in intervals that are not symmetric around the estimate of relative risk (Van Sickle et al 2006). The wide confidence intervals for the estimates given in Figure 9 indicate that error for this analysis was too large for reliable estimates of relative risk.

B. Targeted Riffle Sampling Method Results

Forty-five sites were sampled with targeted riffle methods; in this section, these are evaluated for estimates of the extent of biological and chemical impairment and relative risk of biological impairment for each chemical/nutrient stressor. Since there were more reachwide and shore samples in the dataset, measures of the extent of impairment and the extent of stressors would be more representative of statewide conditions if that data were used. More than 30% of total statewide stream length was unassessed by targeted riffle samples, compared to only 7% of stream length that was not assessed by reachwide and shore methods. The effect of the different sample size is most apparent when relative risk is assessed.

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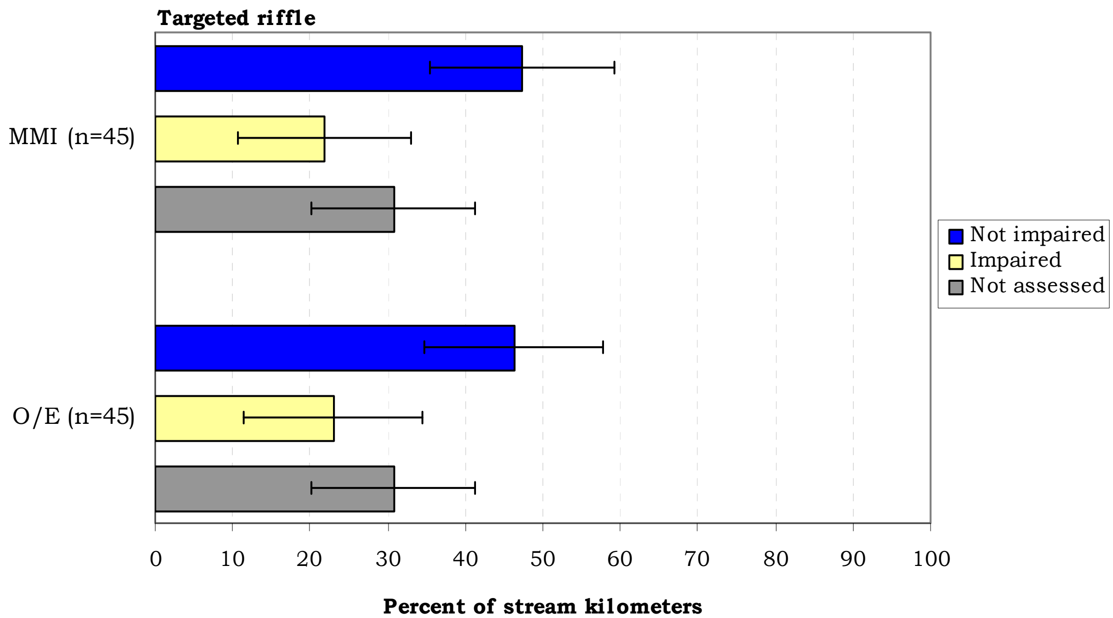

Figure 10. Biological condition of targeted riffle samples using macroinvertebrate assessment tools. The percentage of total statewide stream length in each biological impairment classification along with 95% confidence intervals is plotted. Data for 45 sites sampled with the targeted riffle protocol are depicted.

Biological condition

Similar to the findings for the reachwide sampling method, the analysis of targeted riffle samples indicates that the greater proportion (>45%) of total statewide stream length is classified as unimpaired as evaluated with MDEQ macroinvertebrate assessments. About 22% of total statewide stream extent is impaired. Figure 10 plots the percent of total stream length in each impairment category when targeted riffle samples are analyzed.

The assessment methods give similar estimates of the extent of impairment. The MMI and O/E resulted in the same impairment classification for 82% of targeted riffle samples.

Like their reachwide counterparts, targeted riffle samples indicate a wider extent of impairment for first order streams than for other Strahler stream orders when macroinvertebrate tools are used for assessment. The statewide extent of impairment for each stream order is graphed in Figure 11.

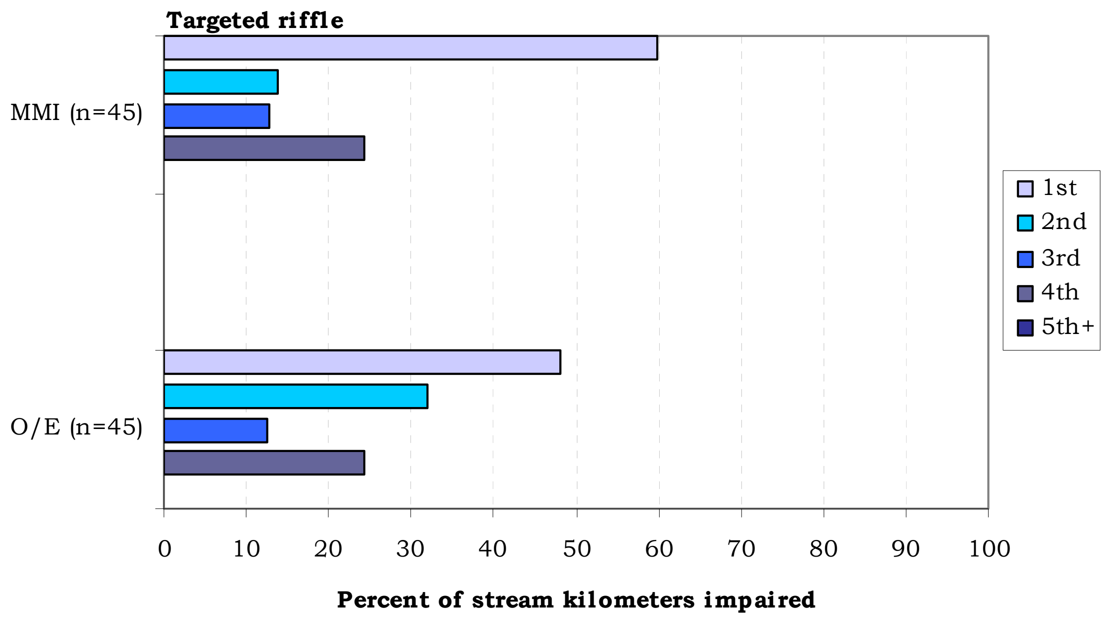

Figure 11. Statewide extent of impairment of total stream miles in each Strahler stream order. Data for 45 sites sampled with the targeted riffle protocol are depicted.

Stressor extent

The graph of the statewide extent of stressors for targeted riffle samples differs from the corresponding reachwide graphs only in the number of samples used to estimate extent. Thus it is not surprising that analysis of targeted riffle results are similar to reachwide results, both for the statewide extent of stressors (Figure 12) and for the extent of stressors within each Strahler stream order (Figure 13).

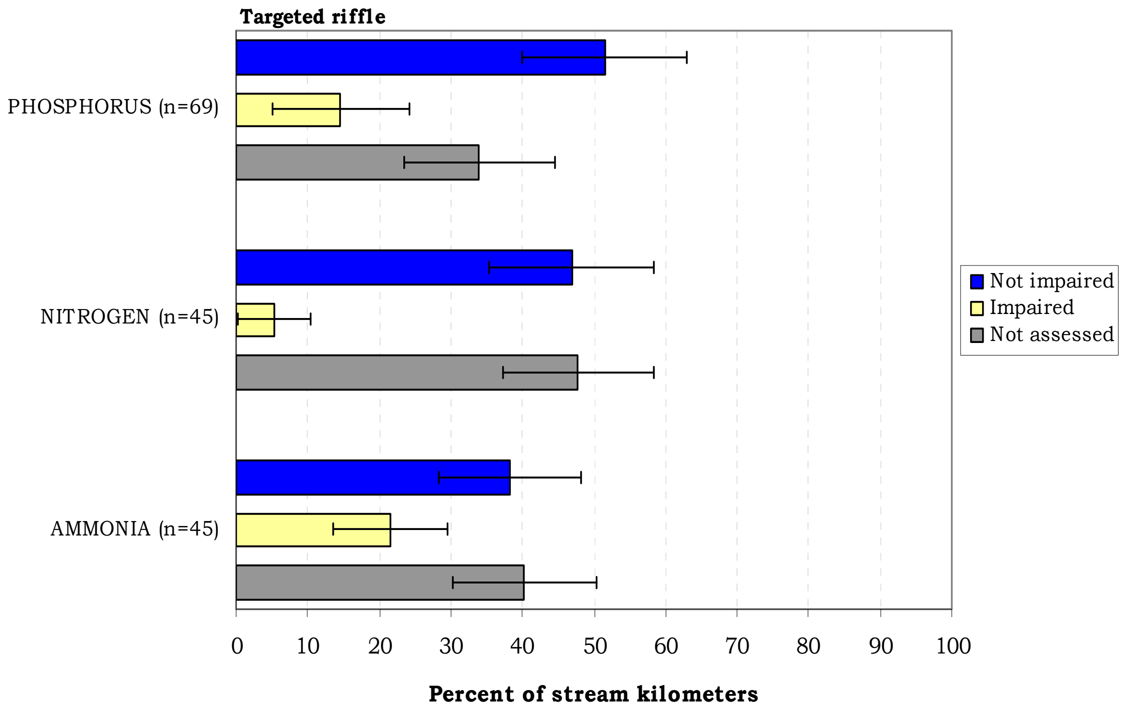

Figure 12. The statewide extent of impairment classifications for 3 stressors. The percentage of total statewide stream length in each biological impairment classification along with 95% confidence intervals is plotted. Data for 45 sites sampled with the targeted riffle protocol are depicted.

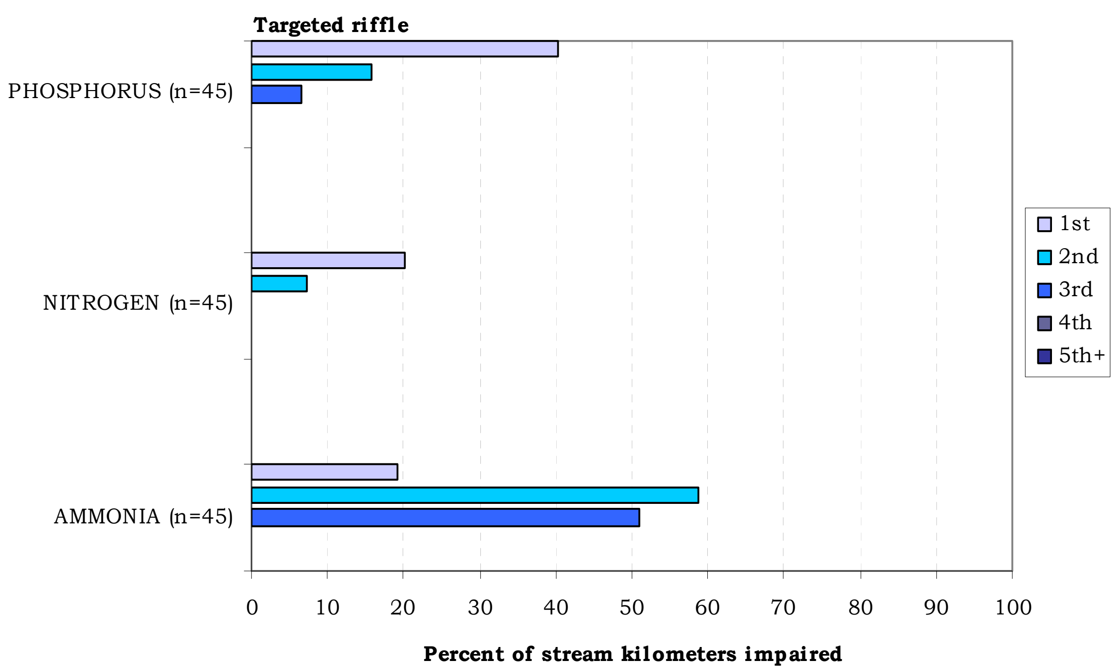

Figure 13. Statewide extent of impaired stream length for each chemical stressor in each Strahler stream order. Data for 45 sites sampled with the targeted riffle protocol are depicted.

Relative risk

The smaller number of samples in the targeted riffle data set has a remarkable effect on the estimation of relative risk of impairment to biological assemblages. For these data, impairment for phosphorus is seen to greatly increase the risk of impairment to macroinvertebrates. When phosphorus levels exceed criteria, there is more than twice the risk that the O/E score will indicate impairment, and the risk of MMI impairment increases almost 3 times. Both results are statistically significant.

The moderate increase of risk to MMI scores when nitrogen levels exceed standards is not statistically significant, nor is the mild increase of risk to O/E scores of elevated ammonia levels.

Calculations for confidence intervals for relative risk estimates result in intervals that are not symmetric around the estimate of relative risk (Van Sickle et al. 2006). The wide confidence intervals for the estimates given in Figure 14 suggest that error too large for reliable estimates of relative risk.

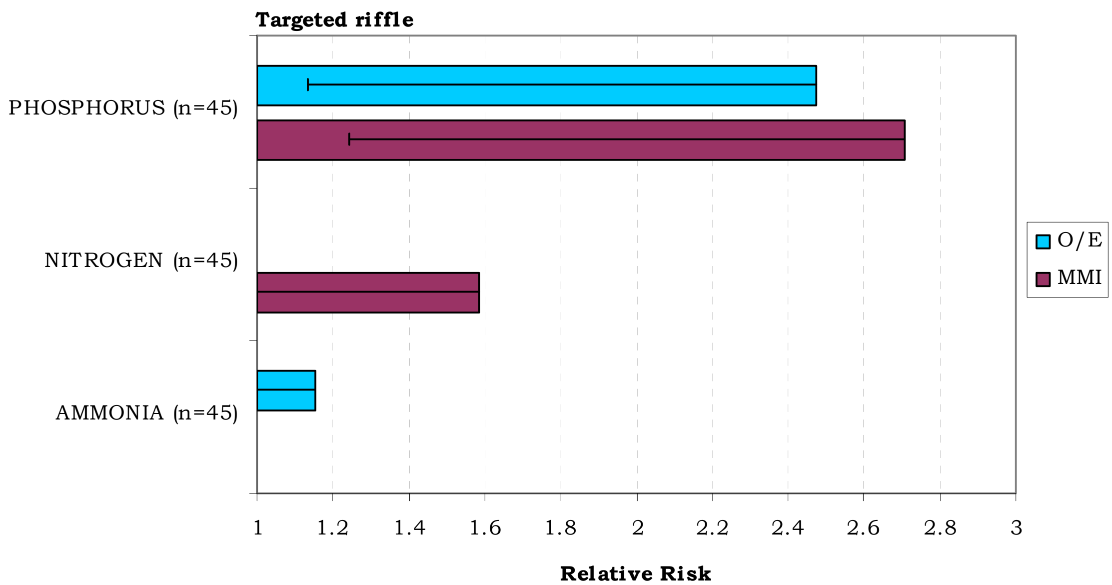

Figure 14. The relative risk of impairment to macroinvertebrates from stressors. Bars indicate 95% confidence intervals. Data for 45 targeted riffle samples are depicted.

C. Periphyton Sample Results: Sediment Impairment in the Middle Rockies Ecoregion

Thirty-two sites in the Middle Rockies ecoregion were sampled for periphyton. Two of the 32 sites are not included in the statewide analysis, since they did not fit the probabilistic model criteria for inclusion in the EMAP dataset. Manipulation of the EPA model was necessary in order to obtain stream extent estimations that included the added sites. A simple model manipulation was used. Length estimates were assigned to the added sites by totaling the number of stream kilometers within each Strahler stream order class, and averaging that total extent over the number of sites included in the larger periphyton dataset. Although this manipulation does not account for all of the variables considered for weighting in the EPA model and likely violates rules used to construct it, the estimations are probably reasonable for this analysis.

Figure 15 plots the percent of total Middle Rockies ecoregion stream length in each impairment category when the periphyton sediment impairment tool is used. The analysis indicates that 86% of total stream length in the Middle Rockies is unimpaired by sediment. About 12% of stream length in the region is impaired by sediment. About 2% of stream length was not assessed. The results were statistically significant.

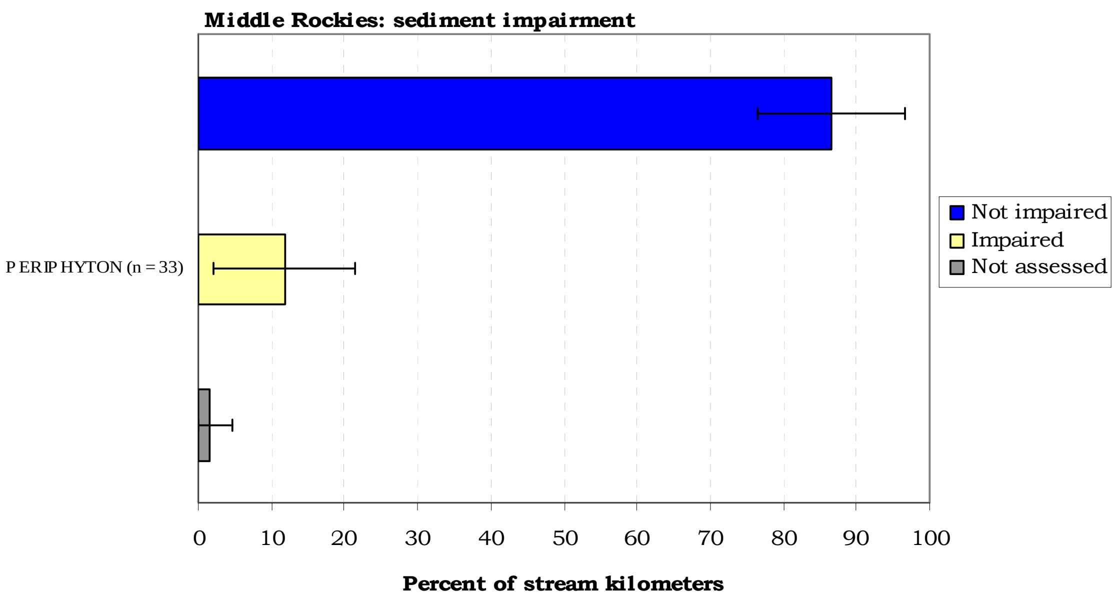

Figure 15. The extent of sediment impairment classifications in the Middle Rockies ecoregion, as estimated by the periphyton sediment tool. The percentage of total statewide stream length in each sediment-impairment classification along with 95% confidence intervals is plotted. Data for 33 sites in the Middle Rockies ecoregion that were sampled for periphyton are depicted.

Figure 16 plots the percent of sediment-impaired stream kilometers, as assessed with the periphyton tool, in each Strahler stream order class for the Middle Rockies ecoregion. Only about 6% of first order streams in the region are impaired by sediment, while impairment by sediment is more extensive in third order streams (about 25% of stream length) and stream systems fifth order and larger (about 20% of stream length).

Relative risk for sediment impairment measured by the periphyton tool given nutrient stressor impairment was not evaluated.

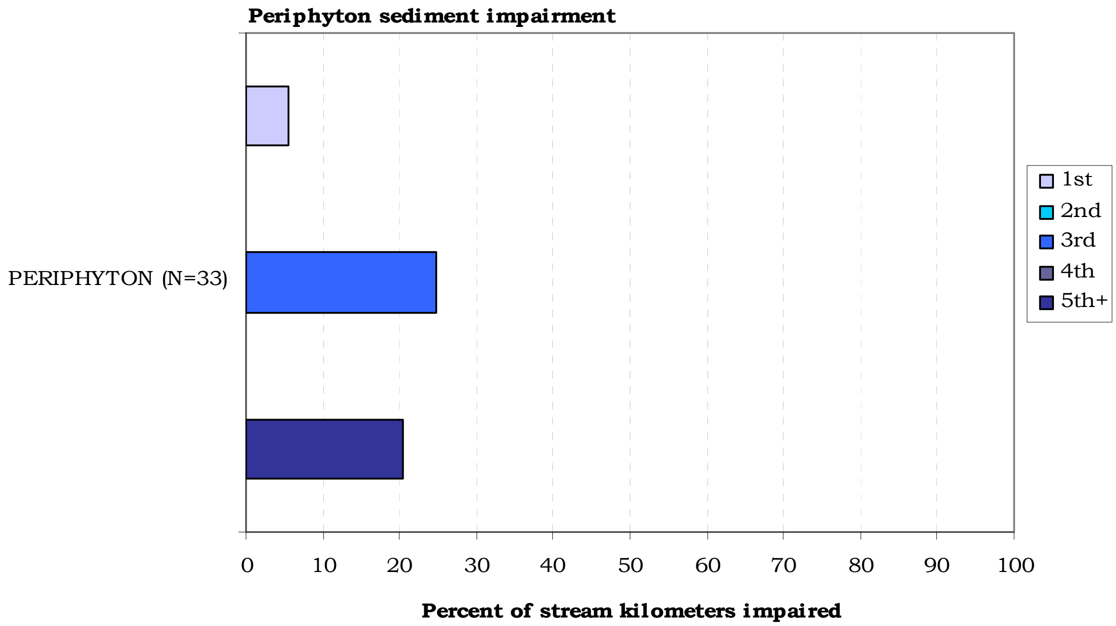

Figure 16. Extent of impaired stream length in the Middle Rockies ecoregion for sediment, as estimated by the periphyton sediment tool, in each Strahler stream order. Data for 33 sites in the Middle Rockies ecoregion that were sampled for periphyton are depicted.

Discussion

Site selection for EMAP sampling followed a carefully-crafted procedure, designed to give an unbiased estimate of the condition of streams over a large geographic area using a small number of samples. The probabilistic design ensures that (1) the population being sampled is unambiguously described; (2) every element in the population has the opportunity to be sampled with a known probability; and (3) sample selection is carried out by a random process (US EPA 2002). It is possible that impaired sites are simply overrepresented in the dataset; however, this seems very unlikely. EMAP employed two types of samples, a “targeted riffle” sample and a “reachwide” sample. Ideally, both sample types are collected from each sampled stream segment (US EPA 2003). (In the data analyzed in this report, paired reachwide and targeted riffle samples were collected for 45 of 80 sites.)

The EPA model estimate indicates that the greater part of total stream length in the State of Montana is located in the mountainous ecoregions. Streams in the plains regions account for only about 26% of the State’s total stream length. In the analysis of reachwide and shore sample data, which is the larger of the 2 datasets treated in this report, 7% (about 3400 kilometers) of statewide stream length was not assessed; the sites excluded from the assessment were sites on the Yellowstone, Kootenai, and Flathead Rivers. Since several sites had reachwide samples but no targeted riffle samples, the proportion of unassessed stream length was much greater (30%) in that dataset, rendering both extent and relative risk estimates less reliable for those data.

Extent of biological impairment: Macroinvertebrates

The reachwide and shore sample results show that about 60% of the assessed stream length in the State can be considered biologically unimpaired. For comparison, Stoddard et al. (2005) report that about 50% of stream length in the entire Western EMAP pilot study (of which these Montana data are a part) can be classified as unimpaired. These findings suggest that Montana has a greater extent of biologically intact stream and river length than the Western United States as a whole. The interesting issues about the extent of biological and nutrient impairment in each ecoregion remain unanswered in the statewide analysis. However, observations concerning impairment in the various Strahler classes and comparisons of the results of different sampling methods can be made.

The analysis of impairment extent by stream order indicates that biological impairment is extensive among first order streams statewide. First order streams account for about 29% of total stream length in the State. The MMI and O/E tools indicate biological impairment in 75% (10204 kilometers) and 63% (8,571 kilometers) of first order streams, respectively. This finding runs counter to the perception that headwaters ought to be the least impaired. While first order streams in plains regions may be exposed to intense anthropogenic disturbance by cattle grazing and other agricultural activities, first order streams in montane regions generally suffer less apparent disruption than higher order streams in those regions. Since headwater streams in plains regions account for only 14.5% of the total statewide first order length, the results of the analysis clearly imply that the greater portion of first order stream length in montane regions is biologically impaired. If accurate, this is an unexpected result.

Extensive biological impairment of first order streams in the montane regions of the State may be a consequence of the widespread forest fires that occurred during the sampling years. Other possible causes of impairment to these systems include acid deposition or effects of recreation activities. On the other hand, the results may be spurious and attributable to problems with site selection, sampling methods, or assessment tools.

Although there was some representation of EMAP-style samples, development of the MMI and O/E tools for use in Montana relied largely on data from samples collected using MDEQ sampling protocols. It is not clear how samples produced with “traveling kicknet” and “jab” techniques compare with EMAP samples, and whether assessment tools based on these techniques are useful in evaluating EMAP samples. MMI and O/E scores frequently differed between reachwide and targeted riffle samples (see below), suggesting that differences in sampled habitats affect assessment scores. It is not unreasonable to speculate that assessment tools are not readily transferable between sample types.

Another possible pitfall may be related to inherent problems with the MMI and O/E tools with respect to their ability to accurately assess first order streams. Headwater streams are unique environments, typically supporting fewer taxa in lower numbers, with different functional characteristics. In montane regions, these are typically cold, oligotrophic, and harsh environments; taxa that are ubiquitous in higher order streams do not occur there. It is not clear whether accurate assessments of first order streams can be expected from the same tools used to evaluate third and higher order streams. A site-by-site analysis of the biological assemblages collected at these sites, and the responses of individual metrics, indices, and predictive models to assemblage components may help to shed light on these issues.

The estimate of the extent of biological impairment was similar for both the MMI and O/E assessment tools (Figure 7). There was also general agreement in the extent of impairment measured by reachwide and targeted riffle sampling methods (Figure 7 and Figure 10). When site-by-site classifications are examined, it is apparent that MMI and O/E impairment classifications disagreed 20% of the time for reachwide samples and 18% of the time for targeted riffle samples. For 45 sites in the statewide dataset, results from both a reachwide sample and a targeted riffle sample were available. In 14 cases (29%), impairment classifications given by MMI or O/E for reachwide samples did not agree with classifications attained by targeted riffle samples. The O/E method performed somewhat better than the MMI in this regard; whereas there was disagreement between targeted riffle and reachwide sample results in 7 O/E classifications, 11 MMI results disagreed.

Extent of biological impairment by sediment in the Middle Rockies ecoregion: Periphyton

Sediment impairment in the Middle Rockies ecoregion was not extensive, affecting only 12% of stream extent region-wide. For comparison, Stoddard et al. (2005) report that about 26% of stream length in the entire Western EMAP pilot study are impaired by sediment problems, mostly due to excessive fine sediments. In montane ecoregions West-wide, about 21% of stream extent was in most-impaired condition due to the presence of more fine sediments than expected. The Western EMAP estimates, however, are based on direct physical measures of relative bed stability (RBS) which is a comparison between the particle sizes of sediments present in the stream channel with the size of sediment particles a stream can move or scour during its flood stage. These estimates may not be directly comparable to estimates which are based on a biological model that predicts the likelihood of impairment based on the relative abundance of diatom taxa known to increase with the increase of fine sediment. However, the data suggest that streams in the Middle Rockies ecoregion may be less extensively sediment-impaired than streams in montane ecoregions in the Western United States as a whole.

Distribution of sediment-impairment among stream orders in the Middle Rockies follows an expected pattern. Lower order streams are less extensively impaired by sediment, while middle order and higher order streams are more affected. High inputs of fine sediment are typically associated with human influences on the landscape that result in erosion or increased flood frequency or magnitude, such as agriculture, logging, road building, and grazing. Natural erosive episodes may also influence the sediment balance in streams; these episodes may be related to forest fires or naturally erosive soil composition. While natural causes of sediment input may affect first order streams in the high mountains and wilderness areas, it is reasonable to assume that most human-influenced erosion and hydrologic alteration are concentrated in middle to lower order streams, where logging and its associated roads, as well as grazing and other agricultural activities are more concentrated.

Extent of impairment by nutrient stressors

Montana ecoregions did not follow the pattern of the Western United States as a whole for the relative extent of impairment by nitrogen and phosphorus. The Western EMAP pilot study (Stoddard et al. 2005) found that for most regions in the West, the proportion of stream length in poor condition for nitrogen (27%) was higher than the impaired extent for phosphorus (15%). In the montane ecoregions of the Western United states, 26% of stream length was impaired by nitrogen, and 15% were impaired by phosphorus. In contrast, the proportion of Montana stream extent with phosphorus impairment (20%) was 2 times greater than the extent impaired by nitrogen (10%). Ammonia[3] impairment was not investigated by the Western EMAP pilot study; in Montana ecoregions, ammonia was the most extensive nutrient-caused impairment, with 28% of stream kilometers impaired state-wide.

Analysis of stressor extent by stream order indicates that phosphorus pollution is extensive in first order streams statewide, affecting 40% of total first order stream length in the State. Although nitrogen exceedances were much less extensive than either of the other 2 nutrients studied here, the greatest extent of impairment by nitrogen was among first order streams. Ammonia pollution was extensive not only in middle order and higher order streams where septic systems and wastewater treatment facilities are typically located, but second order streams were also extensively impaired by ammonia statewide.

Relative risk

Combining the results of stressor extent and relative risk analyses for reachwide and shore samples, it appears that while above-threshold levels of ammonia are the most widespread impairment statewide, phosphorus impairment poses the greatest risk to the integrity of the macroinvertebrate assemblages as measured by the O/E tool. Increased risk to macroinvertebrates from phosphorus is also demonstrated by the MMI, but the response of MMI to the stressor in terms of increased risk is slight. Whereas the MMI is not responsive to nitrogen or ammonia pollution, the O/E indicates increased risk to all stressors, however, the response to nitrogen is very small, and the response to ammonia is only moderate. Only the increased risk of phosphorus to O/E impairment is statistically significant. However, error bars for all risk analyses are so wide as to suggest that results are not reliable.

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[3] Ammonia concentrations were elevated above concentrations derived from regional reference streams, but they did not exceed toxicity ammonia thresholds in DEQ-7 (DEQ 2006).

The analysis of targeted riffle data suggests that EMAP sampling methods may produce samples with differential responses to nutrient stressors. The MMI tool showed a greater response to both nitrogen and phosphorus than the O/E tool in the analysis of targeted riffle samples. The MMI was almost 3 times as likely to show impairment when phosphorus standards were exceeded, while the O/E exhibited a somewhat lower risk for an impaired score. While the O/E was not responsive to nitrogen pollution, the MMI exhibited a moderately increased risk of impairment when nitrogen criteria were violated, but the increased risk was not statistically significant. However, it must be noted that wide confidence intervals for all relative risk measures indicate that error precluded reliability for these relative risk results.

Phosphorus levels that exceeded criteria were associated with increased risk of biological impairment regardless of sampling method. The extensive impairment of first order streams by phosphorus exceedances is an unexpected finding. Phosphorus criteria for Montana were established at levels that were associated with early impacts to beneficial water uses (Suplee et al. 2007). Sewage effluent is one source of phosphorus pollution, but in Montana it may more often be associated with streambank instability; eroded particulate matter carries phosphate which enters streams.

Nutrient-influencing geographic factors are considered in ecoregion-specific criteria developed for Montana. Since phosphorus is most often limiting to the primary productivity in Montana streams and rivers, phosphorus pollution is the most likely cause of increased growth of photosynthetic algae and other plants in those systems. Nuisance crops of periphyton may cause "bottom-up" effects on macroinvertebrate assemblage composition and function in a number of ways. Shifts in habitat availability may result when filamentous algae growth becomes excessive, obliterating access to substrates. Increased phosphorus concentrations have been associated with diminished diversity and increased abundance of macroinvertebrates and increased overall assemblage tolerance (Lenz 1998, Smith et al. 2007). Nocturnal respiration and decay of dead plant material may reduce dissolved oxygen to critical levels, at which only tolerant organisms can survive. Hemoglobin-bearers such as tubificid worms (Oligochaeta: Tubificidae), physid snails, and certain chironomids are advantaged, while more sensitive members of the Ephemeroptera, Plecoptera, and Trichoptera orders are generally disadvantaged. Senescence of algal crops may result in increased abundance of tolerant filter-feeding organisms downstream.

The widespread pollution of second and third order streams by ammonia[4] is an unexpected finding. Fifty-six percent of the total second and third order stream length in the State demonstrates ammonia levels in excess of the draft ammonia criteria (Suplee 2007). However, nearly all ammonia levels reported for second and third order sites are only slightly in excess (0.001 - 0.004 mg/l) of the draft ammonia criteria. This may account for the small, and statistically insignificant, increased risk of O/E impairment when draft

[4] Ammonia concentrations were elevated above concentrations derived from regional reference streams, but they did not exceed toxicity ammonia thresholds in DEQ-7 (DEQ 2006)

ammonia criteria are exceeded. The MMI did not indicate increased risk of biological impairment when draft ammonia criteria is exceeded.

PART 3. ANALYSIS OF INDIVIDUAL ECOREGIONS

Data Sources and Model Manipulation

In addition to the 69 sites in the EPA model, data for 11 additional sites from the EMAP dataset were provided by MDEQ for intra-ecoregion analyses. Although sampled in the EMAP effort, these sites could not be included in the EPA stream extent model, since criteria for their inclusion in the probabilistic model had not been met (T. Johnson, pers. comm.) Table 6 quantifies the estimated extent of kilometers of perennial streams in the State, and indicates the number of sites in each ecoregion/stream order category used in the ecoregion-specific analyses. Of the 80 sites used in the ecoregion-specific analyses, 5 sites were excluded; the stream length they represent appears as "not assessed" in graphs of impairment class extent. Excluded sites were located on the Yellowstone, Flathead, and Kootenai Rivers.

Since the additional 11 sites were not part of the EMAP probability dataset, manipulation of the EPA model was necessary in order to obtain stream extent estimations that included the added sites. A simple model manipulation was used. Length estimates were assigned to the added sites by totaling the number of stream kilometers within each ecoregion/Strahler stream order class, and averaging that total extent over the number of sites included in the larger dataset. Although this manipulation does not account for all of the variables considered for weighting in the EPA model and likely violates rules used to construct it, the estimations are probably reasonable for these analyses.

Intra-Ecoregion Assessments

The combined MDEQ expanded dataset includes 80 sites. Of these, 75 sites were selected by MDEQ for analysis of individual ecoregions. Eighty sites were used to analyze the extent of biological and chemical condition for individual ecoregions. To achieve the best possible representation, the larger reachwide and shore dataset was used in this analysis. Nevertheless, sample sizes for individual ecoregions were small, in some cases very small. No ecoregion was represented by enough sites to produce significant results for all estimates of impairment extent and relative risk. The extent of impairment in most of these analyses may be greatly overestimated.

Table 6. Estimated extent of kilometers of perennial streams in the State and the number of sites in each ecoregion/stream order category used in the ecoregion-specific analyses.

Ecoregion	Stream order	Stream length (km.)	Representative sites
15 Northern Rockies	1st	2009.8	1
	2nd	2009.8	2

	3rd	0	0
	4th	0	0
	5th +	3433.4	3
16 Idaho Batholith	1st	0	0
	2nd	513.0	1
	3rd	0	0
	4th	0	0
	5th +	0	0
17 Middle Rockies	1st	8596.8	7
	2nd	5600.5	10
	3rd	5301.2	12
	4th	683.9	1
	5th +	3363.7	3
41 Canadian Rockies	1st	1025.9	1
	2nd	1517.9	2
	3rd	1607.8	2
	4th	0	0
	5th +	0	0
Mountain total		35663.7	45
42 NW Glaciated Plains	1st	1025.9	1
	2nd	0	0
	3rd	1308.1	5
	4th	1846.7	5
	5th +	384.7	1
43 NW Great Plains	1st	947.0	3
	2nd	1538.9	4
	3rd	1179.8	5
	4th	1846.7	4
	5th +	2453.7	7
Plains total		12531.5	35

Northern Rockies ecoregion (15)

Six EMAP sites represent the total Northern Rockies ecoregion stream extent of 7,453 kilometers. Two sites in the EMAP extent model were excluded from the evaluation, thus 28% of stream extent was not evaluated. Biological assessment tools did not agree well on the extent of impairment in the Northern Rockies. The MMI indicates that biological impairment was more extensive (45% of stream length) than good biological condition (27% of stream length) in Northern Rockies streams. O/E scores, however, indicate the reverse (Figure 17). The width of the 95% confidence intervals indicates a high degree of uncertainty in all results; small sample size undoubtedly contributes to this.

Stressor extent (Figure 18) estimates are also fraught with uncertainty in this analysis. Nitrogen draft criteria for several sites and seasons (i.e. winter) have not been established, so the extent of nutrient condition in this region is not well-assessed. A Clark Fork River site, representing about 18% of stream length in the Northern Rockies, was unimpaired for both nitrogen and phosphorus. Phosphorus impairment, evaluated for 2 additional sites, is estimated to be almost as extensive as unimpaired stream length in the region.

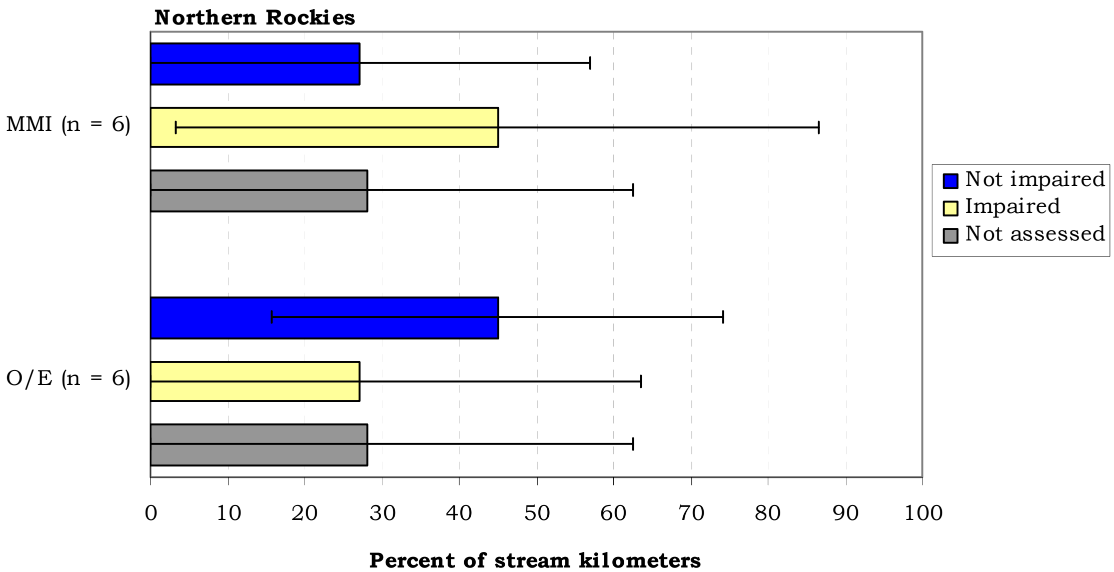

Figure 17. Biological condition evaluated for the Northern Rockies ecoregion using macroinvertebrate assessment tools. The percentage of total regional stream length in each biological impairment classification along with 95% confidence intervals is plotted. Data for 6 sites sampled with the reachwide or shore protocols are depicted.

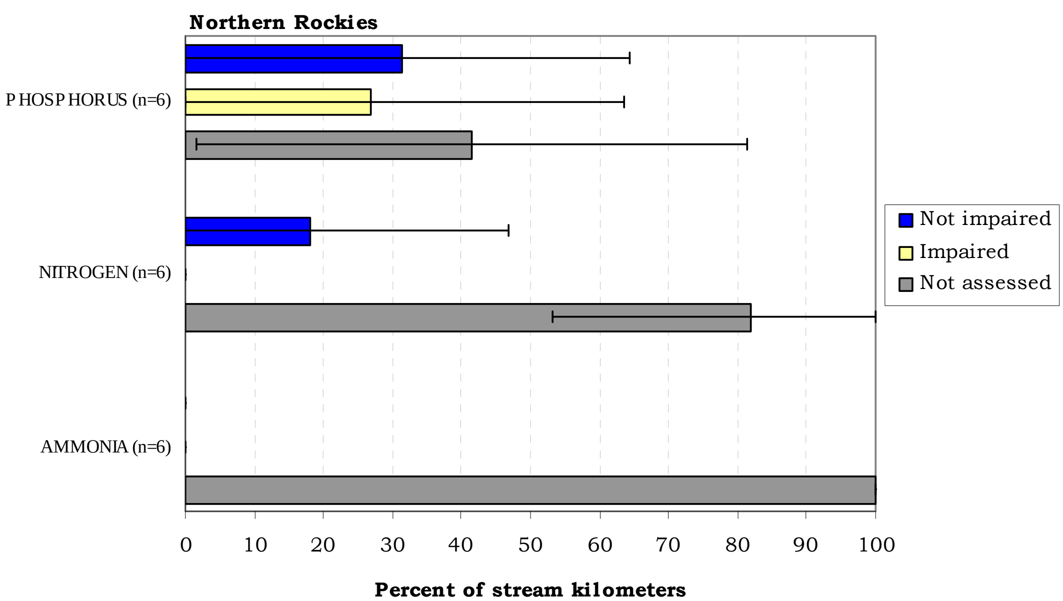

Figure 18. The extent of impairment classifications for 3 stressors in the Northern Rockies ecoregion. The percentage of total regional stream length in each biological impairment classification along with 95% confidence intervals is plotted. Data for 6 sites sampled with the reachwide or shore protocols are depicted.

Phosphorus was the only stressor to be associated with increased risk of biological impairment in the Northern Rockies (Figure 19), but increased risk was small and not statistically significant. An increased risk response was only noted for the MMI.

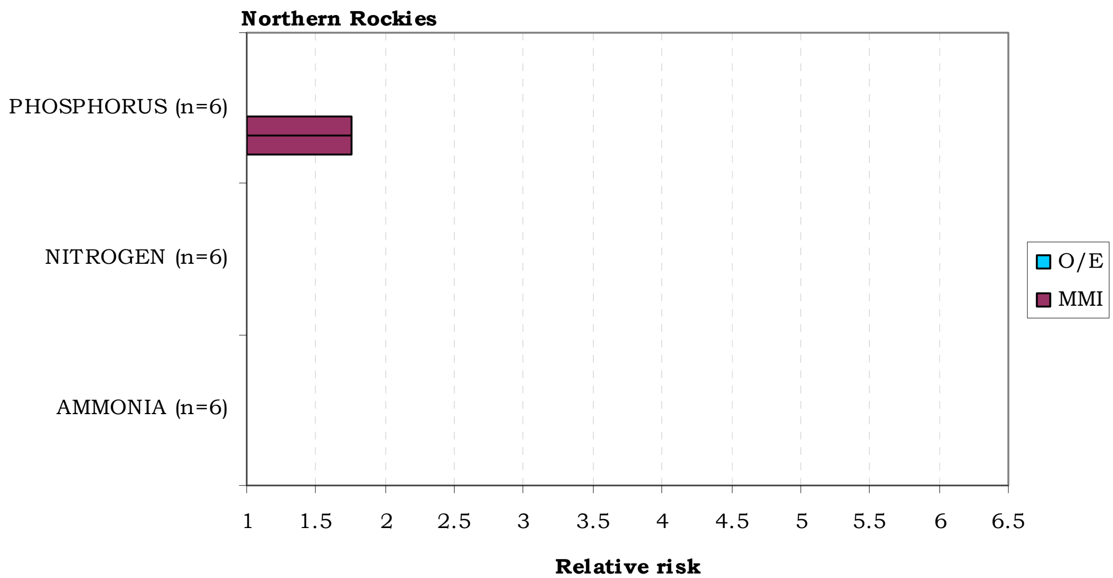

Figure 19. The relative risk of impairment to macroinvertebrates from stressors in the Northern Rockies ecoregion. Bars indicate 95% confidence intervals. Data for 6 sites sampled with the reachwide or shore protocols are depicted.

Idaho Batholith ecoregion (16)

This ecoregion was represented in the data by a single site; the model indicates that some 513 kilometers of stream length occur in the Idaho Batholith region. Macroinvertebrate tools indicated that the site was not biologically impaired. No nutrient draft criteria have been established for the Idaho Batholith ecoregion, so the extent of chemical impairment cannot be estimated, and risk to biota from nutrients cannot be calculated.

Middle Rockies ecoregion (17)

The Middle Rockies ecoregion is represented by 33 sites in the EMAP data; stream extent in the region is estimated to be 23,546 kilometers, by far the largest concentration of stream kilometers of any ecoregion in the State. The single large river site excluded from the assessment accounts for under 2% of total stream extent in the region. MMI scores indicate that 45% of stream length in the Middle Rockies region is impaired (Figure 20), almost equaling the extent of stream length in good condition (53%). Forty percent of stream length is impaired for O/E scores. Periphyton assessment evaluations indicate that 12% of regional stream extent is impaired by sediments. Confidence intervals calculated for these results indicate that only the periphyton results are statistically significant. Considerable overlap between impaired and unimpaired confidence intervals for MMI and O/E results indicates that these results are not reliable.

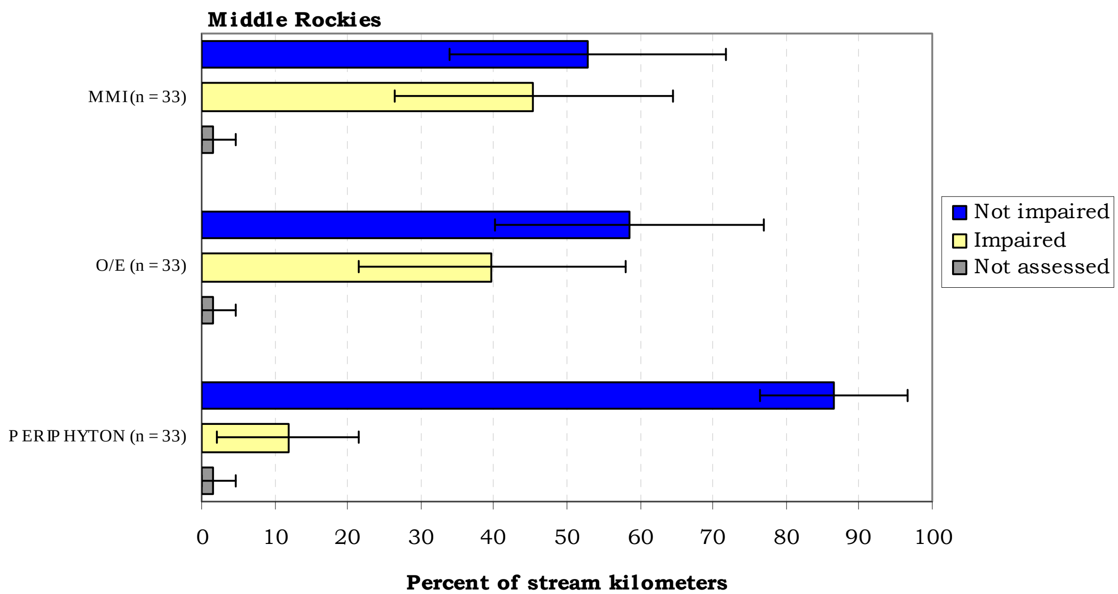

Figure 20. Biological condition evaluated for the Middle Rockies ecoregion using macroinvertebrate and periphyton (for sediment only) assessment tools. The percentage of total regional stream length in each biological impairment classification along with 95% confidence intervals is plotted. Data for 33 sites sampled with the reachwide or shore protocols are depicted.

Chemical stressors are not as widespread in the Middle Rockies ecoregion as biological impairment (Figure 21). Ammonia concentrations that exceeded draft ammonia[5] criteria were the most widespread in the region, impairing 35% of stream length. Nitrogen impairment was estimated to affect 10% of the stream extent in the Middle Rockies, and phosphorus impairment was estimated to affect 18% of stream extent in the region. While the estimates of nitrogen and phosphorus impairment were statistically significant, the estimate of ammonia impairment was not.

When data were further examined, it became apparent that impairment was most extensive in third order streams according to assessments of sediment impairment using periphyton data. In contrast, macroinvertebrate tools indicated that impairment among Middle Rockies streams was most extensive among first order streams. The MMI showed no increased risk of impairment from any nutrient stressor (Figure 22). The increased risk of O/E impairment associated with nitrogen and ammonia were small.

[5] Ammonia concentrations were elevated above concentrations derived from regional reference streams, but they did not exceed toxicity ammonia thresholds in DEQ-7 (DEQ 2006).

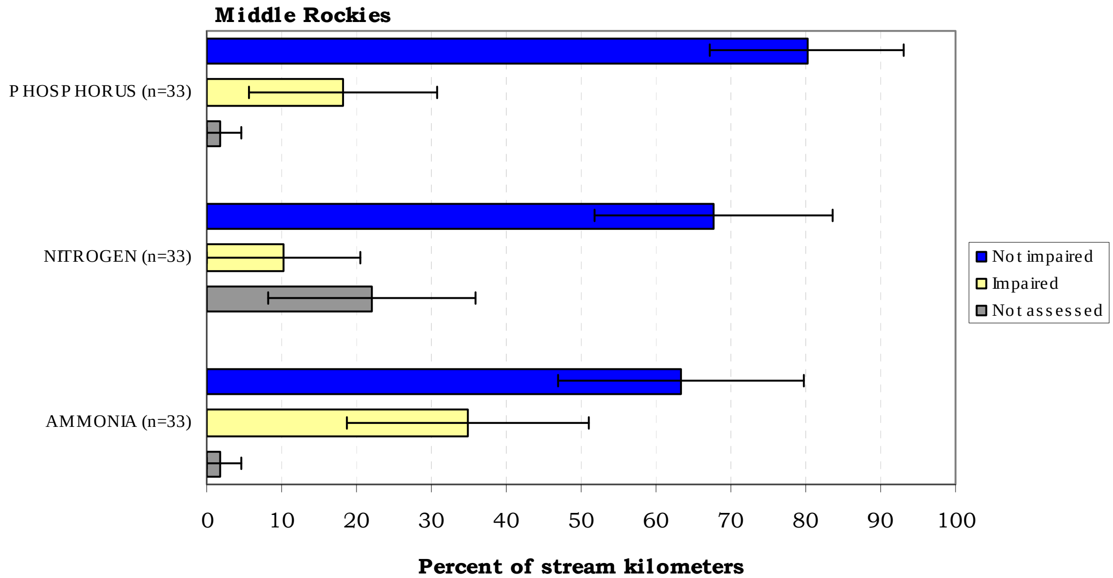

Figure 21. The extent of impairment classifications for 3 stressors in the Middle Rockies ecoregion. The percentage of total regional stream length in each biological impairment classification along with 95% confidence intervals is plotted. Data for 33 sites sampled with the reachwide or shore protocols are depicted.

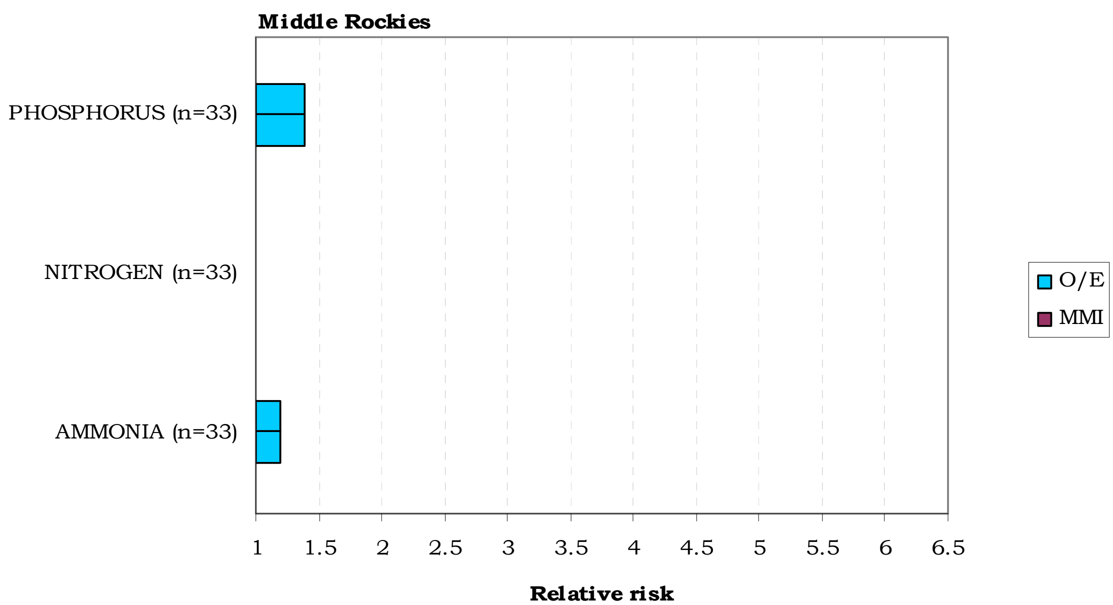

Figure 22. The relative risk of impairment to macroinvertebrates from stressors in the Middle Rockies ecoregion. Bars indicate 95% confidence intervals. Data for 33 sites sampled with the reachwide or shore protocols are depicted.

Canadian Rockies ecoregion (41)

The 5 sites sampled in the Canadian Rockies ecoregion represent 4,152 kilometers of stream extent. No sites were excluded from the assessment. There was notable disagreement between macroinvertebrate tools in this region. The MMI did not detect biological impairment in any of the Canadian Rockies sites, but the O/E indicated that 37% of stream extent was impaired (Figure 23). The wide overlap of confidence intervals indicates that this result was not statistically significant. The small number of sites in the data for this region likely accounts for the magnitude of disagreement between the MMI and O/E and the lack of significant results.

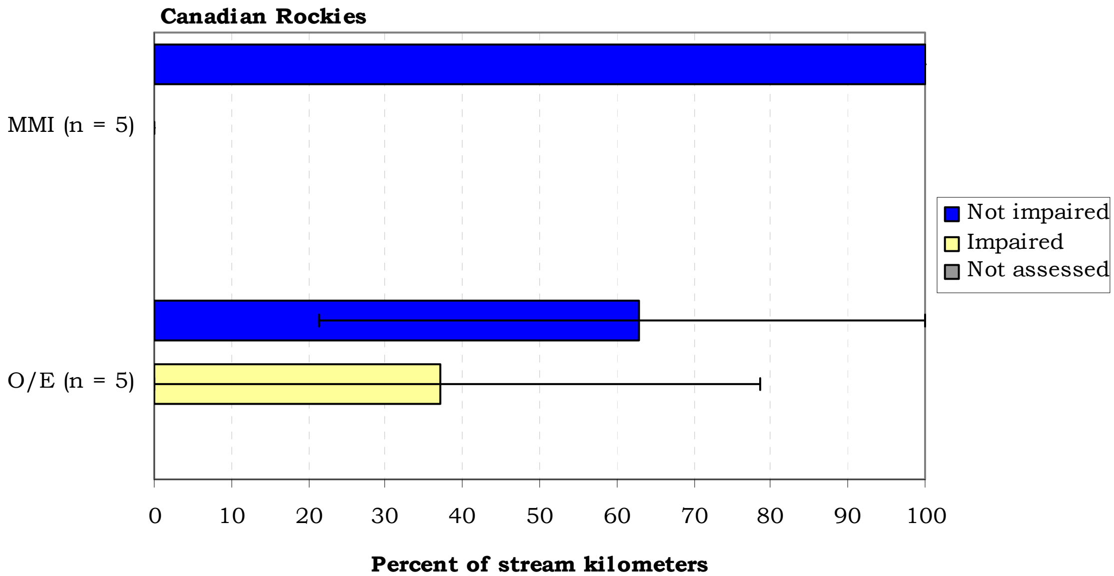

Figure 23. Biological condition evaluated for the Canadian Rockies ecoregion using macroinvertebrate assessment tools. The percentage of total regional stream length in each biological impairment classification along with 95% confidence intervals is plotted. Data for 5 sites sampled with the reachwide or shore protocols are depicted.

Ammonia[6] impairment was the most widespread nutrient stressor, essentially affecting 100% of stream length in the Canadian Rockies (Figure 24). In 4 of the 5 sampled sites, exceedances were small (~ 0.00015 mg/l); nevertheless, the result is unexpected. Phosphorus impairment is indicated for 25% of stream length in this ecoregion, while nitrogen impairment is indicated for 12% of stream length.

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[6] Ammonia concentrations were elevated above concentrations derived from regional reference streams, but they did not exceed toxicity ammonia thresholds in DEQ-7 (DEQ 2006).

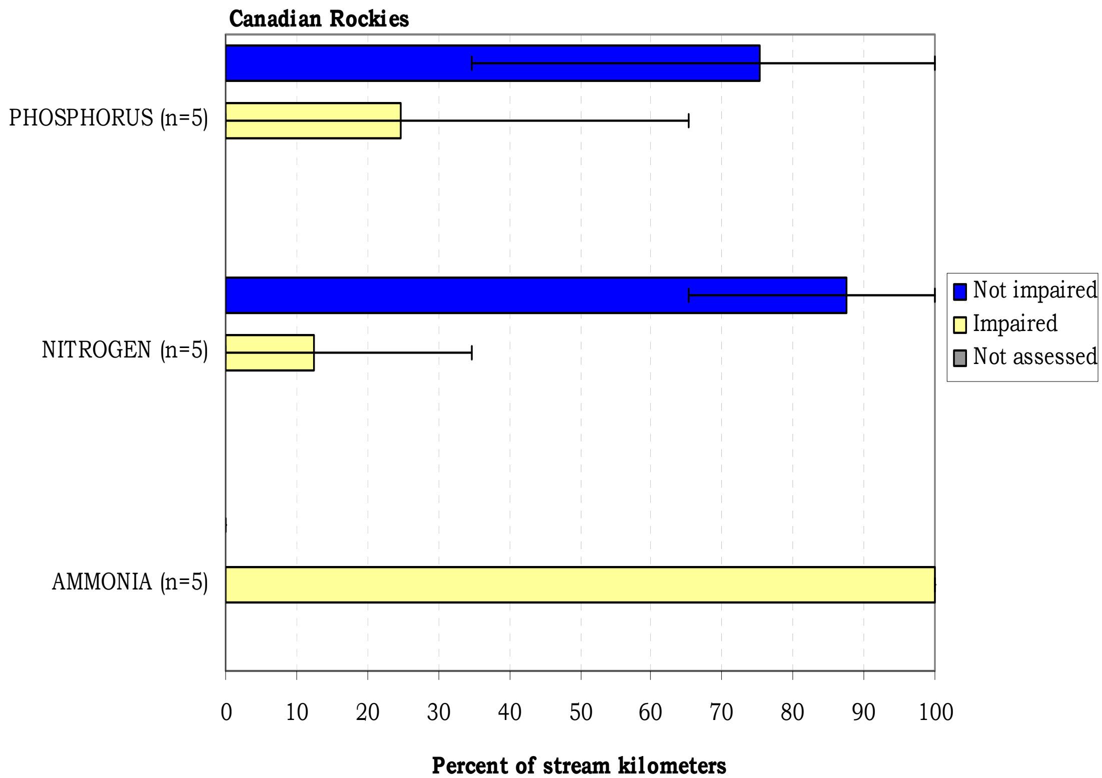

Figure 24. The extent of impairment classifications for 3 stressors in the Canadian Rockies ecoregion. The percentage of total regional stream length in each impairment classification along with 95% confidence intervals is plotted. Data for 5 sites sampled with the reachwide or shore protocols are depicted.

Since 100% of stream extent was biologically intact as measured by the MMI, no chemical stressor was associated with lower MMI scores (Figure 25). Since all sites were impaired by ammonia, the probability of biological impairment without ammonia stress is zero, and the relative risk calculation is meaningless. O/E scores were 6 times as likely to result in an impaired classification when phosphorus criteria were exceeded; in spite of the low sample number, this result was statistically significant. Nitrogen impairment also was associated with an increased risk of O/E impairment, though the increase was not statistically significant. O/E scores were 3.5 times as likely to be low when nitrogen criteria were exceeded.

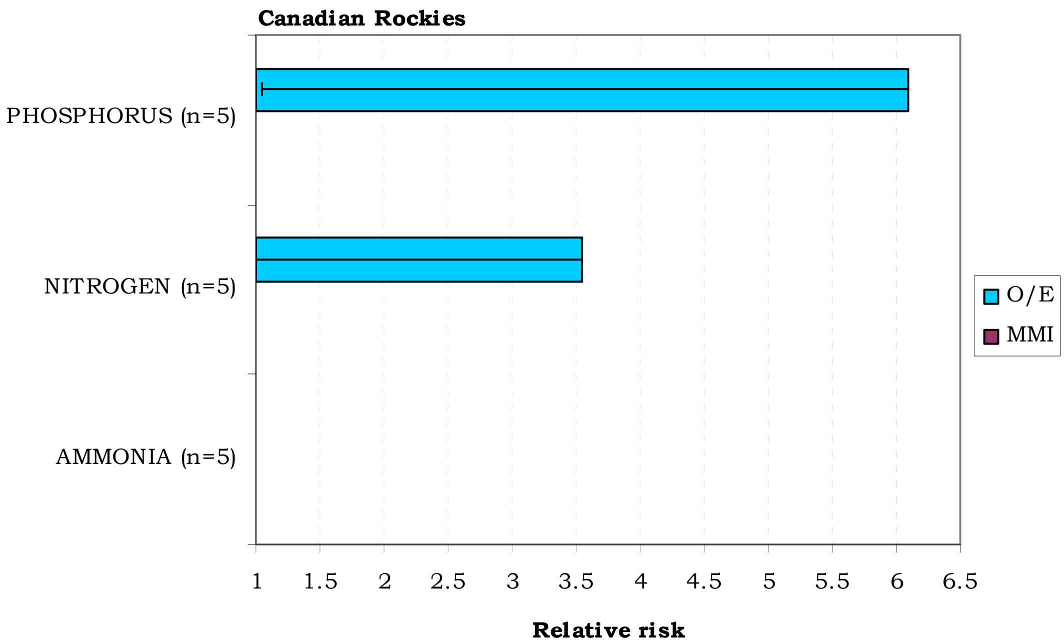

Figure 25. The relative risk of impairment to macroinvertebrates from stressors in the Canadian Rockies ecoregion. Bars indicate 95% confidence intervals. Data for 5 sites sampled with the reachwide or shore protocols are depicted.

Northwestern Glaciated Plains ecoregion (42)

Twelve sites, representing 4,565 kilometers of total regional stream extent, were sampled in the Northwestern Glaciated Plains ecoregion. No large river sites were excluded from the analysis, thus 100% of stream extent is represented in the results. MDEQ biological assessment tools indicate that biological impairment is not widespread in this region (Figure 26). Results suggest that about 80% of stream length in the Northwestern Glaciated Plains ecoregion is biologically intact. O/E assessment detects slightly more impairment (21% of stream length) than the MMI (17% of stream length). This ecoregion has the lowest incidence of impairment to macroinvertebrates among Montana's ecoregions. Despite its low incidence of impairment to macroinvertebrates, the Northwestern Glaciated Plains has the highest proportion of stream length impaired by both phosphorus (37%) and nitrogen (27%) (Figure 27). As estimated by these results, however, impairment by ammonia is virtually non-existent in the region.

Phosphorus impairment is associated with a moderately increased risk (1.6 times) of low O/E scores (Figure 28). Nitrogen impairment increases the risk of O/E impairment by more than 2.5 times. Neither phosphorus nor nitrogen impairment is associated with increased risk of low MMI scores. None of the relative risk analyses produced statistically significant results.

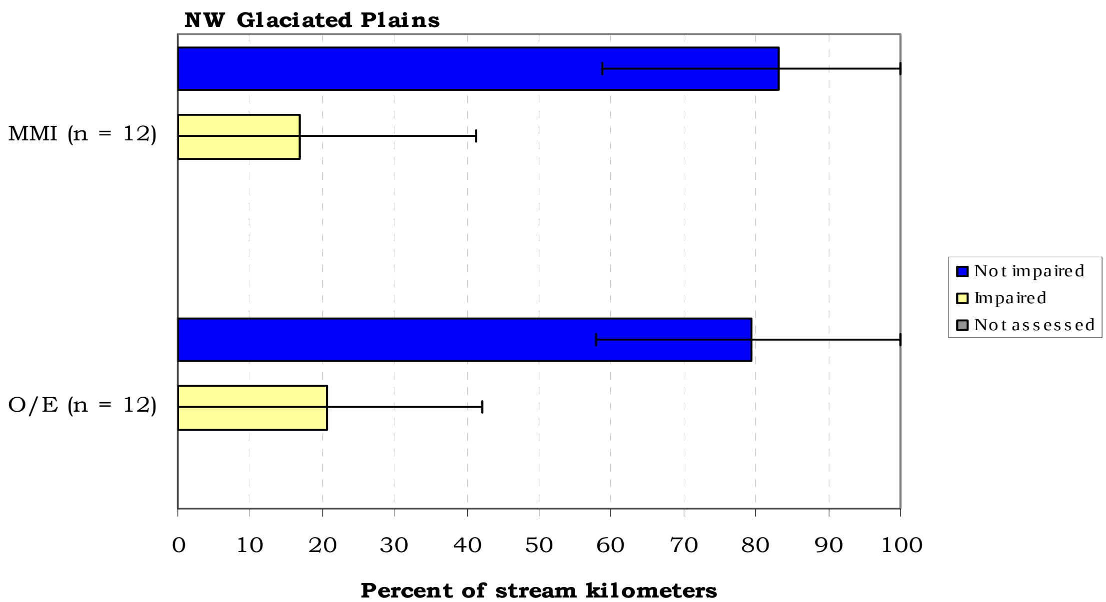

Figure 26. Biological condition evaluated for the Northwestern Glaciated Plains ecoregion using macroinvertebrate assessment tools. The percentage of total regional stream length in each biological impairment classification along with 95% confidence intervals is plotted. Data for 12 sites sampled with the reachwide or shore protocols are depicted.

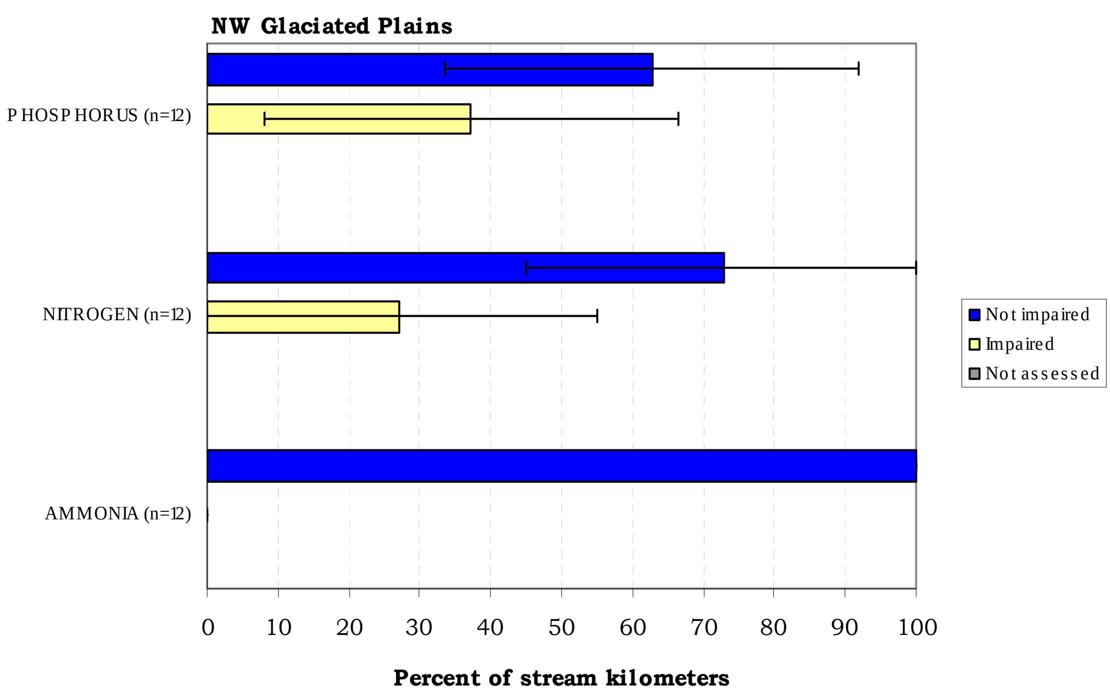

Figure 27. The extent of impairment classifications for 3 stressors in the Northwestern Glaciated Plains ecoregion. The percentage of total regional stream length in each biological impairment classification along with 95% confidence intervals is plotted. Data for 12 sites sampled with the reachwide or shore protocols are depicted.

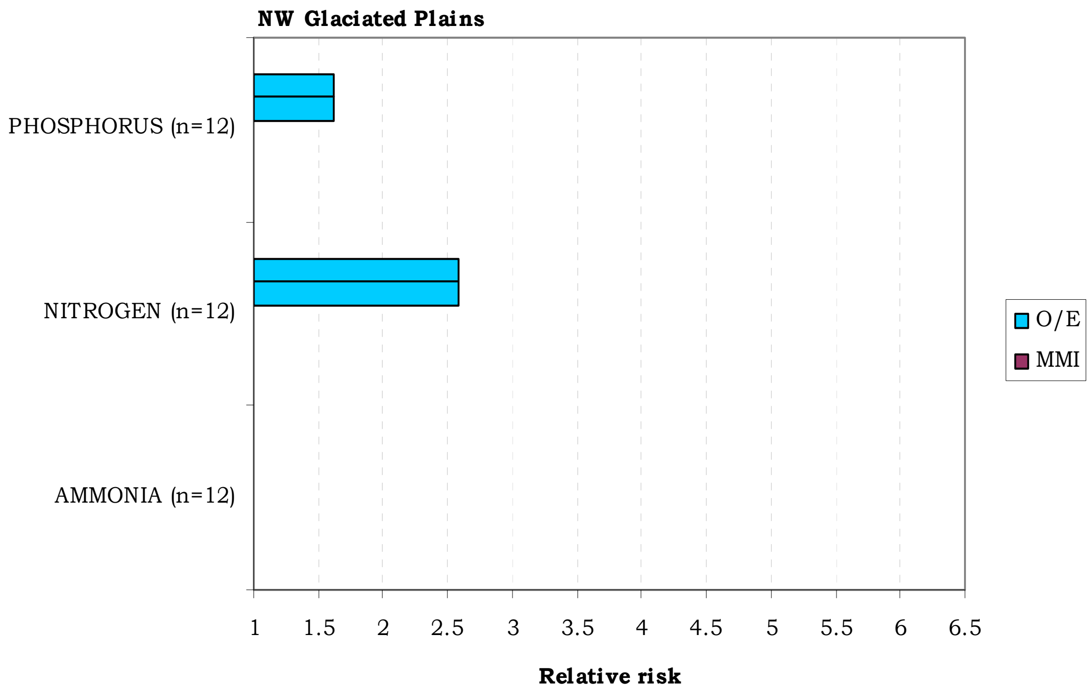

Figure 28. The relative risk of impairment to macroinvertebrates from stressors in the Northwestern Glaciated Plains ecoregion. Bars indicate 95% confidence intervals. Data for 12 sites sampled with the reachwide or shore protocols are depicted.

Northwestern Great Plains ecoregion (43)

Total stream length in the Northwestern Great Plains ecoregion, estimated at 7,966 kilometers, is represented by data from 23 sites. Yellowstone River sites, representing 947 kilometers (about 9%) of stream extent in the region, were not assessed. Impairment to macroinvertebrates was not widespread in this ecoregion (Figure 29). The MMI detected impairment in 17% of total stream length, while the O/E tool indicated impaired conditions for 27% of total stream length.

Unlike the Glaciated Plains, the Northwestern Great Plains has negligible incidence of phosphorus or nitrogen pollution (Figure 30). Impairment due to ammonia is limited to about 7% of stream extent. There was no increase in relative risk to macroinvertebrate integrity associated with any nutrient stressor.

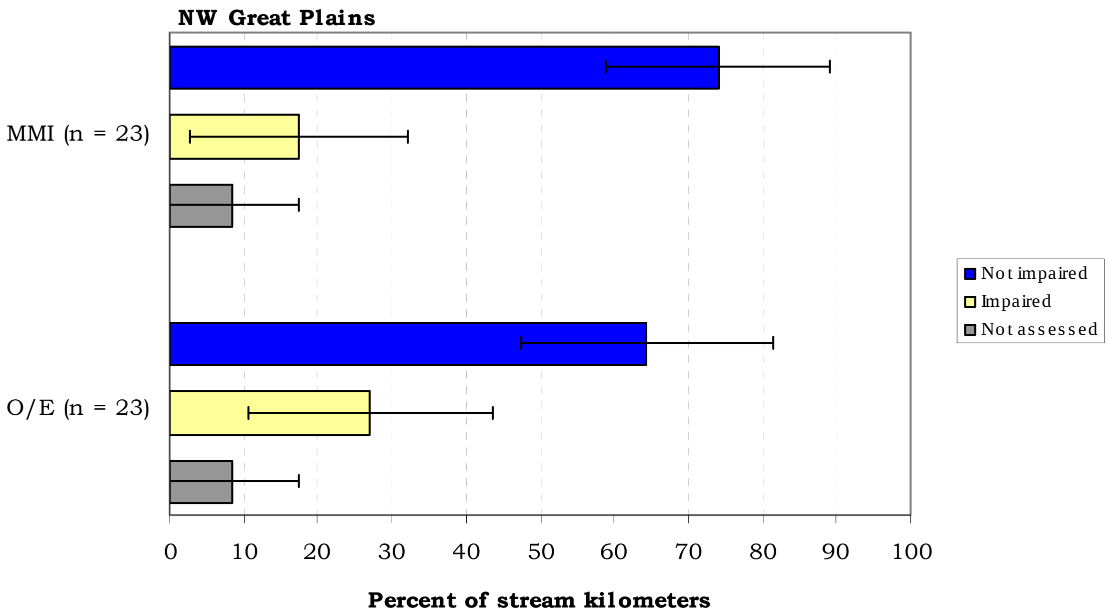

Figure 29. Biological condition evaluated for the Northwestern Great Plains ecoregion using macroinvertebrate assessment tools. The percentage of total regional stream length in each biological impairment classification along with 95% confidence intervals is plotted. Data for 23 sites sampled with the reachwide or shore protocols are depicted.

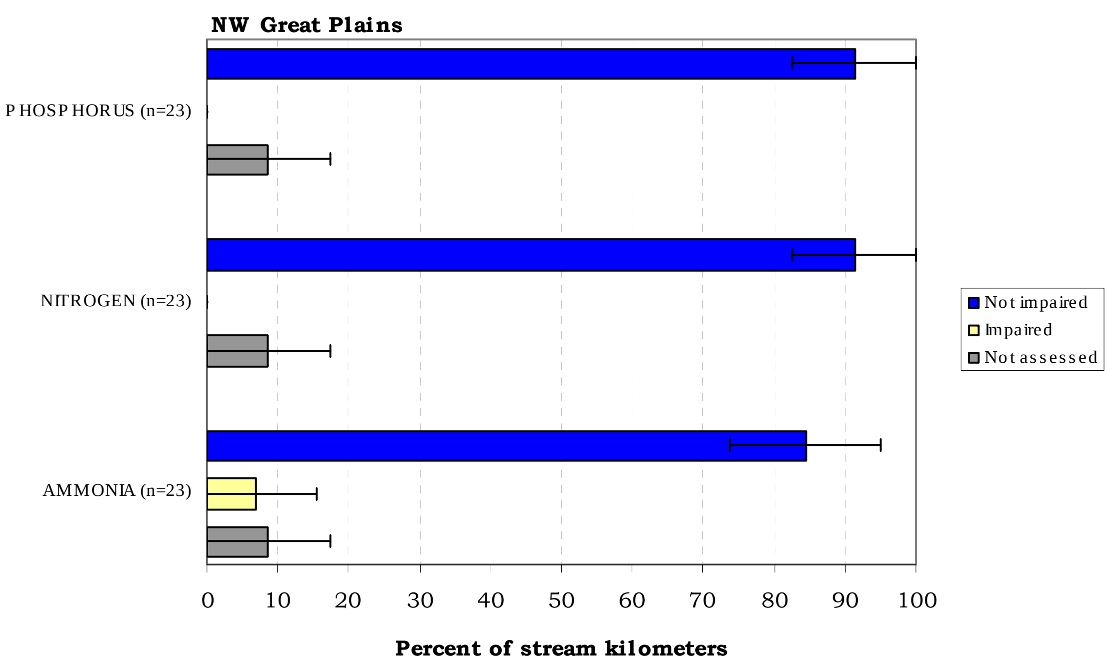

Figure 30. The extent of impairment classifications for 3 stressors in the Northwestern Great Plains ecoregion. The percentage of total regional stream length in each biological impairment classification along with 95% confidence intervals is plotted. Data for 23 sites sampled with the reachwide or shore protocols are depicted.

Discussion

The analyses of the relative extent of biological and nutrient impairment in individual ecoregions gave interesting results that run contrary to some common perceptions. In particular, some contrasts between extent of impairment in montane regions and in the plains were not expected. In general, both the MMI and O/E tools assessed more extensive biological impairment in the mountainous ecoregions than in the plains. Impairment was most extensive in streams of the Middle Rockies ecoregion, and least extensive in streams of the Northwestern Great Plains. Middle Rockies biological impairment was also more extensive than impairment in the Northwestern Glaciated Plains. This would be the case even if all unassessed stream kilometers in the plains regions were found to be impaired. Although comparison is limited by the small number of sites sampled, streams in the Northern Rockies ecoregion were also more extensively impaired than streams in either of the 2 plains regions. Both the MMI and O/E returned similar results in this regard.

Further examination of the data indicated that the widest extent of biological impairment in the montane ecoregions is located in first order streams. The extensive impairment of these systems is both surprising and disturbing. MMI and O/E scores indicate that 70% of first order stream kilometers in the montane ecoregions of the State are biologically impaired. These are the streams that are located in relatively undisrupted wilderness areas, Forest Service, and National Park lands. If these results reflect actual conditions, widespread stress due to drought or forest fires may have influenced assessment scores. Another consideration that warrants further investigation is the possibility that currently developed bioassessment tools are not appropriate for the evaluation of first order streams in the mountains. Models used for the development of the MMI and O/E were developed for small- to mid-sized streams, generally second to fourth order systems. The functional and compositional changes in macroinvertebrate assemblages over the longitudinal continuum are well-documented. Tools developed using data from mid-sized streams cannot be expected to accurately assess conditions in either very small or very large streams. The limitations of the use of MMI and O/E models in high-linkage rivers were discussed in Bollman and Teply (2006). In first order systems, diversity of macroinvertebrates is expected to be low due to naturally increased stresses of temperature, habitat limitations, scouring flows, and nutrient limitations. Metrics that rely on richness or on behaviors such as burrowing may not be meaningful in headwater streams if they are scaled to reflect expectations of larger systems. Although only measured for the Middle Rockies ecoregion, it is notable that impairment to periphyton assemblages is more extensive in higher-linkage systems; only 5% of first order stream kilometers in that region are impaired according to diatom criteria.

The MMI and O/E indicated that impairment extent in the plains regions of the State is more evenly distributed among stream orders, although the MMI evaluations suggest that half of first order stream kilometers in the plains are impaired. The predominance of agricultural activities over extensive areas in the plains makes an even distribution of impairment reasonable in these regions.

More extensive impairment in first order streams may be related to the comparative resilience of larger streams to stressors associated with cattle grazing and crops. Smaller stream channels may be more thoroughly disrupted by these activities, and water quality is more readily impaired by non-point source pollutants when water volume is small.

The distribution of nutrient impairment among ecoregions is also unexpected in some ways. While 30-40% of stream kilometers in the Northwestern Glaciated Plains were impaired by nitrogen and phosphorus, no impairment by these nutrients was apparent in the Northwestern Great Plains region. Impairment by ammonia was rare in the plains, and was entirely limited to the Great Plains. In contrast, nutrient impairment was present in all montane ecoregions for which draft criteria have been set. Among the nutrients, impairment by ammonia was most extensive in the Middle Rockies ecoregion. Impairment by nitrogen and by phosphorus was most extensive in the Glaciated Plains. The region with the least extent of impairment by nutrients was, unexpectedly, the Northwestern Great Plains. The Glaciated Plains and Middle Rockies ecoregions tied for the dubious honor of regions with the most extensive impairment by nutrients. These results somewhat agree with those of Suplee et al. (2007), who find that elevated nutrient concentrations in Western Montana were greater that they had anticipated at the onset of their analysis.

All of the EMAP sites in the Canadian Rockies exceeded draft criteria for ammonia, but there is some uncertainty about whether these criteria are too stringent (M. Suplee, personal communication), and further adjustments of these criteria may have a significant effect on these results.

Error due to small sample sizes or large variance in the data substantially affected the usefulness of the macroinvertebrate impairment extent estimates in the Northern Rockies and Canadian Rockies ecoregions, where only a few sites were sampled. In particular, the Northern Rockies ecoregion appears to have been poorly-represented. On average, each site in that region represented 1386 kilometers of stream extent; the average for the other montane ecoregions was 734 kilometers per sampled site. To a lesser degree, error was also a considerable factor in the Northwestern Glaciated Plains, where wide confidence intervals suggested unreliable results. Error was less of a factor in the Middle Rockies and Northwestern Great Plains ecoregions, where the number of sampled sites was adequate for statistically significant results for reachwide and shore samples.

Estimates of relative risk were fraught with error due to inadequate sample sizes; the technique appears to be better suited to the Western EMAP data than to data generated from a single state. The only result that was statistically significant was the response of O/E to phosphorus exceedance in the Canadian Rockies ecoregion, where all sites were considered to be impaired by phosphorus, perhaps because of a too-stringent criteria for that nutrient in that region. Compared to the O/E tool, the MMI was relatively unresponsive to nutrient impairment, indicating increased risk of impairment in a single instance; phosphorus impairment in the Northern Rockies slightly increased the likelihood of low MMI scores. As expected, the diatom assessment tool was responsive to both phosphorus and nitrogen impairment in the Middle Rockies.

As primary producers, diatom abundance and assemblage composition are intimately related to nutrient concentrations.

In general, the MMI and O/E tools gav

e similar estimates of the extent of impairment in individual ecoregions. The exceptions were the Northern Rockies and Canadian Rockies where few disagreements were liable to produce large differences in estimated extents.

PART 4. ECOLOGICAL INTERPRETATION OF BIOLOGICAL ASSEMBLAGES

Approach

Narrative interpretations of the taxonomic and functional composition of invertebrate assemblages are based on demonstrated associations between assemblage components and habitat and water quality variables gleaned from the published literature, the writer's own research (especially Bollman 1998) and professional judgment, and those of other expert sources (especially Wisseman 1996). These interpretations are not intended to replace canonical procedures for stressor identification, since such procedures require substantial surveys of habitat, and historical and current data related to water quality, land use, point and non-point source influences, soils, hydrology, geology, and other resources that were not readily available for this study. Instead, attributes of invertebrate taxa that are well-substantiated in diverse literature, published and unpublished research, and that are generally accepted by regional aquatic ecologists, are combined into descriptions of probable water quality and instream and reach-scale habitat conditions.

The approach to this analysis uses some assemblage attributes that are interpreted as evidence of water quality and other attributes that are interpreted as evidence of habitat integrity. To arrive at impairment classifications, attributes are considered individually, so information is maximized by not relying on a single cumulative score, which may mask stress on the biota. Such an approach also minimizes the possibility of using inappropriate assessment strategies when the biota at a site is atypical of "characteristic" sites in a region. For example, flora and fauna that are uncharacteristic of the plains regions occur in transitional stream reaches, where the influence of foothill or montane headwaters supports assemblages distinct from the more warm water, generally sediment tolerant biota typical of the plains. While MMI and O/E approaches evaluate these assemblages by comparison with expectations for streams in the mapped ecoregions, this approach assesses these assemblages by comparison with expectations consistent with transitional systems, rather than with the mapped ecoregion.

Water quality variables are estimated by examining mayfly taxa richness and the Hilsenhoff Biotic Index (HBI) value. Other indications of water quality include the richness and abundance of hemoglobin-bearing taxa and the richness of sensitive taxa. Mayfly taxa richness has been demonstrated to be significantly correlated with chemical measures of dissolved oxygen, pH, and conductivity (e.g. Bollman 1998, Fore et al. 1996, Wisseman 1996). The Hilsenhoff Biotic Index (HBI) (Hilsenhoff 1987) has a long history of use and validation (Cairns and Pratt 1993). In Montana foothills, the HBI was demonstrated to be significantly associated with conductivity, pH, water temperature, sediment deposition, and the presence of filamentous algae (Bollman 1998). The presence of filamentous algae is also suspected when macroinvertebrates associated or dependent on it (e.g. LeSage and Harrison 1980, Anderson 1976) are abundant. Nutrient enrichment in Montana streams often results in large crops of filamentous algae (Watson 1988). Sensitive taxa exhibit intolerance to a wide range of stressors (e.g. Wisseman 1996, Hellawell 1986, Friedrich 1990, Barbour et al. 1999), including nutrient enrichment, acidification, thermal stress, sediment deposition, habitat disruption, and others. These taxa are expected to be present in predictable numbers in functioning montane and foothills streams (e.g. Bollman 1998).

Among the diatoms, tolerance to nutrients has been established for many taxa (e.g. Van Dam et al. 1994, Fairchild et al. 1985, Carrick et al. 1988, Teply and Bahls 2007). Diatom taxa with specific tolerances to saprobity, (e.g. Van Dam et al. 1994) organic pollution (e.g. Lange-Bertalot 1979), salinity (e.g. Van Dam et al. 1994), conductivity and ionic composition (Potapova and Charles 2003), and adaptations to sediment (e.g. Lowe 1974, Lowe 2003) and general habitat disturbance (e.g. Lange-Bertalot 1996) have been identified.

Thermal characteristics of the sampled site are predicted by the richness and abundance of cold stenotherm taxa (Clark 1997), and by calculation of the temperature preference of the macroinvertebrate assemblage (Brandt 2001). Hemoglobin-bearing taxa are also indicators of warm water temperatures (Walshe 1947), since dissolved oxygen is directly associated with water temperature; oxygen concentrations can also vary with the degree of nutrient enrichment. Increased temperatures and high nutrient concentrations can, alone or in concert, create conditions favorable to hypoxic sediments, habitats preferred by hemoglobin-bearers.

Thermal preference among diatoms has been described for many taxa (e.g. Kociolek and Spaulding 2003) although many taxa appear to have broad temperature tolerances. In this approach, only a few taxa were used to estimate thermal conditions. These estimates were limited to foothills and montane regions.

Metals sensitivity for some groups, especially the heptageniid mayflies, is well-known (e.g. Clements 1999, Clements 2004). In the present approach, the absence of these groups in environs where they are typically expected to occur is considered a signal of possible metals contamination, but only when combined with a measure of overall assemblage tolerance of metals. The Metals Tolerance Index (McGuire 1998) ranks taxa according to their sensitivity to metals. Weighting taxa by their abundance in a sample, assemblage tolerance is estimated by averaging the tolerance of all sampled individuals. Since metals contamination is not expected in plains regions due to the dearth of metals mining, evaluation for this stressor is not addressed there.

Indications of metal contamination can also be discerned in diatom assemblages. Species that increase in abundance with contamination are listed in Teply and Bahls 2007 (see also Stoermer and Smol 1999).

The condition of instream and streamside habitats is also estimated by characteristics of the macroinvertebrate assemblages. Stress from sediment is evaluated by caddisfly richness and by "clinger" richness (Kleindl 1996, Bollman 1998, Karr and Chu 1999) A newer tool, the Fine Sediment Biotic Index (FSBI) (Relyea et al. 2000) shows promise when applied to the montane and foothills regions, but its use is limited in plains regions, where taxa characteristic of these sites have not been studied for sediment tolerance.

Sediment tolerance among the diatoms has been established (Lowe 1974) and is demonstrated for motile varieties, which can alter their position in response to alteration of substrates by sediment deposition. Groups of diatoms known to increase with sediment (Teply and Bahls 2007) serve as indicators of probable stress.

The functional characteristics of macroinvertebrate assemblages are based on the morphology and behaviors associated with feeding, and are interpreted in terms of the River Continuum Concept (Vannote et al. 1980) in the narratives. Alterations from predicted patterns in montane and foothills streams may be interpreted as evidence of water quality or habitat disruption. For example, shredders and the microbes they depend on are sensitive to modifications of the riparian zone (Plafkin et al. 1989). Characteristic plains streams, however, are not functionally organized in the same predictable pattern as montane systems (Stagliano and Whiles 2002). Instead, turbidity and the seasonal persistence of flow account for the variability of functional characteristics in plains streams (Dodds et al. 2004).

Site-by-Site Analysis

Northern Rockies ecoregion (15) – 4 sites

South Fork Little Joe Creek

Metric indicators of water quality indicate that cold clean water characterized this site. Taxa temperature preference index suggests that water temperature was around 11.4°C, near the median for sites in the Northern Rockies. At least 16 sensitive cold stenotherm taxa were supported at this site; these include the mayfly *Epeorus grandis* and the stonefly *Yoraperla* sp. Although oligochaetes were abundant, accounting for 16% of sampled animals, coarse taxonomic resolution prohibits any conclusions about them. They may be representatives of the family Enchytraeidae, which are common in montane streams and are relatively sensitive. Their abundance in the sample results in an HBI value (2.81) conservatively high, since oligochaetes are assigned a high tolerance value by MDEQ. The turbellarian *Polycelis* sp. was a common find in these samples, suggesting that groundwater augmented surface flows in the reach. Both caddisflies and "clinger" taxa were abundant at this site, suggesting that sediment deposition did not influence the biota significantly. The FSBI score of 5.5 is well above the median value for Northern Rockies sites. High overall taxa richness (64) suggests complex instream habitats. Dewatering, thermal extremes, scouring sediment pulses or other catastrophes seem unlikely, since 5 less-motile semivoltine taxa were collected. All expected functional components were present; gatherers were the most abundant group.

The diatom assemblage was dominated by *Achnanthidium minutissimum*, which accounted for 62% of sampled organisms. This small, non-motile diatom prefers fast currents, cool temperatures, well-oxygenated water, and low nutrient concentrations. Natural stress from scouring flow conditions may be indicated by its abundance. There was no evidence of increasing abundance among taxa that typically respond positively to nutrient enrichment. Impairment by sediments or metals is not indicated by the flora.

Tributary to Mount Creek

Nine mayfly taxa were collected at this site, and the HBI value (3.91) was only slightly higher than the median value calculated for Northern Rockies streams. Other indicators of water quality suggest that the thermal regime was cold; mean temperature preference was 11.9°C. Eight sensitive cold stenotherm taxa were collected, including large numbers of the mayfly *Cinygma* sp. as well as *Baetis bicaudatus*. It seems likely that water quality was good in this reach, and thermal conditions were apparently typical of a montane stream. Groundwater inputs are suggested by the common occurrence of *Polycelis* sp. in the samples. The FSBI score (2.85) was lower than the mean value for Northern Rockies sites in this study, but there were other indications that sediment deposition may have been influential here. Although caddisfly richness (9 taxa) was not severely depressed, caddisfly abundance was very low; only 25 individuals were counted in the samples. In addition, "clinger" taxa richness was low. It seems likely that access to stony substrate habitats was limited. Taxa richness was quite high, suggesting that deposited sediments and aquatic plants may have added to habitat complexity. Midges and non-insects, especially ostracods and fingernail clams (Corbiculacea: Sphaeriidae), dominated the taxonomic composition of the samples; the midge fauna was especially diverse, with 19 unique taxa represented. Abundant ostracods suggest a well-oxygenated water-sediment surface interface, and large numbers of fingernail clams may indicate abundant soft sediments, since these animals typically burrow and filter bacteria. Year-round surface flow and the absence of recent catastrophic scouring sediment flows are suggested by the presence of 5 semivoltine taxa. Although all expected functional groups were represented, shredders were notably uncommon for this type of system. Gatherers dominated the mix, and filter-feeders (especially the fingernail clams) were somewhat more abundant than expected.

No single diatom taxon dominated the assemblage collected at this site. Instead, this community was balanced among many taxa. There is no evidence that nutrients, sediment, or metals influenced the composition of the periphyton assemblage at this site.

West Fork Lolo Creek

The low HBI value (2.04) and high mayfly taxa richness were 2 metric indications of good water quality in this reach. At least 16 sensitive cold stenotherm taxa were collected in samples taken here, and the temperature preference index predicts a temperature of about 11.7°C for the site. Taxa taken here that indicate good water quality and cold thermal regimes include *Baetis bicaudatus*, *Yoraperla* sp., *Neothremma* sp., and *Caudatella edmundsi*. Stony substrate habitats were probably clean of deposited sediment, since 14 caddisfly taxa and 31 "clinger" taxa were counted in samples. The FSBI score (5.11) was among the higher values in this study. Taxa richness was very high; instream habitats were probably complex and undisturbed. Eight semivoltine taxa were counted in samples; the presence of long-lived animals indicates that no recent dewatering, scour, or toxic inputs influenced the biota here. Although all expected functional groups were represented, shredders were not abundant. Gatherers dominated the functional groups, but scrapers, especially the mayfly *Cinygmula* sp., were also very abundant. These findings suggest that riparian canopy cover may have been limited in this reach, diminishing the food source for shredders, but allowing algal films to flourish.

No pollution-increasers were prominent in the diatom community collected here. It seems likely that neither sediment, nutrients, nor metals stressed the periphyton assemblage. *Planothidium lanceolatum* was the most common diatom counted in the assemblage.

Clark Fork River

Seven mayfly taxa were collected at this site; this number is within expectations for a large riverine system. The HBI value (5.72) may be somewhat higher than expected, but the value may have been influenced by the abundance of corixids, which account for more than 10% of sampled animals, and which are collectively assigned a high tolerance value by MDEQ. In this instance, it seems likely that the sampling effort included a lentic area, perhaps a backwater, since this is the type of environment preferred by corixids. The presence of filamentous algae is suggested by abundant midges in the genus *Cricotopus* spp. and in the *Orthocladius* complex, which account for 24% of the sample. Moderate to large crops of filamentous algae may be associated with nutrient enrichment. Four hemoglobin-bearing taxa were among the collected specimens, accounting for 5% of sampled animals. Tolerant of low dissolved oxygen, these animals suggest that areas of hypoxic sediment may have been present in the sampled reach. It seems likely that mild-to-moderate nutrient enrichment influenced the biota here. The dominant taxon, the mayfly *Tricorythodes* sp., suggests a warm thermal regime in the reach; the temperature preference index indicates an assemblage adapted to about 17.5°C, which seems to be reasonable for the lower Clark Fork basin in early August. Fifteen "clinger" taxa and 5 caddisfly taxa were counted, and the FSBI value (3.79) seemed appropriate for a riverine environment. Sediment deposition probably did not appreciably limit access to stony substrate habitats. Overall taxa richness (48) was within expectations for a large river. Gatherers dominated the functional mix, which included all expected groups in proportions that seemed appropriate for this system.

The diatom assemblage sampled here included a significant proportion of metals-tolerant taxa, such as *Diatoma vulgaris* and *Encyonema minutum*. Contamination by metals cannot be ruled out here. Taxa that increase in abundance with sediment also exhibited a greater proportional presence, but did not produce a significant signal. There was no evidence that nutrient enrichment stressed the periphyton assemblage at this site.

Idaho Batholith ecoregion (16) – 1 site

Pintler Creek

Samples collected from this site yielded 11 mayfly taxa, suggesting good water quality. However, the HBI value (3.65) was elevated compared to expectations for this site. Large numbers of midges were collected, especially *Eukiefferiella* spp., *Tvetenia* spp., and *Micropsectra* spp.; because of their ubiquity, high tolerance values are assigned to these taxa. Their abundance accounts for the higher HBI value, and may be attributable to seasonal succession; the site was sampled in mid-September. The 14 sensitive cold stenotherm taxa present in the samples are stronger evidence for good water quality and a thermal regime appropriate to a montane stream. Among these taxa were the stoneflies *Doroneuria* sp. and *Yoraperla* sp., and the caddisfly *Neothremma* sp. The assemblage is adapted to a temperature of 11.7°C. Sixteen caddisfly taxa and 24 "clinger" taxa were counted, suggesting stony substrates uncontaminated by deposited sediment. The FSBI value (4.57) was slightly higher than the median value for Northern Rockies sites, but lower than that of the Canadian Rockies sites in this study. Complex and undisrupted instream habitats are suggested by the high taxa richness (77). At least 6 semivoltine taxa were supported at the site, indicating year-round surface flow. All expected functional components were present; gatherers dominated the functional mix.

No evidence for water quality degradation was apparent in the composition of the diatom assemblage collected here. Sandy substrates are suggested by the abundance of the psammophilic taxon *Karayevia suchlandtii*, which was the most frequently-encountered diatom in the sample. Sediment influence was not apparent. Taxa responsive to nutrient enrichment were not a significant part of the assemblage.

Middle Rockies ecoregions (17) – 32 sites

Belt Creek

Mayfly taxa richness (6) at this site was somewhat lower than the median count for Middle Rockies sites in this study, suggesting a diminishment of water quality. The HBI value (3.79) was slightly lower than the median value for similar streams. Six sensitive cold stenotherm taxa were supported here. These sensitive taxa included *Caudatella hystrix* and the perlid *Doroneuria* sp. Thermal conditions, as indicated by the thermal preference index, appeared to be within expectations for a Middle Rockies site; the assemblage was adapted to temperatures around 12.6°C, which was near the median temperature preference for sites in this ecoregion. The dominant taxon was the midge *Cricotopus nostocicola*, which is associated with the blue-green alga *Nostoc* sp. Stress from sediment deposition was not apparent. Thirteen caddisfly taxa and 23 "clinger" taxa were collected, and the FSBI value (5.43) suggests that the assemblage exhibits somewhat more sensitivity to sediment than most Middle Rockies sites. Taxa richness was somewhat lower than expected (58) and overall abundance of invertebrates was relatively low; instream habitats may have been monotonous. Abundant *Nostoc* sp. colonies may have limited habitats in this reach. Semivoltine taxa were well-represented. These long-lived animals indicate that dewatering or toxic pollutants did not recently influence the biota in the reach. All expected functional groups were present in the samples. Scrapers were less prominent in the mix than expected, suggesting limited algal growth. There may have been substantial riparian shading; high stonefly taxa richness may be associated with intact riparian function. The relatively high proportion of filterers may be entirely appropriate for a third order stream.

Metals contamination may have stressed the periphyton assemblage at this site. There was an increased incidence of metals-tolerant taxa, including *Encyonema minutum*, *Nitzschia fonticola*, *Rhoicosphenia abbreviata*, and *Staurosira construens*. Sediment impairment was not evident, nor was nutrient enrichment.

Dutchman Creek

Metric indicators of water quality suggest that conditions at this site were good, although the thermal regime may have been somewhat warmer than expected. Mayfly taxa richness (9) and the HBI value (3.82) were within expected limits, and 3 pollution-sensitive taxa were collected, although none was abundant. The assemblage mean temperature preference was 14.1°C, higher than the median for Middle Rockies sites in this study. Caddisfly taxa richness (14) and "clinger" richness (26) were both high, and the FSBI value (3.45) was relatively low, suggesting that the invertebrate community was sensitive to sediment deposition. High taxa richness may be related to complex instream habitats. Recent dewatering, scouring sediment pulses, and other catastrophes can probably be ruled out, since long-lived taxa were well-represented in the samples. The invertebrate assemblage appeared to be functionally intact, since all expected groups were present in appropriate proportions. The abundance of shredders, especially the caddisfly *Lepidostoma* sp., suggests ample riparian input of large organic material and hydrologic conditions that permit its retention.

Evidence from the periphyton assemblage indicated that this site was not impaired by sediments, nutrients, or metals contamination. The cosmopolitan *Cocconeis placentula* var. *lineata* was the most commonly counted diatom, but *Planothidium lanceolatum* was also very abundant.

Sixmile Creek

High mayfly taxa richness (16) and an acceptable HBI value (3.43) suggest good water quality at this site. Temperature preference for the invertebrate assemblage is calculated as 11.5°C. The reach supports at least 9 sensitive cold stenotherm taxa, including *Baetis bicaudatus*, *Krenosmittia* sp., and *Dolophilodes* sp. Oligochaetes were numerous, but coarse taxonomic resolution weakens their significance in this interpretation; if these were enchytraeid worms, the HBI value would be lower. The assemblage was sensitive to sediment stress, producing an FSBI value of 5.57, higher than the median value for Middle Rockies streams in this study. Ten caddisfly taxa and 27 "clinger" taxa were collected, strengthening the hypothesis that sediment deposition did not influence the biota in this reach. The presence of the hyporheic stonefly *Paraperla* sp. also suggests stony substrates uncontaminated by sediment. Instream habitats were probably diverse and undisrupted, since the site supported 68 taxa. Ample representation of semivoltine taxa suggests that surface flow persisted year-round in the reach. Among the functional components, shredders were notably scarce. This suggests a dearth of riparian inputs of large organic material, or hydrologic conditions that did not favor its retention. All other expected groups were present.

Low diversity and the dominance of *Achnanthidium minutissimum*, which accounted for 40% of the diatoms in the sample, suggest that the periphyton assemblage at this site was naturally limited by fast flows, cold water, and very low nutrient concentrations. Sediment or metals contamination were not likely stressors here.

Little Sleeping Child Creek

Mayfly taxa richness (9) was lower than the median richness for third order sites in the Middle Rockies, but the HBI value (3.40) was within expected limits. The site supported at least 9 sensitive cold stenotherm taxa, including the stoneflies *Yoraperla* sp. and *Megarcys* sp. It seems likely that water quality was good in this reach. Temperature preference of the sampled assemblage was 12.6°C, indicating an appropriate thermal regime. Sediment deposition does not seem to have been influential here, since 10 caddisfly taxa and 20 "clinger" taxa were counted in the samples. The FSBI value (4.80) was somewhat higher than the median value for Middle Rockies sites in this study, suggesting a moderately sediment-sensitive assemblage. Riffle beetles and midges dominated the taxonomic composition of the samples; other insect groups, especially caddisflies, were not as abundantly represented as expected. Seasonal succession may influence these taxonomic components, since the samples were collected in mid-September. Overall taxa richness (63) seems appropriate for a second order stream; instream habitats were probably intact and diverse. Year-round surface flow and absence of catastrophic scouring events is indicated by the presence of 8 semivoltine taxa. All expected functional components were present; gatherers, especially the gregarious riffle beetle *Heterlimnius* sp., dominated the mix.

The abundance of the diatom *Navicula inconspicua* suggests that sediment may impair this reach of Little Sleeping Child Creek. No evidence for metals contamination was evident. Signals for nutrient enrichment were not significant.

Muddy Creek

Samples collected in Muddy Creek yielded fewer mayfly taxa (7) than expected, but the HBI value (2.86) indicated a sensitive assemblage, appropriate for a first order montane stream. Although 4 sensitive cold stenotherm taxa were collected, only 2 of these (*Doroneuria* sp. and *Anagapetus* sp.) were represented by more than a single individual. Physid snails (*Physa* sp.) were not uncommon, suggesting warmer thermal conditions than typical of a first order montane stream. Temperature preference for the assemblage was calculated at 13.0°C, somewhat higher than the median value for all orders of Middle Rockies streams in this study. Large numbers of the turbellarian *Polycelis coronata* suggest that ground water augments surface flow in this reach. Caddisflies were represented by 10 taxa, but the number of “clinger” taxa (17) was low. The FSBI value (4.13) suggests that the assemblage was moderately tolerant of fine sediments, compared to the median value for this index in first order Middle Rockies streams. Overall taxa richness was high, indicating that instream habitat diversity persisted. Surface flow apparently persisted year-round in this reach, since long-lived taxa were abundant here. The functional composition of the invertebrate assemblage was dominated by gatherers and shredders. The large proportion of shredders in this assemblage is notable; the group was dominated by the nemourid *Zapada cinctipes*. Dominance by this stonefly suggests that substrates may have been covered by large-sized organic material from the riparian zone.

The increased incidence of sediment-tolerant and nutrient-tolerant diatoms in the sample suggests that this site is impaired. Sediment impairment is implied by the abundance of *Gomphonema olivaceum*, and nutrient impairment is suggested by the abundance of *Gomphonema angustum*. *Rhoicosphenia abbreviata*, which accounted for 13% of diatoms, is associated with both sediment and nutrient impairment.

Keep Cool Creek

Although mayfly taxa richness (13) was high at this site, the HBI value (4.13) suggests that water quality may have been degraded here. More than half (52%) of the animals taken in the samples were midges; these included several genera that may have higher assigned tolerance values than they deserve. The site supported 5 sensitive cold stenotherm taxa, including *Baetis bicaudatus* and *Parapsyche elsis*; these were the only sensitive taxa with more than a single representative. Calculated thermal preference for the assemblage is 12.5°C. Although thermal conditions appear to be appropriate for a third order stream, the possibility of mild nutrient enrichment cannot be ruled out here. The presence of 11 caddisfly taxa and 25 “clinger” taxa strongly suggest that sediment deposition was not influential to the biota in this reach. The FSBI value (5.00) indicates an assemblage that is sensitive to sediment stress. Instream habitats were probably intact. Semivoltine taxa were well-represented, indicating that catastrophic events that would interrupt long life cycles were not influential. Gatherers, especially among the midges, *Heterlimnius* sp., and *Baetis tricaudatus*, overwhelmed the functional composition of the assemblage. This pattern is sometimes interpreted as evidence for degraded water quality. The proportional contribution of other functional groups was low.

The diatom assemblage indicated that there was a high probability of sediment impairment at this site. The dominant taxon, *Navicula reichardtiana*, accounted for 25% of the diatoms in this sample. This taxon is known to increase in abundance as sediment stress increases. Nutrient or metals impairment were not apparent.

Jack Creek

High mayfly taxa richness (16) suggests good water quality at this site; however, the high HBI value (5.77) implies a tolerant assemblage. Large numbers of oligochaetes were collected here, accounting for 29% of sampled animals. Coarse taxonomic resolution for these worm specimens prohibits interpretation of these results, since some oligochaete families are less tolerant of disturbance and pollution than others. However, as a group, oligochaetes are assigned a very high tolerance value. The HBI value may be skewed high because of this. Six sensitive cold stenotherm taxa were present in samples, including the dipteran *Deuterophlebia* sp. and the midge *Krenosmittia* sp.; notably, none of these taxa were abundant. Temperature preference for the assemblage was calculated at 12.7°C. The dominant taxa at this site were ubiquitous types such as *Baetis tricaudatus*, and *Optioservus* sp.; these are typical taxa in third order streams of the Middle Rockies. Water quality was probably not impaired in this reach. Both "clingers" (25 taxa) and caddisflies (11 taxa) were well-represented in samples, strongly suggesting that fine sediment deposition was not influential. The FSBI value (4.61) was below the median for similar streams, and suggests that the assemblage was moderately sensitive to fine sediment. High overall taxa richness (63) may be associated with undisrupted instream habitats. Year-round surface flow is probably indicated by the presence of 7 semivoltine taxa. Gatherers overwhelmed the functional composition of these samples; this pattern is sometimes interpreted as evidence for water quality degradation. Shredders were scarce, suggesting minimal riparian inputs of large organic material or hydrologic conditions that did not favor the retention of such material.

Among the most abundant diatom taxa collected at this site were several sediment-tolerant types, such as *Gomphonema olivaceum* and *Amphora pediculus*. There is a high likelihood that this site was impaired by sediments. Neither nutrient nor metals stress was evident.

Spring Park Creek

The dominant taxon collected at this site was the midge *Hydrobaenus* sp., which is assigned a high tolerance value by MDEQ. Many taxonomic sources, however, indicate that most species in this midge genus prefer oligotrophic conditions; thus, it appears that the high HBI value (4.15) may have underestimated the sensitivity of this assemblage. Sensitive cold stenotherms such as *Yoraperla* sp. and *Zapada columbiana* were abundant, and in all, 11 such taxa were represented in these samples. Thermal preference for the assemblage was calculated at 11.2°C. It seems likely that cold water and unpolluted conditions characterized the environment here. The presence of the uncommon caddisfly taxon *Desmona* sp. suggests that spring seeps were prominent hydrologic features of this reach. The turbellarian *Polycelis* sp. was also common here. Both caddisfly taxa richness (9) and "clinger" richness (16) were near the median values for Middle Rockies sites in this study. The FBSI value (4.70) suggests that the assemblage was moderately sensitive to sediment deposition. It seems unlikely that sediment deposition influenced this assemblage. Taxa richness (62) was moderately high, suggesting diverse instream habitats. Semivoltine taxa were well-represented, indicating year-round surface flow. All expected functional components, in apparently appropriate proportions, were represented.

The diatom assemblage may have been influenced by metals pollution. Forty-eight percent of the diatoms collected here were *Staurosirella pinnata*, which is known to increase when metals contamination is present. The periphyton assemblage did not exhibit stress from nutrients or sediment.

Tributary to Loco Creek

Mayfly taxa richness (10) and the HBI (2.93) suggest that water quality was good at this site. At least 11 sensitive cold stenotherm taxa were supported here, including the stoneflies *Yoraperla* sp. and *Visoka cataractae*, and the mayfly *Baetis bicaudatus*, all of which were abundant. The invertebrate assemblage exhibited a thermal preference of 10.5°C, below the mean for first order streams in the Middle Rockies ecoregion. Cold, clean water apparently characterized the site. "Clinger" richness and caddisfly richness were high, suggesting clean stony substrates; the fauna was probably not influenced by fine sediment deposition. The FSBI value (4.90) indicated that the assemblage was moderately intolerant of sediment deposition. Taxa richness (60) was high; this metric may be associated with the diversity of instream habitats. Year-round surface flow and stable instream conditions were indicated by the presence of 3 semivoltine taxa. All expected functional components were amply represented in the samples collected here.

Achnanthidium minutissimum accounted for 52% of the diatoms collected at this site, suggesting that natural stress from cold water, scouring flows, and oligotrophic conditions may have characterized this site. Diatom diversity was low here, probably due to the unfavorable natural conditions. The assemblage did not exhibit changes due to metals contamination or sediment.

Ruby Creek

Samples collected at this site were dominated by the filter-feeding midge *Tanytarsus* sp. This animal is often associated with filamentous algae, and at this site, it was accompanied by the hydroptilid caddisflies *Hydroptila* sp. and *Oxyethira* sp., which are also associated with filamentous algae. A single mayfly taxon (*Ephemerella infrequens/inermis*) was collected, and the HBI value (5.97) was much higher than the median value for third order streams in the Middle Rockies. The thermal preference calculated for this assemblage was 17.2°C, which is much higher than the median value for third order streams in this ecoregion. At least 7 hemoglobin-bearing taxa were present at the site, suggesting hypoxic substrates. No cold stenotherm taxa were collected. These findings suggest that water quality may have been degraded by nutrient pollution and warmer water temperatures. Caddisfly richness was low, and "clinger" taxa were underrepresented. Sediment deposition may have influenced the benthic fauna at this site, limiting access to stony substrate habitats. The FSBI value (4.30) indicated an assemblage tolerant of sediment. Very low total taxa richness (33) suggests monotonous or disturbed instream habitats. Only one less-motile semivoltine taxon was collected; this site may experience periodic thermal extremes, dewatering, or other stresses that may interrupt long life cycles. The functional composition of the invertebrate assemblage was skewed toward filter-feeders, *Tanytarsus* sp. being prominent among this group. Fine suspended particulates may be in excessive supply. Scrapers were notably scarce here.

Nitzschia fonticola, Staurosira construens, Staurosirella pinnata, and *Pseudostaurosira brevistriata* dominated the taxonomic composition of the diatom assemblage collected at this site. The abundance of these taxa makes it seem likely that this site on Ruby Creek was impaired by metals and sediment. Together this quartet of diatoms accounted for 44% of the organisms in the sample.

Buck Creek

Metric indicators of water quality gave unequivocally good results for this site. High mayfly taxa richness (12) and low HBI value (3.01) suggest excellent water quality here. At least 13 sensitive cold stenotherm taxa were supported here; these included the mayfly *Epeorus grandis* and caddisflies in the Rhyacophila Hyalinata and Rhyacophila Vofixa Groups. Thermal preference calculated for the invertebrate assemblage was 11.1°C; this value is lower than the median value for third order streams in the Middle Rockies. It seems likely that cold, clean water characterized the site. Fourteen caddisfly taxa and 27 "clinger" taxa were counted in the samples, suggesting that stony substrate habitats were not affected by fine sediment deposition. The FSBI value was 5.75, indicating an assemblage intolerant of sediment. Overall taxa richness was very high. Instream habitats were probably complex and intact. Semivoltine taxa were poorly represented; only a few individuals in 2 taxa were collected. However, the diversity and functionality of the invertebrate assemblage suggests that surface flow was probably not periodically interrupted, and thermal or toxic stresses were probably not influential. Functional components included all expected groups, and each was represented in expected proportions.

Evidence of stress from nutrient enrichment and sediments was apparent in the diatom assemblage sampled at this site. *Cocconeis placentula* was abundant, suggesting nutrient stress, and *Navicula reichardtiana* was common, suggesting sediment impairment. Metals contamination was not indicated by the periphyton flora.

Blackfoot River

Mayfly taxa richness (11) was only slightly below the median value for high-order riverine sites in the Middle Rockies. The HBI value (4.23) indicated a moderately sensitive assemblage. Water quality was probably good in this reach. There were no cold stenotherm taxa in the collection, and the thermal preference for the sampled animals was 15.4°C, which is somewhat cooler than the median value for similar systems. The invertebrate fauna was made up of taxa typical for a riverine environment; commonly-collected animals included the caddisfly *Brachycentrus occidentalis*, the ubiquitous mayfly *Baetis tricaudatus*, and the midge *Cladotanytarsus* sp. Ephemerellid mayflies (*Serratella tibialis* and *Ephemerella inermis/infrequens*) were also frequently encountered. Both "clingers" and caddisflies were well-represented, suggesting that fine sediment deposition did not stress the assemblage. The FSBI calculated for the sample was 4.92, indicating moderate sensitivity to sediment. Overall taxa richness (53) fit well with expectations, and indicated diverse instream habitats. At least 7 semivoltine taxa were collected; their long life cycles make them vulnerable to catastrophic events such as toxic pollutants or thermal extremes, both of which seem unlikely. Gatherers and filter-feeders dominate the functional composition of the assemblage. This pattern is probably appropriate for a high-order stream

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Diatom taxa that increase with impairment by metals and/or sediment were among the dominant taxa in the periphyton assemblage here. The metal-tolerant taxon *Staurosirella pinnata* was abundant in this sample, and the sediment-increaser *Gomphonema olivaceum* was common. Contamination by metals and impairment due to sediment cannot be ruled out.

Fred Burr Creek

Cold, clean water was indicated by the invertebrate assemblage at this site. Samples contained 15 mayfly taxa, and the HBI value was 2.72, which is lower than the median value for second order streams in the Middle Rockies ecoregion, indicating a sensitive assemblage. At least 12 sensitive cold stenotherm taxa were supported at this site; these included the nemourid stonefly *Zapada columbiana* and the mayfly *Epeorus grandis*. Thermal preference of the assemblage was calculated at 11.6°C, which is lower than the median thermal preference for assemblages in second order streams in this ecoregion. Fine sediment deposition apparently did not influence the biota. Both "clingers" and caddisflies were well-represented, and the FSBI value of 4.45 suggests moderate sensitivity to sediment. Overall taxa richness was very high, indicating ample undisrupted instream habitats. Six semivoltine taxa were counted, making it seem very unlikely that the site was periodically dewatered or suffered scouring sediment pulses. The functional composition of the assemblage closely resembled expected conditions for a second order montane stream.

The periphyton assemblage did not exhibit evidence of impairment at this site. The dominant taxon, *Achnanthidium minutissimum*, accounted for 62% of the diatoms in the sample, and suggested that cold, oligotrophic conditions characterized the site.

Little Boulder River

Metric indicators of water quality calculated for the assemblage sampled at this site hovered around the median values for third order streams in the Middle Rockies ecoregion. Mayfly taxa richness (12) was slightly lower, and the HBI value (3.91) slightly higher than median values. However, both metric values were within expectations for a montane stream in good condition. Thermal preference of the community was 13.0°C, which is slightly warmer than the median condition. Although none were represented by more than a few individuals, 5 cold stenotherm taxa were present in the samples. These included the mayfly *Caudatella* sp. and the stonefly *Doroneuria* sp. The elmid beetle *Cleptelmis addenda* accounted for 22% of the animals present in the samples; the abundance of this gregarious taxon may have influenced metric values. Gregarious taxa are more likely than other taxa to occur in high numbers in samples, so that their abundance in the stream environment may be overrepresented. Metric indications of sediment deposition gave equivocal results for these samples. Values for both caddisfly and "clinger" richness metrics were near the median; these were high enough to suggest that sediment deposition did not limit access to stony substrates. The FSBI value (3.54), however, indicated that the assemblage was very tolerant to sediment compared to expectations for lower order streams in the Middle Rockies. Once again, the common occurrence of *Cleptelmis addenda*, considered tolerant to fine sediment in the FSBI model, may have influenced the outcome of the metric. While the taxonomic components of the benthic assemblage suggest that sediment deposition was not influential here, it cannot be entirely ruled out. Taxa richness was slightly lower than expected, which could indicate disrupted instream habitats, and once again suggests that sediment deposition may have been present. Semivoltine taxa were well-represented, indicating persistent surface flow and the absence of thermal extremes or toxic pollutants. The functional composition of the invertebrate assemblage included all expected groups in appropriate balance.

Sandy substrates are suggested by the dominance of *Karayevia suchlandtii*, which was the most frequently-encountered diatom in the sample collected here. There was no evidence that the site was stressed by sediments, nutrients, or metals pollution.

McCormick Creek

Fingernail clams (Sphaeriidae), black fly larvae, and worms dominated the sampled assemblage at this site. Mayflies in only 4 taxa were represented, and none of these was abundant. The HBI value (6.80) was the highest calculated among all of the Middle Rockies streams in this study, and indicated a very tolerant assemblage. No cold stenotherms were present in the samples. Thermal preference of the invertebrate assemblage was calculated at 16.2°C, the highest value for any second order stream in the Middle Rockies region. Consistent with warm water temperatures and nutrient enrichment, the presence of 5 hemoglobin-bearing taxa suggests that sediments were hypoxic here. Not a single stonefly was taken in the samples. Fine sediments appear to have contributed additional stress to the invertebrate assemblage. The caddisfly fauna was neither rich nor abundant, and "clinger" richness was low. The FSBI value of 2.48 indicates an assemblage that was very tolerant of sediment deposition. Overall taxa richness was depressed (52), suggesting monotonous instream habitats. The presence of 4 less-motile semivoltine taxa indicates that surface flow persisted year-round here. The functional composition of the sampled assemblage was overwhelmed by gatherers and filter-feeders. This pattern is not expected in a third-order montane stream and is consistent with nutrient enrichment.

The common occurrence of *Staurosirella pinnata* in the periphyton sample collected here increased the probability that this site was contaminated by metals pollution. No other stressor was apparent, considering the evidence of the diatom assemblage.

Fish Creek

High mayfly taxa richness (14) and low HBI (2.66) suggests that water quality was good at this site. A more accurate value of the HBI may be even lower, since coarse taxonomic levels for oligochaetes may overestimate the tolerance of this group. At least 10 sensitive cold stenotherm taxa were supported here, including *Baetis bicaudatus* and stoneflies in the family

Leuctridae. The assemblage exhibited a thermal preference of 11.07°C, which is colder than the median value for third order streams in the Middle Rockies ecoregion. It seems likely that cold, clean water characterized this site. It seems very unlikely that sediment deposition influenced this assemblage, since both caddisflies and "clingers" were diverse. The FSBI value was calculated as 5.64, which was higher than the median value for third order streams in the Middle Rockies. This indicates an assemblage moderately sensitive to sediment. Overall taxa richness was slightly lower than expected; instream habitats may have been limited. Semivoltine taxa were only adequately represented; nevertheless, the composition of the assemblage suggested that periodic dewatering or thermal extremes were unlikely. Gatherers overwhelmed the functional components, but mayflies in the genus *Epeorus* spp., which are described as scrapers in most sources, are classified as gatherers by MDEQ. These taxa accounted for 15% of the animals collected, and grouping them as scrapers would give a more accurate rendering of the functional composition of this assemblage. The abundance of scrapers suggests ample solar input and lack of riparian shading. The scarcity of shredders is notable in this community, further suggesting a lack of riparian canopy. Riparian inputs of organic material may have been lacking, or hydrologic conditions may not have favored retention of such material.

Low diversity and abundant *Achnanthidium minutissimum* suggest that fast flows, oligotrophic conditions, and cold water temperatures provided a natural limitation to diatoms at this site. Anthropogenic stressors such as sediment, nutrients, or metals did not apparently influence the flora here.

Spain Ferris Ditch

Although mayfly taxa richness (11) compared favorably with the median value for first order streams in the Middle Rockies ecoregion, the HBI value (5.63) for the assemblage sampled at this site was high. Samples were overwhelmed by black fly larvae (*Simulium* sp.), the ubiquitous *Baetis tricaudatus*, and worms; this tolerant combination is highly suggestive of nutrient enrichment and warmer water temperatures than expected for a first order montane stream. No cold stenotherm taxa were collected, and the thermal preference of the sampled assemblage was calculated as 15.6°C, nearly 4° warmer than the median value for similar systems. A tolerant lymnaeid snail was one of 2 hemoglobin-bearing animals present at the site. Sediments may have been hypoxic in some areas of the reach. Sediment deposition may have also stressed the benthic assemblage at this site. Caddisflies were represented by 2 taxa, and "clingers" were also scarce. The FSBI value for this assemblage was 3.69, indicating high tolerance to sediment. Overall taxa richness was very low, suggesting monotonous or disturbed instream habitats. A single specimen of the salmonfly *Pteronarcella* sp. was collected, but other than this individual, only less-motile semivoltine taxa were counted in the sample. Periodic dewatering, thermal extremes, or other catastrophes may limit long life cycles at this site. Gatherers and filter-feeders overwhelmed the functional mix; this is a highly unbalanced pattern for a first order, montane stream. No other functional group was well-represented.

Sediment and nutrient stress was apparent from the composition of the diatom assemblage at this site. The dominant taxon, *Cocconeis placentula*, is known to increase in abundance with nutrient enrichment. It accounted for 31% of the diatoms in the sample. Several sediment-tolerant taxa contributed to the increased probability that sediment influenced the flora here

Unknown Creek

Mayfly taxa richness (7) at this site was lower than the median value for second order streams in the Middle Rockies. However, the HBI value was near the median for these systems. At least 13 sensitive cold stenotherm taxa were supported at this site; these included the caddisfly *Neothremma* sp. and the stoneflies *Yoraperla* sp., *Visoka cataractae*, and *Zapada columbiana*. Overall assemblage thermal preference was 10.4ºC; this is lower than the median value for similar streams. It seems likely that cold temperatures and good water quality prevailed here. Slight impairment to habitat quality by sediment deposition cannot be ruled out at this site; "clingers" were not as diverse as expected, although caddisfly richness was only slightly lower than the median value for second order streams in the region. The FSBI value indicated sensitivity to sediment that was on a par with similar systems. Overall taxa richness was lower than expected, suggesting limitations to instream habitats. Midges, especially *Micropsectra* sp., dominated the taxonomic composition of the samples. Semivoltine taxa were represented by abundant *Yoraperla* sp. and *Parapsyche elsis*; it seems unlikely that periodic dewatering or thermal stress influenced this assemblage. Gatherers, especially midges and ostracods, were somewhat more prominent in the functional mix than expected.

The dominant diatom taxon at this site was *Achnanthidium minutissimum*, but *Cocconeis placentula* was also abundant. The probability that this site was impaired by nutrient enrichment was increased by the incidence of *C. placentula*. Low overall diversity characterized this flora. Neither sediments nor metals left a strong signal in the periphyton community at this site.

West Boulder River

This site was the sole representative of fourth order streams in the Middle Rockies ecoregion. Mayfly taxa richness (14) was high in the samples collected here, and the HBI value (4.24) was comparable to the median value for larger order stream systems in the region. Six sensitive cold stenotherm taxa were counted, including *Baetis bicaudatus*, *Drunella doddsii*, and the stonefly *Doroneuria* sp. The assemblage exhibited a thermal preference of 13.3ºC. This was considerably lower than values for higher-order streams in the Middle Rockies. It seems likely that an appropriate thermal regime and unpolluted water characterized this reach. Caddisfly and "clinger" diversity compared favorably with that of large rivers, suggesting that sediment deposition did not appreciably limit access to stony substrate habitats here. The FSBI value (5.15) corroborated this hypothesis; this was among the highest values calculated for Middle Rockies sites, and indicated an assemblage that was very sensitive to sediment deposition. High overall taxa richness indicates complex and intact instream habitats. Midges were the dominant taxonomic group in the samples collected at this site. At least 7 semivoltine taxa were supported here, ruling out the possibility that periodic dewatering or thermal extremes affected the fauna. Gatherers, mainly among the midges, overwhelmed the functional composition of the assemblage. This pattern is not unexpected for a higher order stream system.

Evidence of impairment could not be discerned in the diatom assemblage sampled at this site. The flora was dominated by *Achnanthidium minutissimum*, which suggests that oligotrophic conditions, cold water temperatures, and rapid flow characterized the site.

Basin Creek

Mayfly taxa richness (10) was within expectations at this site, and the HBI value (3.83) was lower than the surprisingly high median value for first order streams in the Middle Rockies ecoregion, suggesting a more sensitive assemblage than was found in most similar systems in the EMAP study. Ostracods were the dominant taxon at this site, and MDEQ assigns this speciose group a high tolerance value. It is likely that various ostracod species exhibit variable tolerance to stressors; generalizations over large taxonomic groups may make biotic index values less accurate than desired. The sampled site on Basin Creek supported at least 11 sensitive cold stenotherm taxa, including *Cinygma* sp., *Zapada frigida*, and *Yoraperla* sp. The presence of the uncommon caddisfly *Desmona* sp. suggests that the sampled area was influenced by springs. The presence of large numbers of the turbellarian *Polycelis* sp. also suggests that groundwater supplemented surface flow in this reach. These findings indicate that water quality was good in this reach, and that cold water temperatures were prevalent. The thermal preference of the assemblage was calculated as 11.02°C, colder than the median value for first order streams in the Middle Rockies. Caddisfly and "clinger" taxa richness were both within expectations; thus, it seems unlikely that sediment deposition limited access to stony substrate habitats. The FSBI value (4.36), however, was somewhat lower than the median value for similar systems. Overall taxa richness was high, indicating diverse and abundant instream habitats. At least 3 semivoltine taxa were present; surface flow apparently persisted year-round here, and scouring sediment pulses probably were not a recent influence. All expected functional components were accounted for, and proportions of each group seem appropriate.

The diatom flora at this site was dominated by *Achnanthidium* spp. (*A. deflexum* and *A. minutissimum*), suggesting well oxygenated and rapidly-flowing water. These taxa are also associated with oligotrophic conditions and cold water temperatures. Evidence for stress from sediment, nutrients, or metals was not apparent.

Big Hole River

This Big Hole River site was sampled twice for the EMAP study: once in July and once in September. In July, mayfly taxa richness (13) was within expected limits, and the HBI value (4.66) was slightly lower than the median value for large-order riverine systems in the Middle Rockies ecoregion. These findings suggest that water quality was good in this reach. It is not surprising that no cold stenotherms were collected; the thermal preference for the sampled assemblage was 17.4ºC which was a full degree higher than the median for similar systems. Four hemoglobin-bearing taxa were counted, accounting for 1.4% of the sampled animals. Hypoxic sediments may have been present in some areas. Good water quality, and a cool-to-warm thermal regime, appropriate for a large river, is indicated by these findings. The warm-water mayfly *Tricorythodes* sp. was dominant in the assemblage. Both "clingers" and caddisflies were represented by an expected number of taxa. The FSBI value (4.55) indicated that the community was moderately sensitive to sediment deposition. It seems likely that sediment did not influence the composition of the fauna. Overall taxa richness was somewhat blunted compared to other large rivers in the region; instream habitats may have been monotonous. Semivoltine taxa were well-represented, suggesting that surface flow persisted year-round in this reach, and that thermal extremes did not interrupt long life cycles. The dominance of gatherers and filter-feeders and the presence of other expected functional groups appeared to be appropriate for a riverine environment.

In September, expected seasonal shifts in the taxonomic composition of the benthic assemblage can be discerned. Although *Tricorythodes* sp. continued to dominate the animals collected here, midges became proportionally more abundant than they had been in the earlier month, accounting for 44% of the sampled animals. In addition, hemoglobin-bearers were more abundant in September, now accounting for 7.4% of the collected organisms. These shifts are consistent with the warming water temperatures and diminished flow typically developing late in the summer in Montana's rivers. Thermal preference (17.7ºC) of the assemblage was remarkably similar to the July value. Mayflies remained abundant and relatively diverse, although taxa richness had fallen to 8. The HBI value (5.93) was higher than the median value for large rivers in the Middle Rockies. This appears to be attributable to the increased abundance of midges, and to the appearance of substantial numbers of oligochaetes in the sample. Metric indicators may exhibit signals of diminished water quality, but apparently this was due to warming temperatures. Taxonomic composition of samples taken in September remains similar to that of July. Sediment deposition seems unlikely, given the moderately rich "clinger" and caddisfly faunae. The FSBI value (4.31) suggests that the assemblage was slightly more tolerant to sediment than it had been in July. Overall taxa richness continued to suggest that instream habitats may have been monotonous. Semivoltine taxa persisted at the site. The functional mix remained characteristic of a system low in the river continuum, with gatherers and filter-feeders dominant.

Impairment by sediment, nutrients, and metals were indicated by the diatom assemblages sampled at this site on the Big Hole River. The dominant taxon for both sampling events was *Epithemia sorex*, which increases in abundance in the presence of various stressors. *E. sorex* accounted for 49% of the diatoms identified in the sample. Indicators of metals contamination, such as *Staurosira construens, Staurosirella pinnata,* and *Nitzschia fonticola* were among the dominant taxa collected here. *Diatoma moniliformis* and *Cocconeis placentula,* which prefer nutrient-enriched environs, were abundant. Sediment indicators included *Navicula capitatoradiata.*

Big Hole River (Upper)

Good water quality is indicated by the very high mayfly taxa richness (16), the low HBI value (3.54) and the presence of at least 5 sensitive taxa at the site. These included the mayflies *Caudatella hystrix* and *Drunella doddsii*, and the caddisfly *Apatania* sp. There were only a few cold stenotherm taxa collected here, and the thermal preference of the assemblage was calculated as 13.5°C, which is somewhat higher than the median value for second order streams in the Middle Rockies ecoregion. Aspect, groundwater influence and natural riparian conditions may influence water temperature; these findings may indicate an appropriate thermal regime for this site. "Clinger" taxa were exceptionally diverse here, and 15 caddisfly taxa were collected. The FSBI value was 4.7, which is near the median value for similar systems. Sediment deposition probably did not influence the fauna in the reach. Overall taxa richness was very high; instream habitats were probably undisrupted and diverse. Surface flow apparently persisted year-round, and other catastrophes such as scouring sediment pulses are unlikely, since many long-lived semivoltine taxa were present. The functional composition of the assemblage included all expected components, and the proportional representation of each was appropriate.

Pseudostaurosira brevistriata was the dominant diatom taxon collected at this site. This diatom increases in abundance in the presence of stress from a wide variety of sources, including metals contamination, sediment, and nutrient pollution. *Staurosirella pinnata* was also notably abundant, suggesting that metals were an influence on the flora here. In addition, large numbers of *Cocconeis placentula* were collected, implying that nutrients were an additional stressor. The probability of sediment impairment was increased by the abundance of *P. brevistriata.*

Jerry Creek

This site was sampled 3 times for the EMAP study: once in July 2002, and in both July and August 2003.

In July 2002, mayfly taxa richness (13) was within expectations for a third order stream in the Middle Rockies, and the HBI value (3.23) indicated a sensitive assemblage. Five sensitive cold stenotherm taxa were collected; although this number was somewhat fewer than expected, some of these taxa, such as *Baetis bicaudatus*, were abundant. The thermal preference exhibited by this assemblage was 11.5°C, somewhat colder than the median value for assemblages in similar systems. Abundant turbellarians (*Polycelis* sp.) suggest the possibility that groundwater influences surface flow in the reach. It seems likely that water quality was good and thermal conditions were appropriate in the reach. Both caddisflies and "clingers" were somewhat less diverse than expected. However, the FSBI value (5.24) indicated a moderately sediment-sensitive assemblage. Overall taxa richness was near the median value for third order Middle Rockies systems. Although there were only 2 semivoltine taxa represented, one of these (*Heterlimnius* sp.) was very abundant, making it seem unlikely that the site was recently dewatered or suffered thermal extremes. Gatherers dominated the functional composition of these samples. This pattern is sometimes interpreted as suggesting water quality degradation, which seems unlikely in this case, given the overall sensitivity of the invertebrate assemblage collected here.

Mayfly taxa richness (17) and the HBI value (3.49) remained consistent between 2002 and 2003. Although the number of sensitive cold stenotherm taxa was higher in the latter year, thermal preference calculated for the assemblage was 11.7°C which was similar to the value calculated for 2002. These findings suggest that water temperatures and water quality remained good. Curiously, the turbellarian *Polycelis* sp., which was abundant in the previous year, did not appear in samples taken in 2003. This animal sometimes clusters around groundwater seeps in streams, and may have been missed in the 2003 sampling. There was a notable shift in the caddisfly fauna between the 2 years. Nine caddisfly taxa were collected in 2002, but at least 13 taxa were present at the site in 2003. "Clinger" richness also increased dramatically in the 2003 samples. These findings suggest that sediment deposition was not influential. The FSBI value remained high in 2003. Mainly due to increased richness among caddisflies and midges, the overall taxa richness was significantly higher in the later year, suggesting that instream habitats were diverse. There was a better representation of semivoltine taxa in 2003; instream conditions were probably stable. The functional mix exhibited a better balance in 2003, with all expected groups in appropriate proportions.

In August 2003, seasonal faunal shifts were apparent, compared to the sampled assemblage in July. Fewer mayfly taxa (11) were collected, and midge diversity increased. The dominant taxon shifted from midges in the Orthocladius species complex to the psychodid fly *Pericoma* sp. This dipteran may be associated with carbonate-rich geology; its sudden appearance in such large numbers may be a seasonal phenomenon. Thermal preference for this assemblage was slightly higher (12.0°C) than the value calculated for July, demonstrating the increase in water temperature which is expected as summer progresses. The number of "clinger" taxa remained near the median value for third order streams in the Middle Rockies, but caddisfly richness was lower than expected; this may be attributable to seasonal emergences. Overall taxa richness (59) was relatively low. Semivoltine taxa persisted at the site, implying year-round surface flow. Gatherers dominated the functional composition of the assemblage, but other evidence for degraded water quality was not apparent.

Elements of the diatom assemblage collected in August 2003 suggested that this site on Jerry Creek was impaired by sediment. *Navicula reichardtiana* and *Synedra ulna* were common in the sample; these taxa are tolerant to sediment and are associated with impaired sites. Neither metals nor nutrients appeared to influence the flora.

McHessor Creek

Low mayfly taxa richness (5) and elevated HBI value (4.56) suggested that water quality was impaired at this site. More disturbingly, the metals tolerance index value (4.88) exceeded the HBI value. No heptageniid mayflies were collected; absence of this group at sites where it is expected may be a bellwether for metals contamination. Thermal preference for the assemblage collected here was 14.6°C, fully 2°C higher than the median value for second order streams in the Middle Rockies ecoregion. The dominant taxa at this site were elmid beetles, especially *Optioservus* sp., which is characteristic of warmer environs than expected in a second order stream. Stoneflies were poorly represented. Both "clingers" and caddisflies exhibited slightly less diversity than typical for similar streams. Mild impairment from sediment deposition cannot be ruled out. The FSBI value (3.55) supports this hypothesis; its value was lower than expected, indicating a sediment-tolerant assemblage. Overall taxa richness (49) was depressed. It seems likely that surface flow was persistent year-round in this reach, since the site supported at least 8 semivoltine taxa. The assemblage was functionally imbalanced, with scrapers (especially *Optioservus* sp.) and gatherers (especially midges) overwhelming the mix.

Achnanthidium minutissimum dominated the diatom assemblage collected at this site, accounting for 31% of the taxa identified here. This suggests that water quality was good, flow rapid, and temperatures cold in the reach. No evidence for nutrient enrichment, sediment impairment, or metals contamination was apparent in the analysis of the diatom flora.

Browns Creek

Non-insect taxa, especially fingernail clams and ostracods, dominated samples collected at this site. Mayfly taxa richness (3) was low, and abundance in this group was also low. The HBI value (6.61) calculated for this assemblage was the highest of any sampled site in the Middle Rockies ecoregion. These findings suggest degraded water quality. The abundance of hydroptilid caddisflies, particularly *Hydroptila* sp., suggests that stands of filamentous algae were common at this site. Large crops of filamentous algae may be associated with nutrient enrichment. No cold stenotherms were collected here, and the calculated thermal preference for the invertebrate community was 15.2°C. This value is 2.5°C higher than the median value for second order streams in the Middle Rockies ecoregion. Three hemoglobin-bearing taxa were supported at this site, suggesting that sediments were hypoxic in some areas of the sampled reach. These findings are consistent with thermal stress and degraded water quality due to nutrient enrichment. Neither caddisflies nor "clingers" were represented by more than a few taxa; fine sediment deposition may have limited access to stony substrate habitats. The FSBI value was 4.20, which is lower than the median value for similar streams. Most of the dominant taxa at this site did not contribute to the FSBI calculation, since sediment tolerance values have not been assigned to them. Low taxa richness (52) may be related to monotonous or disturbed instream habitat conditions. At least 4 semivoltine taxa were present at this site, indicating year-round surface flow. The functional composition of the sampled assemblage was skewed; neither scrapers nor shredders were present in expected numbers, and gatherers and filter-feeders dominated the mix.

Staurosira construens, *Nitzschia fonticola*, and *Staurosirella pinnata* were abundant in the diatom assemblage here. These metals-tolerant taxa suggest that the site was impaired by metal contamination. There was little evidence in the periphyton data for sediment impairment or nutrient enrichment.

Tributary to Peterson Creek

The unusual fauna of this third order stream is overwhelmed by midges, especially 2 taxa: *Micropsectra* sp., which is a diverse genus, and *Pseudosmittia* sp., typically a denizen of rather extreme environments such as wetlands. Some species of *Pseudosmittia* may be associated with manure; this suggests that the sampled site may have been contaminated by cattle dung. The other prominent animals collected here were oligochaetes and nematodes. The typical fauna of low order streams of the Middle Rockies ecoregion, including mayflies, stoneflies, and caddisflies, was absent. Taxa richness (21) was the lowest of any site in the Middle Rockies sampled for this study. Very few obligate rheophiles were present, suggesting that lentic conditions dominated the reach. The calculated estimate of thermal preference for this assemblage was 14.6°C, which is considerably warmer than the median value for third order streams in the Middle Rockies ecoregion. The tolerant midge *Chironomus* sp. was common; when this hemoglobin-bearing taxon is found in montane environments, it usually signals low dissolved oxygen and poor water quality. Severe water quality disturbance or dystrophic conditions are suggested by the fauna at this site. Less-motile semivoltine taxa were not present in the sample; periodic dewatering or thermal extremes may further limit benthic communities here.

There is no evidence in the periphyton data that indicates that nutrients, sediment, or metals influenced the composition of the assemblage at this site.

Jackson Creek

Mayfly taxa richness (12) was high at this site, and the HBI value was lower than the median value for second order streams in the Middle Rockies ecoregion. At least 9 cold stenotherm taxa were supported here, including the mayfly *Drunella grandis* and the stonefly *Doroneuria* sp. Thermal preference for the invertebrate assemblage was calculated as 12.8°C, which is near the median value for second order streams in the region. Similar to some other late-season samples analyzed in this study, a large number of *Pericoma* sp. were collected. Abundance of this psychodid fly may be associated with carbonaceous geology, and calcium-rich waters. One cautionary indicator was notable: the metals tolerance index value (3.72) was slightly higher than the HBI value (3.41). Although this may signal metals contamination, other evidence is hopeful. Heptageniid mayflies (*Cinygmula* sp.), which typically disappear when metals contaminate water quality, were present. They were not abundant, however. Tanytarsine midges, some of which are known to be sensitive to metals, were also present. This group, especially *Micropsectra* sp., was common in the samples collected here. Nonetheless, metals pollution cannot be entirely ruled out. Sediment deposition apparently did not influence the benthic community, since both caddisflies and "clingers" were diverse. The FSBI yielded a value (5.03) which was higher than most second order streams in the region; this indicates a sediment-sensitive assemblage. Instream habitats were probably complex and intact, since taxa richness was within expectations. At least 10 semivoltine taxa were supported here, indicating year-round surface flow and the absence of catastrophes such as scouring sediment pulses. Gatherers, especially *Pericoma* sp., dominated the functional components. This pattern is sometimes interpreted as evidence of water quality impairment. In this case, what may be a seasonal bloom of the psychodid fly makes the functional balance difficult to interpret.

The diatom community was well-balanced among many taxa at this site. *Achnanthidium minutissimum* was the most frequently-encountered taxon in the sample. Nutrients, sediment, or metals do not appear to have limited this assemblage.

Bitterroot River

This site on the Bitterroot River supported more mayfly taxa (17) than any other riverine system sampled for this study. The HBI value (4.82) was slightly higher than the median value for high order streams in the Middle Rockies ecoregion; the score was influenced by the abundant black fly larvae (*Simulium* sp.) present in the sample. Despite these tolerant animals, it seems likely that water quality was good in this reach. At least 4 sensitive taxa were supported here, including the mayflies *Drunella doddsii* and *Drunella grandis*. Thermal conditions were probably appropriate for a riverine system. The thermal preference of the community was calculated at 14.9°C, which is cooler than most Middle Rockies streams in the same size class. The FSBI value (4.27) was relatively high and 11 caddisfly taxa and 30 “clinger” taxa were collected. These findings strongly suggest that stony substrate habitats were not contaminated by fine sediments. Overall taxa richness (74) was very high, indicating complex and intact instream habitats. Semivoltine taxa were common; this reach was not subjected to dewatering and did not suffer thermal extremes recently. The functional composition of the benthic fauna was entirely appropriate for a riverine environment.

The diatom assemblage in this reach exhibited low diversity, and *Achnanthidium minutissimum* dominated the sample, accounting for 55% of the identified taxa. These findings suggest that cold, well-oxygenated water and rapid flow conditions characterized the site. Sediment-tolerant taxa were not abundant, and there was no evidence that metals contamination influenced the flora.

Tributary to Dunkleberg Creek

Mayfly taxa richness (12) was high at this site, but the abundance of mayflies was low. The assemblage was dominated by midges, oligochaetes, and nematodes, which together accounted for 85% of the animals sampled. The HBI value calculated for this assemblage was 5.93, the highest value of any first order stream in the Middle Rockies in this study. This value may have been influenced by the coarse taxonomy for oligochaetes, which include more sensitive families that are typical of first order montane streams. The dominant midge was *Micropsectra* sp., which was very abundant here. This genus is diverse, and some species may be less tolerant than others. In fact, the midge fauna collected at this site included some relatively sensitive taxa, such as *Parochlus* sp., *Pagastia* sp., and *Pseudodiamesa* sp., although none of these were common in the sample. Nevertheless, water quality degradation cannot be ruled out here. The calculated thermal preference for this assemblage was 11.23°C, which is near the median value for first order streams in the Middle Rockies ecoregion. Several cold stenotherm taxa were supported at this site, including *Baetis bicaudatus* and *Yoraperla* sp. Thermal stress seems unlikely. Although caddisfly richness (7) was somewhat lower than expected, “clinger” richness (18) was high compared to similar streams. The FSBI value (4.56) was the same as the median value for first order streams in the region, indicating average tolerance for sediment. Mild stress from sediment deposition cannot be ruled out. Taxa richness was comparable to similar systems, and semivoltine taxa were supported. Instream habitat diversity was probably within expectations, and dewatering apparently did not influence the biota. Consistent with the possibility of water quality degradation, gatherers overwhelmed the functional composition of these samples.

No diatom taxon was obviously dominant at this site. There was no evidence for sediment impairment, nutrient enrichment, or metals contamination in the periphyton data from this site.

Bracket Creek

Both mayfly taxa richness (13) and the HBI value (3.86) were the same as the median values for these metrics for third order streams in the Middle Rockies ecoregion. Importantly, the metals tolerance index value (3.98) was higher than the HBI value. Heptageniid mayflies (e.g. *Epeorus longimanus*) were present in the reach; however, only a few specimens were collected and most of these were immature instars. Tanytarsine midges (especially *Micropsectra* sp. and *Tanytarsus* sp.) were abundant. Some species in these genera may be sensitive to metals, however, the possibility that metals contamination affected water quality here cannot be entirely ruled out. There were fewer sensitive cold stenotherm taxa than expected. Thermal preference for the assemblage was calculated to be 13.9°C, higher than the median value for similar streams. Caddisfly richness and “clinger” richness were high, but the FSBI value (3.67) was lower than expected. Overall taxa richness was within expectations. Semivoltine taxa were well-represented, indicating persistent surface flow. All expected functional groups were present, and proportions of each seemed appropriate for a third order montane system.

The diatom assemblage was neither diverse nor abundant at this site. The composition of the flora signaled nutrient enrichment and sediment impairment. *Cocconeis pediculus* and *Cocconeis placentula* were both abundant; these taxa are tolerant of nutrient pollution. Several sediment-tolerant taxa were counted in the sample. The periphyton community did not appear to be influenced by metals contamination.

Tributary of the North Fork Blackfoot River

Low mayfly richness (7) and relatively high HBI value (4.21) suggest that water quality may have been impaired in this reach. However, the site supported at least 9 sensitive cold stenotherm taxa, including the stoneflies *Yoraperla* sp., *Zapada columbiana*, and *Visoka cataractae*. The HBI value was influenced by the large number of ostracods in the samples; these animals are assigned a high tolerance value by MDEQ, but probably exhibit a wide spectrum of tolerance. It seems likely that water quality was good here, despite low mayfly richness. The presence of the caddisfly *Desmona* sp., which is uncommon in bioassessment collections, suggests that the sampled area was influenced by springs. Thermal conditions appeared to be appropriate; the thermal preference for the assemblage was calculated as 10.8°C, lower than the median value for similar systems. Sediment deposition probably did not limit access to stony substrates, since caddisfly taxa richness (9) and "clinger" richness were both within the range recorded for other first order streams in the Middle Rockies ecoregion. The FSBI value (4.84) indicated a moderately sediment-sensitive community. Overall taxa richness was high, implying diverse instream habitats. Three semivoltine taxa were counted, making it seem likely that the site was not periodically dewatered or subject to scouring sediment pulses. Gatherers dominated the functional mix, but all other expected components were present.

The abundance of *Gomphonema angustatum,* which accounted for 18% of the diatoms identified in the sample collected here strongly signaled nutrient enrichment at this site. Several other enrichment-tolerant taxa were also present. Sediment impairment was not evident, and taxa tolerant to metals were not prominent in the diatom assemblage here.

Unknown Creek

Metric indicators of water quality suggest that cold, clean water characterized this site. Mayfly taxa richness (20) was very high, and the HBI value (3.83) indicated a sensitive assemblage. At least 14 sensitive cold stenotherm taxa were supported in this reach; these included the dipterans *Glutops* sp. and *Rhabdomastix* sp., as well as the stoneflies *Yoraperla* sp. and *Visoka cataractae*. Thermal preference for this assemblage was 10.9°C, which was lower than the median value for second order streams in the Middle Rockies ecoregion. No fewer than 31 "clinger" taxa occurred here, and caddisfly taxa richness (10) was high. The high FSBI value (4.65) indicates moderate sediment-sensitivity for the community. These findings strongly suggest that fine sediment deposition did not appreciably limit access to stony substrate habitats. Overall taxa richness (78) was high; instream habitats were probably diverse and intact. Year-round surface flow and stable instream conditions are implied by the semivoltine taxa collected here. The functional composition of the invertebrate community was dominated by gatherers, but all expected groups were well-represented.

Impairment was not evident in the diatom data. Nutrients, sediment, or metals apparently were not influential at this site. *Achnanthidium minutissimum* and *Planothidium lanceolatum* were the most frequently counted taxa in the sample.

Canadian Rockies (41) – 5 sites

Moose Creek (upper)

High mayfly taxa richness (12) and low HBI value (1.36) indicated excellent water quality conditions at this site. Sensitive cold stenotherm taxa accounted for 42% of the animals collected in the sample; 15 taxa were represented. These bellwethers of cold, clean water included *Epeorus grandis*, *Zapada columbiana*, and caddisflies in the Rhyacophila Hyalinata and Rhyacophila Vofixa Groups. Thermal preference for this assemblage was 10.6°C, which is lower than the median value for streams in the Canadian

Rockies ecoregion. There is no evidence that sediment deposition influenced the benthic community. Caddisfly richness and "clinger" richness were high, and the FSBI value (5.70) indicated a sediment-sensitive assemblage. The presence of the hyporheic chloroperlid stoneflies *Kathroperla* sp. and *Paraperla* sp. indicate that substrates were not embedded and fine sediment deposits were limited. High overall taxa richness (72) implied that instream habitats were complex and intact. Five semivoltine taxa were counted in the samples; it seems likely that periodic dewatering, scouring sediment pulses, or other catastrophes that would interrupt long life cycles were not among recent events. A well-balanced functional distribution was evident.

Motile diatom taxa known to increase in number when sediment impairment is present were abundant in this sample. Such taxa included *Navicula reichardtiana, Nitzschia inconspicua, Pseudostaurosira brevistriata,* and *Rhoicosphenia abbreviata.* Community responses to other stressors such as nutrients or metals were not obvious.

Moose Creek (lower)

The faunal changes between the upper and lower sites on Moose Creek are typical of the shifts expected in the longitudinal continuum of streams. A sensitive, functional, and diverse assemblage persisted between the 2 sites. Metric indicators of water quality indicated that cold, clean water characterized this reach. Thermal preference of the invertebrate community was calculated as 11.25°C, indicating slightly warmer conditions than those encountered in the upper reach. Sensitive cold stenotherm taxa were represented by 15 taxa; these accounted for 26% of sampled animals. "Clingers" and caddisflies remained diverse, suggesting that sediment deposition did not limit access to stony substrate habitats. The FSBI value (5.5) indicated a sediment-sensitive assemblage. Overall taxa richness (72) remained high at this downstream site. Year-round surface flow and stable instream conditions are indicated by the presence of 3 semivoltine taxa. All expected functional groups were represented in proportions appropriate to a third order montane stream.

Achnanthidium minutissimum accounted for 42% of the diatom taxa collected at this site. This taxon prefers fast flowing, well-oxygenated water, cold thermal conditions, and is characteristic of environs with low nutrient concentrations. No impairment was evident in the periphyton data.

Hungry Horse Creek

The sensitive cold stenotherm *Drunella doddsii* dominated the fauna collected at this site, accounting for 26% of sampled animals. Along with the 14 other mayfly taxa taken here, this finding suggests that water quality was excellent in the reach. Thirteen sensitive cold stenotherm taxa were present, accounting for 40% of organisms. Thermal preference for the assemblage was 11.6°C. The presence of the hyporheic stoneflies *Paraperla* sp. and *Kathroperla* sp. indicated that interstitial spaces in stony substrates were not embedded or choked by fine sediment. The diversity and abundance of caddisflies and "clingers" also suggests that sediment deposition was not influential. The FSBI value was 6.13; the assemblage was exquisitely sensitive to sediment. Taxa richness was within expectations for an undisrupted third order stream in the

Canadian Rockies. It seems likely that dewatering or scouring sediment pulses did not recently occur, since semivoltine taxa were supported here. Although all expected functional groups were represented, scrapers were notably abundant, and shredders were notably scarce. These findings may be related to an open riparian canopy that admitted sunlight and limited the amounts of organic material reaching the stream.

Although *Achnanthidium minutissimum* dominated the diatom assemblage at this site, taxa that increase with sediment impairment were a significant component of the periphyton community. Cold water temperatures, rapid flow, and well-oxygenated environs are indicated, but the influence of sediment may have been associated with the increase of diatoms such as *Synedra ulna*, which accounted for 29% of the identified diatoms here. *Gomphonema olivaceum* and *Amphora pediculus* were also among the collected taxa.

Lone Pine Creek

Samples collected from this site were dominated by midges; in particular, the ubiquitous Tvetenia Bavarica Group and *Hydrobaenus* sp. were abundant. High proportions of midges seem to be a seasonal phenomenon characteristic of late-season sampling, especially in higher elevations. *Hydrobaenus* sp. is reported to prefer oligotrophic environs and cold water temperatures, suggesting that nutrient enrichment or thermal stress were probably not influential here. The tolerance value assigned to this animal (8) may underestimate its sensitivity. Thus, the HBI value (3.54) may be less accurate than desired. However, mayfly taxa richness (8) was lower than expected for a stream in the Canadian Rockies. Seasonal succession may account for the abundance of midges as well as low mayfly diversity; the samples were collected in mid-September. The fauna included at least 7 sensitive cold stenotherm taxa, including the stoneflies *Zapada frigida* and *Megarcys* sp. Thermal preference for this assemblage was 11.5°C, similar to values calculated for similar streams. Abundant turbellarians (*Polycelis* sp.) suggest that groundwater contributed to surface flow in this reach. Although diversity and abundance among caddisflies and "clingers" was lower than any other sampled stream in the Canadian Rockies region, the FSBI value (5.25) was within expectations for similar streams. It seems likely that sediment deposition was not influential in this reach, but it cannot be ruled out. Overall taxa richness was low, implying monotonous instream habitats. Periodic dewatering seems unlikely. Gatherers, especially the abundant midges, dominated the functional composition of the assemblage. Scrapers were notably abundant, and shredders were scarce. This suggests an open riparian canopy, with limited inputs of large organic material, or hydrologic conditions that did not favor its retention.

Achnanthidium deflexum and *A. minutissimum* accounted for 56% of the diatoms identified at this site. Diversity of diatoms was notably low at this site. These findings suggest that natural stress from rapid, scouring flow and cold thermal conditions limited the diatom assemblage here. The water was apparently well-oxygenated and nutrient-poor. Sediment or metal stress was not apparent in the periphyton data.

Unnamed Creek

Midges, most of them probably early instars, dominated the benthic assemblage at this site. Generic identifications apparently were not possible for 72% of the midges collected here; it seems likely that immaturity was a factor. Since many of these immature "r-selected" animals persist for only a few days, their abundance may not signal degradation of water quality. The HBI value (4.32) probably does not accurately represent the sensitivity of this assemblage. A large number of turbellarians were collected; these may have been *Polycelis* sp., which may indicate groundwater influence in the reach. The performance of several other metrics may also be influenced. Other indicators of water quality gave mixed results: although mayfly taxa richness (8) was lower than expected, at least 8 sensitive cold stenotherm taxa were supported at this site. These included the caddisfly *Neothremma* sp., and the stoneflies *Visoka cataractae* and *Zapada columbiana*. It seems likely that water quality was good in this reach, and that thermal conditions were appropriate for a first order stream in the Canadian Rockies ecoregion. Thermal preference for the assemblage was 11.1°C. "Clingers" and caddisflies were not as diverse as expected, and the FSBI value (4.58) was lower than expected; stress from sediment deposition cannot be ruled out, but seems unlikely given the other taxonomic components of the assemblage. Overall taxa richness (71) was high, implying diverse instream habitats. At least 4 less-motile semivoltine taxa were collected, making it seem unlikely that the site suffered periodic dewatering or scouring flows. All expected functional groups were represented, but the coarse taxonomic determinations assigned to the early instar midges preclude an analysis of the functional balance of this assemblage.

The abundance of *Cocconeis placentula* and *Gomphonema angustatum* among the diatom flora signaled an increased probability of nutrient enrichment at this site. Other stressors such as nutrients or metals were not in evidence.

Northwestern Glaciated Plains ecoregion (42) – 12 sites

Milk River (upper)

Taxa richness and total abundance were both low at this site. The dominant taxon was the burrowing mayfly *Hexagenia* sp.; these accounted for 16% of the invertebrates in the collection. "Clingers" were not diverse. These findings suggest that substrates were soft silt or sand, and that instream habitats may have been limited. The FSBI value for this assemblage was 3.67, only slightly lower than the median value calculated for third order streams in the Northwestern Glaciated Plains ecoregion. This indicates a moderately sediment-tolerant assemblage, compared to other assemblages in similar streams in the region. Although EPT richness (15) was the lowest among third order streams in the Northwestern Glaciated Plains, the mayfly component was richest (11 taxa) among that group. This suggests that water quality was comparatively good in this reach. The mayfly fauna included taxa such as *Acentrella* sp., *Heptagenia* sp., and *Tricorythodes* sp.; in a plains setting, these are sensitive taxa. The HBI value (5.16) was lower than the median for third order streams in the region. Four hemoglobin-bearing midge taxa were collected, accounting for 9% of sampled animals. Areas of hypoxic sediments may be indicated. Thermal preference of this assemblage was 18.52°C, which was the median value for similar streams. Functional diversity characterized the assemblage; gatherers were dominant, but filterers, scrapers, and shredders contributed significantly to the functional mix.

Diatom taxa known to increase with impairment from sediments or nutrients were not abundant at this site. The dominant taxa were *Fragilaria radians* and *Fragilaria crotonensis*, which together accounted for 81% of the identified diatoms in the sample collected here. The abundance of these planktonic diatoms suggests that lentic conditions may have characterized some of the sampled area here.

Milk River (lower)

This site was the sole representative of large riverine habitats in the Northwestern Glaciated Plains ecoregion. Midges were the most abundant taxa group in this reach of the Milk River, but mayflies were proportionally abundant, accounting for 26.9% of sampled animals. Richness among mayflies was high. The fauna included *Tricorythodes* sp. and immature heptageniids. Hemoglobin-bearing midge taxa were neither as diverse nor as abundant as they were at the upper Milk River site. The HBI value (5.75) suggested a moderately sensitive assemblage. These findings suggest that water quality was good in this reach. Thermal preference of the community was calculated as 18.32°C. Similar to the upper Milk River site, "clingers" were not well-represented. The burrowing mayfly *Hexagenia* sp. was collected at this site, but it was not abundant. Areas of soft, silty or sandy substrates may be indicated. Overall taxa richness and invertebrate abundance were low, suggesting limited habitats. The FSBI value (4.08) indicated that this assemblage was among the most sediment-sensitive communities sampled in the Northwestern Great Plains ecoregion. Typical of plains streams, gatherers were the dominant functional group. Filterers and scrapers were also well-represented.

Fragilaria radians accounted for 81% of the diatoms identified from this site. The abundance of this planktonic taxon, along with the notably low diversity of the diatom flora suggests that lentic conditions were prevalent at this site. No specific stressors were indicated by the periphyton data.

Middle Fork Poplar River

The amphipod *Hyalella* sp. dominated the assemblage collected at this site, accounting for 37% of the invertebrates in the samples. Although *Hyalella* sp. is often interpreted to indicate poor water quality, its tolerance to pollution is probably not as great as its reputation suggests. The abundance of this animal suggests that organic debris may have been abundant in the stream channel. Macrophytes may be the source of this material. Mayfly taxa richness (8) was identical to the median value calculated for third order streams in the Northwestern Glaciated Plains ecoregion. Mayflies accounted for 21% of sampled organisms. A few relatively sensitive taxa were present at the site; these included the caddisflies *Psychomyia* sp. and *Helicopsyche* sp. The thermal preference calculated for this assemblage was 18.64°C, only slightly higher than the median value for similar systems. Hemoglobin-bearers in 10 taxa accounted for 7% of the sample. The HBI value was 6.68, indicating a more tolerant assemblage than most streams in this class. Nevertheless, it seems likely that good water quality and a warm thermal regime characterized this reach. At least 14 "clinger" taxa were supported here; these included the caddisflies *Hydropsyche* sp. and *Cheumatopsyche* sp., and black fly larvae (*Simulium* sp.) Some members of this community are associated with stony substrates, which may have increased the diversity of instream habitats. The FSBI value (3.99) indicated that the assemblage was slightly more sensitive to sediment than that of most third order streams in the region. Overall taxa richness (54) was at the median value for similar streams. The functional composition of this assemblage was simple, with gatherers and filterers dominating the mix.

Diatoms associated with nutrient enrichment were significant components of the flora at this site. These taxa included *Cocconeis pediculus, Epithemia sorex,* and *Rhoicosphenia abbreviata.*

Poplar River

EPT richness at this site (16) was much higher than the median value (4) for fourth order streams in the Northwestern Glaciated Plains. Mayflies in 10 taxa accounted for 23% of the sampled organisms. The assemblage was dominated by the amphipod *Hyalella* sp., which accounted for 32% of the sample. The HBI value was 6.44, indicating a somewhat more sensitive assemblage than most streams in this class. A few relatively sensitive taxa were present in this sample, including the mayflies *Stenonema* sp. and *Paraleptophlebia* sp., and the caddisfly *Helicopsyche* sp., which was abundant. There were 8 hemoglobin-bearing taxa; their abundance (7%) suggested some substrate hypoxia. The temperature preference calculated for this community was 18.71°C, well within the range for the sampled fourth order streams in the region. These findings suggest that water quality was good in the reach, and that the thermal regime was appropriate. Instream habitats appear to have been diverse. Clean cobble substrates are indicated by the abundant "clingers"; 18 taxa in this group accounted for 31% of sampled animals. Soft, silty or sandy substrates were apparently encountered by samplers, since the burrowing mayfly *Hexagenia* sp. was also present. (Interestingly, *Hexagenia* sp. in this sample was accompanied by 2 midge taxa that are often phoretically associated with it; these are *Epoicocladius* sp. and *Nanocladius* sp.) The presence of filamentous algae is suggested by *Hydroptila* sp., and macrophyte-associated taxa (e.g. *Dubiraphia* sp., *Hyalella* sp.) were also collected. Diverse instream habitats are also suggested by the high overall taxa richness (59). The FSBI value was 3.05; this was the lowest value calculated for any fourth order stream in the region, and suggests a moderately sediment-tolerant community. Gatherers, filterers, and scrapers were the most abundant functional groups, with gatherers dominating the mix.

Taxa known to increase with impairment by nutrients or sediment were not significant components of the diatom assemblage here. More sensitive floral components were also not well-represented, but good conditions are likely indicated by the diatoms present at this site.

West Fork Poplar River

Abundant mayflies contributed significantly (23%) to the composition of the assemblage collected at this site. Twenty-three taxa were represented in this group. Some of these were relatively sensitive types, such as *Leucrocuta* sp., *Stenacron* sp., and *Paraleptophlebia* sp. The sensitivity of the assemblage as measured by the HBI value was 5.91, the lowest value calculated for fourth order streams of the

Northwestern Glaciated Plains region. These findings suggest that water quality was good in this reach. Contrarily, hemoglobin-bearer richness was higher than any other fourth order stream in the region, and these animals accounted for 13% of the sample. The abundance of hemoglobin-bearing taxa may be related to nutrient pollution and/or warm water temperatures. The calculated thermal preference of the assemblage was 18.6°C, within the range of temperature preferences exhibited by invertebrate communities at similar sites. It seems likely that water quality was good at this site. The lowest FSBI value (2.48) for any assemblage in this site class was calculated for this site. This implies a sediment-tolerant community. On the other hand, "clinger" richness was much higher than the median for similar streams. Large numbers of hydropsychid caddisflies (*Hydropsyche* sp., *Cheumatopsyche* sp.) were collected. These insects prefer stony substrates without deposited sediment. Clean cobble substrates were apparently available. It seems likely that macrophytes added to habitat complexity, since some animals associated with aquatic plant communities (e.g. *Dubiraphia* sp., immature corixids) were present in samples. Taxa richness (73) was notably high. The invertebrate assemblage was functionally diverse; while gatherers and filterers dominated the mix, scrapers, shredders, and predators were also well-represented.

A diverse diatom assemblage was supported at this site. Sediment or nutrient impairment was not apparent. More sensitive taxa were not abundant, but no specific stressors are indicated by this flora.

Big Muddy Creek

The taxonomic composition of the invertebrate assemblage collected at this site strongly suggests lentic conditions. No rheophilic taxa occurred in the sample; this precludes comparison with the flowing-water systems sampled in the region. Consistent with a prairie pool environment, diversity was low. Only two mayfly taxa were collected, but these were abundant, accounting for 16% of the sampled assemblage. The HBI value (8.26) was high, but this may be expected of slack water environs. Thermal preference of this assemblage was calculated as 19.1°C, warmer than any other fourth order system in the Northwestern Glaciated Plains ecoregion sampled for this study. The amphipod *Hyalella* sp. dominated the sample, accounting for 56% of sampled animals. Immature corixids were also abundant. The abundance of these animals suggests that macrophytes were significant components of both the available habitats and the energy sources for the aquatic assemblage. The FSBI could not be calculated for this assemblage, since very few of the taxa collected here have been assigned sediment-tolerance values. Three midge taxa were collected; all were hemoglobin-bearing types, but none were abundant. Ostracods were common, suggesting that the sediment-water interface was well-oxygenated. Gatherers, mainly mayflies and the amphipod *Hyalella* sp., overwhelmed the functional composition of the community, with herbivorous piercers, mainly the immature corixids, being the only other group with a significant contribution to the functional mix.

Diversity and abundance of diatoms were notably low at this site. These findings may be associated with lentic conditions. No specific stressors were indicated by the diatom assemblage.

Frenchman Creek

A lentic environment was indicated by the few taxa present in the sample collected at this site. Comparison with flowing-water systems is precluded. Very low abundance and very low diversity (11 taxa) suggest that aquatic habitats were limited. The burrowing mayfly *Hexagenia limbata* was abundant, suggesting that soft, silty or sandy sediments were a major habitat component. It also suggests that sediments were not exclusively hypoxic. However, two hemoglobin-bearing taxa were present at the site; these were the midges *Chironomus* sp. and *Glyptotendipes* sp. Together, they accounted for 9% of sampled animals. Macrophytes may have also provided some available habitat. The dominant taxa were the mayfly *Caenis latipennis* and immature corixids, both of which are typically associated with aquatic macrophytes. Gnat larvae (*Probezzia* sp.) were common, suggesting that cattle were near this system. Water quality is difficult to evaluate in lentic systems. The HBI value (8.28) was high, as expected. Although *Caenis latipennis* and *Hexagenia limbata* are tolerant of warm water temperatures and some nutrient enrichment, their abundance (43% of sampled animals) suggests that water quality was not severely degraded. Thermal preference of this assemblage was 20.8°C. Similar to other lentic sites with macrophytes, gatherers and herbivorous piercers were the major contributors to the functional composition of the invertebrate assemblage.

Diversity and abundance of diatoms were low at this site. Lentic conditions may be indicated. No specific stressors were indicated by the diatom assemblage.

School Section Coulee

The invertebrate assemblage sampled at this site is suggestive of a cool-to-warm foothills-to-plains transitional fauna. Atypical of the majority of plains streams, this system is likely distinguished from them by higher gradient, cooler water temperatures, cobble-dominated substrates, and hydrologic characteristics that are more common in systems in the intermountain foothills and valleys. *Brachycentrus occidentalis*, *Acentrella insignificans*, *Eukiefferiella* spp., and the Tvetenia Groups are abundant in the samples collected here; these taxa are typical of valley and foothills invertebrates. Indicators of water quality suggest that nutrient enrichment may have influenced the invertebrate assemblage at this site. Oligochaetes were the dominant taxon in these samples; coarse taxonomic resolution of this group prevents speculation about whether these animals indicated low oxygen conditions in the substrates, or large crops of filamentous algae. Either situation suggests nutrient enrichment. Midges were the dominant taxonomic group, composed of 22 taxa and accounting for 46% of animals in the samples. Notably, the dominant groups among the midges were species in the *Orthocladius* complex, the genus *Cricotopus* spp., including the Cricotopus Trifascia Group and *Cricotopus bicinctus*. These midges are usually associated with filamentous algae and their abundance suggests that crops may have attained nuisance levels in the reach. Large crops of filamentous algae may be associated with nutrient enrichment. The HBI value (6.04) calculated for this assemblage was higher than expected for a foothills transitional system. Mayfly taxa richness, however, was within expectations. Five hemoglobin-bearing midge taxa were collected; they accounted for 3% of the invertebrates taken in the samples. Thermal preference for this assemblage was 17.9°C. "Clingers" and caddisflies were well-represented, suggesting that stony substrates were not obliterated by fine sediment deposition. The FSBI value (5.50), while not directly comparable to any other plains values, suggests a sediment-sensitive assemblage. Overall taxa richness was moderate, implying that instream habitat diversity may have been somewhat limited. It seems likely that dewatering was not influential here, since semivoltine taxa were well-represented. Among the functional groups, shredders were notably abundant, but this group was mostly made up of the midges associated with filamentous algae. Gatherers and filterers were the dominant feeding groups; this pattern is sometimes interpreted as evidence of water quality impairment.

Achnanthidium minutissimum was the dominant diatom taxon at this site, suggesting cold temperatures, rapid flow conditions, and well-oxygenated water. Sediment-tolerant taxa, especially *Amphora pediculus*, were abundant. Nutrient enrichment did not appear to be influential here.

Clear Creek

The invertebrate assemblage sampled at this site is characteristic of a foothills stream, and is atypical of most plains systems. The presence of chloroperlid stoneflies, perlodid stoneflies (including *Skwala* sp.), and the mayfly *Cinygmula* sp. identifies this as a high gradient, cobbled, cool-to-cold water stream, with few faunal characteristics in common with expectations for the Northwestern Glaciated Plains ecoregion. Seven mayfly taxa were counted in the sample, and the HBI value (5.50) was higher than expected for a trout stream. Some nutrient enrichment may influence the assemblage. Other evidence that might support this hypothesis includes the large number of midges in the genus *Cricotopus* spp. and in the *Orthocladius* complex. These taxa are typically associated with filamentous algae. Large crops of filamentous algae may indicate nutrient enrichment. No cold stenotherms were collected; the thermal preference of the assemblage was calculated as 16.0°C, which is much cooler than the median value for thermal preference for the Northwestern Glaciated Plains. Fifteen "clinger" taxa and 7 caddisfly taxa were present in the sample; fine sediment deposition probably had little influence here. Overall taxa richness was moderately high, implying diverse instream habitats. Semivoltine taxa were present; dewatering or scouring flows seem unlikely. Gatherers were the dominant functional group, but all components of a foothills stream were represented in expected proportions.

The diatom assemblage collected at this site was diverse, and harbored abundant sediment-tolerant taxa. These included *Amphora pediculus* and *Navicula reichardtiana.* Evidence for nutrient enrichment was not apparent in the periphyton data.

Highwood Creek

The invertebrate assemblage sampled at this site is suggestive of a cold-to-cool foothills-to-plains transitional fauna. The assemblage has more characteristics of a foothill stream fauna than of a plains stream fauna. The presence of chloroperlid stoneflies, the mayfly *Drunella grandis*, and the heptageniids *Epeorus* sp., *Cinygmula* sp., and *Rhithrogena* sp. distinguish the community; trout may be supported here. Mayfly taxa richness (11) was similar to that of a montane stream; a few specimens of the cool-to-warm water taxon *Tricorythodes* sp. were collected.

The HBI value (3.71) was similar to the median value calculated for montane ecoregions in the State. This was a moderately sensitive assemblage. Thermal preference for the community was 15.9°C, within the expected range of a montane system. Cold-to-cool temperatures and good water quality apparently characterized this reach. Twenty-two “clinger” taxa and 7 caddisfly taxa were present in the samples, suggesting that sediment deposition did not appreciably influence the invertebrate assemblage. The FSBI value (3.85), however, indicated a moderately sediment-tolerant group. The value was skewed by the abundance of the gregarious elmid *Optioservus* sp., and the cool-to-warm water tolerant *Helicopsyche borealis*. Overall taxa richness was moderately high; instream habitats were probably limited to some extent. Surface flow likely persisted year-round. Scrapers and gatherers dominated the functional mix. This pattern suggests an open canopy with significant sunlight penetration. All other expected functional groups were amply represented.

The diversity of the diatom flora was notable. No single taxon was dominant. Instead, dominance was shared among numerous organisms. No evidence of nutrient enrichment or sediment impairment was apparent.

Willow Creek

Rheophiles were not well-represented in the fauna collected at this site; a single specimen each of the caddisfly *Cheumatopsyche* sp. and the elmid beetle *Optioservus* sp. were collected. No other flow-dependent organisms appeared in the samples taken here. Organisms limited to lentic environs were present; these included the phantom midge *Chaoborus* sp. It seems likely that lentic conditions dominated this site, although some flowing water appears to have been sampled as well. The dominant taxon was the mayfly *Caenis* sp., which accounted for 68% of sampled organisms; it was the only mayfly taxon present in the sample. The other dominant groups were oligochaetes and midges. Soft sediments and macrophytes may have been the dominant habitats here. “Clingers” were not an important faunal component. Overall taxa richness (27) was low, implying monotonous instream habitats or water quality degradation. The HBI score (7.17) was higher than the median value for fourth order streams in the Northwestern Glaciated Plains ecoregion. A tolerant assemblage is indicated. At least 7 hemoglobin-bearing taxa were present at this site, accounting for 9% of sampled animals and implying hypoxic sediments. These findings suggest that nutrient enrichment influenced the invertebrate fauna here. Thermal stress may have additionally limited the biota; the thermal preference for the assemblage was 19.5°C, the highest value calculated for fourth order streams in the region. Gatherers, especially *Caenis* sp., overwhelmed the functional composition of the community. Predators were the only other group with significant representation. This is a common pattern in lentic, degraded plains systems, but in this case, the majority of predators are tolerant, tanypodine midges (e.g. *Tanypus* sp., *Procladius* sp.) whereas the typical dominant predators in similar systems are often odonates.

Low abundance and low diversity characterized the diatom flora at this site. However, evidence of stress from nutrients or sediment was not apparent in the periphyton data. No single taxon dominated this assemblage.

Tule Creek

Mayflies were neither diverse nor abundant at this site. The HBI value (6.85) was the median value calculated for fourth order streams of the Northwestern Glaciated Plains region. The dominant taxon in the sampled assemblage was the black fly *Simulium* sp.; the amphipod *Hyalella* sp. was also abundant. These taxa suggest that organic material was in plentiful supply, both as fine suspended particulates and as deposits of larger, senescent material. Evidence for the presence of filamentous algae could be discerned; although oligochaetes were not identified to levels that are interpretable in this regard, midges in the genus *Cricotopus* spp. were common. The most abundant midge was the orthocladine *Diplocladius* sp. which is sometimes associated with stream reaches below wastewater treatment plants. Nine hemoglobin-bearing taxa were counted, but these accounted for only 4% of sampled animals. Abundant ostracods suggested that hypoxic sediments were limited. In sum, these findings suggest that nutrient enrichment may have influenced the assemblage here. The thermal preference of this community was 18.94°C, consistent with similar streams in the region. Moderately high taxa richness (52) was mostly attributable to the notably diverse midge fauna. Microhabitats were probably diverse in the reach. “Clingers” accounted for 25% of collected organisms, but *Simulium* sp. accounted for the majority of these. In plains streams, *Simulium* sp. is just as likely to cling to macrophytes as to stony substrates. Other evidence seems to indicate that soft sediments and macrophyte surfaces were the main habitats available here. The FSBI value (3.16) indicated a sediment-tolerant community. Gatherers and filterers dominated the functional mix. No periphyton data was available for this site.

Northwestern Great Plains ecoregion (43) – 21 sites

Tongue River (upper)

This site was sampled in 2002. It was near the lower site, which was sampled in 2000, and may have been intended to indicate temporal trends in the invertebrate fauna of this section of the Tongue River. At least 11 mayfly taxa were supported at this site, accounting for 31% of sampled animals. Among the mayflies were specimens of *Camelobaetidius* sp., a bellwether of a cool-to-warm transitional plains river. The mayfly *Tricorythodes* sp. was the most abundant taxon in the collection. The HBI value (6.06) indicated that the invertebrate assemblage was more sensitive than most assemblages sampled at seventh order rivers in the Northwestern Great Plains. Four hemoglobin-bearing taxa were counted; these accounted for only 3% of organisms. These findings suggest that cool, clean water characterized this reach. The thermal preference calculated for the assemblage was 18.47°C; this was the median value for similar rivers in this region. “Clingers” and caddisflies were well-represented, suggesting that stony substrate habitats were not substantially degraded by fine sediment deposition. The FSBI value (4.00) was near the median value calculated for similar rivers. Overall taxa richness was relatively high, implying diverse and undisrupted instream habitats. Gatherers dominated the functional mix.

Cocconeis pediculus, Epithemia sorex and *Nitzschia dissipata* accounted for 46% of the diatom taxa identified at this site. These taxa are known to increase in response to both sediment and nutrient impairment in plains streams.

Tongue River (lower)

This site was not far below the upper Tongue River site, and may have been intended to demonstrate benchmark conditions for this section of the river. It was sampled in 2000. Although *Camelobaetidius* sp. was not collected in this reach, evidence for a transitional assemblage could still be discerned; a few specimens of the mayfly *Rhithrogena* sp. were collected. Mayfly taxa richness (15) was high, and mayflies accounted for 33% of the sampled organisms. The HBI value (7.07) was higher than for the Tongue River assemblage collected in 2002; oligochaetes and immature corixids were more abundant in this sample. Both of these groups are collectively assigned high tolerance values. However, other components of the sample suggest that community tolerance was probably comparable between the 2 years. The thermal preference for this assemblage was 18.22°C, similar to the calculated value for the 2002 sample. There were fewer caddisflies in the 2000 sample, and although the diversity of "clingers" was similar to the later year, this group was also less abundant in this sample. The FSBI value (4.13), however, did not indicate greater sediment tolerance. Overall taxa richness was lower, suggesting that instream habitats may have been more limited in 2000 than in 2002. Impairment due to sediment deposition cannot be ruled out at this site. Gatherers and herbivorous piercers (mainly immature corixids) dominated the functional composition of the assemblage.

Although sediment-tolerant diatom taxa were common in the sample collected here, their abundance was not significant. No specific stressors were indicated by the periphyton assemblage. No single diatom taxon was clearly dominant in this diverse and well-balanced community.

Powder River

This site was the single representative of first order streams in the Northwestern Great Plains. Midges (especially the filterer *Tanytarsus* sp.), biting gnats (Ceratopogonidae), and filtering caddisflies (*Cheumatopsyche* sp.) were the dominant taxa in the assemblage collected at this site. Although 8 mayfly taxa were counted, none of these was represented by more than a few specimens. Mayflies accounted for only 4% of sampled animals. The HBI value was 5.89, reflecting the tolerance values assigned to the dominant taxa. It seems likely that this assemblage was influenced by nutrient enrichment, with abundant fine suspended particulate matter being the manifestation of this. Cattle may have created stressing conditions; their proximity is suggested by the abundance of ceratopogonid gnats. The abundance of the midge *Pseudosmittia* sp. may also be associated with cattle dung in the stream channel. Hypoxic areas probably did not dominate substrates, however, since hemoglobin-bearing animals in 7 taxa accounted for only 5% of collected organisms. Four caddisfly taxa and 13 "clinger" taxa were present in samples, suggesting that fine sediment deposition did not obliterate stony substrate habitats. However, the FSBI value (2.71) was considerably lower than most values calculated for the Northwestern Great Plains. Stress from sediment deposition cannot be ruled out. A total of 43 taxa were counted. The functional mix reflected the feeding habits of the dominant taxa: filterers dominated the assemblage, and predators were very abundant.

Diatoms were very poorly represented at this site. Only 9 taxa were identified. No specific stressors were indicated by the flora present here.

Spring Creek

Rheophilic taxa were not present in the collection made at this site, suggesting that lentic conditions may have been predominant. Caenid mayflies (probably *Caenis* sp.) dominated the assemblage sampled at this site. This single taxon accounted for 23% of sampled animals. Other abundant taxa included the amphipod *Hyalella* sp., the elmid *Dubiraphia* sp., and damselflies (*Coenagrion/Enallagma* spp.) This combination of taxa suggests a wetland setting, with ample macrophytes. Nutrient enrichment may have been an influential factor here; the HBI value (7.11) was relatively high, compared to other low-linkage streams in the Northwestern Great Plains ecoregion. Ten hemoglobin-bearing taxa were collected, accounting for 11% of the collected organisms. The thermal preference calculated for this assemblage was 19.9°C, the highest value calculated for third order streams in the region. No caddisflies were collected, and "clinger" taxa were neither diverse nor abundant. Soft sediments probably characterized substrates here. The FSBI value could not be calculated, due to the absence of any taxa familiar to the model. Gatherers, especially *Caenis* sp., overwhelmed the functional composition of the community. Predators (primarily odonates, but ceratopogonid gnats were also common) were the only other group with significant representation. This is a common pattern in lentic, degraded plains systems.

Notably low abundance and low diversity of diatoms suggested that lentic conditions may have been prevalent at this site. No specific stressors were indicated by the flora collected here.

Cabin Creek

Two mayfly taxa were collected at this site; they accounted for 15% of sampled animals. The HBI value (6.33) was slightly higher than the median value for fourth order streams in the Northwestern Great Plains ecoregion. Hemoglobin-bearing taxa were not common: 2 genera accounted for only 3% of organisms in the samples. Hypoxic substrates were not extensive here. The thermal preference for this assemblage was 19.0°C, within the narrow range calculated for similar streams in the region. These findings suggest that water quality was probably relatively good in this reach. The dominant taxon was the filterer *Cheumatopsyche* sp. Its abundance suggests that fine particulate organic material was an important energy source in this reach. The abundance of the biting gnats in the family Ceratopogonidae suggests the proximity of cattle. Caddisfly diversity was low, but 10 "clinger" taxa were collected and these accounted for 50% of the sample. Sediment deposition apparently did not obliterate stony substrates here. Thirty-one taxa were collected, which is the lowest taxa count among similar streams. Instream habitats may have been limited. Scrapers were notably absent from the assemblage; gatherers and filterers were the dominant functional components.

Notably low abundance and low diversity of diatoms suggested that lentic conditions may have been prevalent at this site. No specific stressors were indicated by the flora collected here.

O'Fallon Creek

Metric indicators of water quality suggested that conditions at this site were good. Four mayfly taxa were collected; they accounted for 19% of sampled animals. The HBI value (5.95) was the lowest value calculated for fourth order streams in the Northwestern Great Plains ecoregion, indicating a more sensitive assemblage than at any similar site. Thermal preference of this assemblage was calculated as 18.76°C, lower than the median for similar streams. Although hemoglobin-bearing taxa were relatively abundant, it seems likely that water quality was good and thermal conditions were appropriate at this site. "Clingers" accounted for 57% of the sample. Caddisflies were not diverse, but the filterer *Cheumatopsyche* sp. was abundant. Sediment deposition apparently did not obliterate stony substrate habitats. The presence of *Hexagenia limbata* indicates that soft, silty or sandy substrates were present, but oxygenation of these substrates was apparently adequate to support this burrowing mayfly. The FSBI value (2.18) was low, but the performance of this metric may be limited when plains faunae are considered. Overall taxa richness was near the median value for streams in this class. Gatherers and filterers dominated the functional composition of the samples.

There were no specific indications of stress from sediments or nutrients among the components of the diatom assemblage collected at this site. Less tolerant taxa were not well-represented, and diatom abundance was low, but diversity among the group was high.

Bighorn River

Midges and worms overwhelmed the sample taken at this site; these groups accounted for 91% of the sampled assemblage. Mayflies were scarce. A few individuals of a single taxon represented this group. The HBI value (7.26) was higher than the median value calculated for high order rivers in the Northwestern Great Plains ecoregion. This indicates a tolerant assemblage, compared to those occurring in the sites sampled for this study. The dominant taxon was the midge *Cricotopus* spp., and midges in the *Orthocladius* complex were also abundant. These midges are frequently associated with filamentous algae, large crops of which may indicate nutrient enrichment. It seems likely that such pollution was present at this site. The thermal preference of this assemblage was 16.67°C, lower than the median value for riverine environs in the region. Thermal stress apparently did not influence the assemblage. Caddisflies were scarce. A single taxon was collected; only a few specimens appeared in the sample. Although "clinger" taxa accounted for 60% of the sampled assemblage, most of these were *Cricotopus* spp., which in this instance were probably not associated with the substrates. Characteristics of the substrate are not readily evidenced by this assemblage, which is heavily skewed toward filamentous alga associates. Overall taxa richness (24) was much lower than expected, suggesting that instream habitats were monotonous. Shredders, mainly *Cricotopus* spp., and gatherers overwhelmed the functional composition of this assemblage.

Cocconeis pediculus and *Rhoicosphenia abbreviata* dominated the diatom assemblage at this site, together accounting for 86% of the diatoms identified in the sample collected here. These taxa increase in response to sediment impairment and nutrient enrichment. Stress from either or both of these causes may influence the composition of the periphyton flora at this site.

Middle Fork Beaver Creek

Sampling at this site occurred in October; thus, it is unclear whether seasonal successions account for much of what appears to be impairment here. Midges and worms overwhelmed the invertebrate assemblage sampled at this site. These groups accounted for 92% of sampled animals. Three specimens in 2 mayfly taxa were the only representatives of this group. The HBI value (7.58) was higher than the median value for third order streams in the Northwestern Great Plains ecoregion. These findings indicate a very tolerant assemblage, and strongly suggest that nutrient enrichment was an influential stressor at this site. The thermal preference of this community was calculated as 17.9°C, about the same as the median value for similar streams in this region. However, thermal stress may be indicated. Eleven hemoglobin-bearing taxa were counted in the sample; these animals accounted for 25% of organisms collected here. Neither caddisflies nor “clingers” were diverse or abundant. The FSBI value (3.64) was near the median value for third order streams in the region. Given the abundance of hemoglobin-bearing midges, it seems likely that soft sediments characterized the reach. Taxa richness (41) was relatively high for sites in this class. This assemblage was more functionally diverse than many other assemblages in this region. Gatherers and filterers dominated the mix, but predators, shredders, and scrapers were also represented.

No specific stressors were indicated by the diatom assemblage collected at this site. No less tolerant taxa were significant components of the flora, but the assemblage was diverse and diatoms were abundant here.

Dry Gulch Creek

The invertebrate assemblage collected at this site exhibits characteristics of a cool-to-warm transitional fauna. The presence of taxa such as *Eukiefferiella* spp., *Tvetenia* sp., *Diamesa* sp., *Pagastia* sp., and *Agapetus* sp. distinguishes the fauna as one with strong foothills influence. The dominant taxon was the elmid *Optioservus* sp., a frequently encountered insect characteristic of warmer-water foothills streams. This animal accounted for 52% of sampled organisms; its gregarious nature sometimes results in samples that over represent its abundance in the stream. Low mayfly richness and abundance are notable in this community. The HBI value (4.36), however, seems appropriate for a stream with warmer water temperatures than typical of a stream located squarely in the foothills regions. Good water quality probably characterized this site. Thermal preference for this assemblage was calculated as 16.02°C, cooler than expected for a plains stream, but probably appropriate for a transitional, potentially trout-sustaining stream. Hemoglobin-bearing taxa accounted for less than 1% of organisms. Nine caddisfly taxa and 12 “clinger” taxa were counted; it seems likely that stony substrate habitats were largely free from deposited sediment. The FSBI value (3.07) is comparable to those calculated for montane streams. Scrapers, mainly *Optioservus* sp., dominated the functional composition of samples collected here.

The dominant taxon among the diatom assemblage at this site was *Staurosirella leptostauron,* a relatively sensitive, non-motile taxon that probably indicates well-oxygenated environs and clean stony substrates. No specific stressors were indicated by the composition of the periphyton flora here.

Box Elder Creek

Five mayfly taxa accounted for 8% of sampled animals at this site. The HBI result (6.49) was at the median value calculated for high-linkage sites in the Northwestern Great Plains ecoregion. The less-tolerant mayfly *Stenonema terminatum* was abundant at this site. Water quality was probably good here. Eight hemoglobin-bearing taxa accounted for 13% of the sampled animals. The thermal preference calculated for this assemblage was 19.1°C, warmer than most of the similar streams sampled. Caddisflies were represented by 2 taxa, one of which (*Cheumatopsyche* sp.) dominated the sample. "Clingers" were diverse and abundant. The FSBI could not be calculated because too few taxa collected here were familiar to the model. Sediment deposition apparently did not influence the biota at this site. Overall taxa richness was moderately high. Gatherers and filterers dominated the functional composition of the samples.

Although not abundant, diatoms were notably diverse at this site. Less tolerant taxa were not a significant part of the assemblage, but no specific stressors were indicated by this flora. No single diatom taxon dominated the assemblage.

Fish Creek

Midges were the most abundant faunal group here. Seasonal influences may have affected the taxonomic components of these samples, since collecting was done in mid-October. Mayflies may have been less diverse than in other seasons; even so 6 mayfly taxa accounted for 22% of organisms. Among these, *Tricorythodes* sp. was notably abundant. The HBI value (6.03) was lower than the median for fourth order streams in the Northwestern Great Plains, indicating a moderately sensitive assemblage. Hemoglobin-bearing taxa were not abundant; six taxa accounted for 5% of animals in the sample. The thermal preference of the community was calculated at 19.2°C, similar to that of the other fourth order streams in the region. Water quality was probably good here, and the thermal regime was probably appropriate. Indicators of sediment deposition did not give a clear signal: six caddisfly taxa were collected, and "clingers" were also diverse, but they were not as abundant as expected. "Clingers" accounted for only 22% of the animals taken here. The FSBI value (3.69) was higher than the median value calculated for fourth order streams in the Northwestern Great Plains, suggesting an assemblage moderately sensitive to sediment. Overall taxa richness was moderately high; this finding may be associated with diverse instream habitats. Among the functional components, gatherers were most abundant, but filterers and predators were also significant contributors to the mix.

No fewer than 78 diatom taxa were present at this site. There was no single dominant taxon among the flora collected here. Although less tolerant taxa were not a significant part of the assemblage, no specific stressors were evident.

Little Powder River (Site 1)

It appears that the Little Powder River was sampled on 2 consecutive days. It does not appear that the same site was sampled, however because of the differences in the macroinvertebrate assemblages in the respective samples. Only a reachwide transect sample was taken on this date. No rheophilic taxa were collected; it seems likely that lentic conditions characterized this site. Midges were the dominant group; the dominant taxon was *Parakiefferiella* sp., many species of which are associated with non-flowing aquatic environments. Mayfly taxa richness and abundance were low. The HBI value (7.49) indicated a tolerant assemblage. Thermal preference for this assemblage was 19.73°C, higher than the median value for large riverine sites in the Northwestern Great Plains ecoregion. Nine hemoglobin-bearing taxa were collected and accounted for 34% of sampled organisms. These findings suggest that nutrient enrichment, stagnant water, and warm water temperatures resulted in extensive areas of hypoxic sediments. Low taxa richness and low overall invertebrate abundance suggest monotonous instream habitats. Soft sediments and macrophyte surfaces may have accounted for most habitat space at this site. Gatherers dominated the functional composition of the assemblage.

The diatom flora collected at this site was neither diverse nor abundant; these characteristics may be associated with lentic environs. There was no evidence of specific stressors in the periphyton data.

Little Powder River (Site 2)

Rheophilic taxa were abundant in samples taken at this site. Five mayfly taxa were collected in samples taken here, and these accounted for 41% of sampled animals. The HBI value (5.52) indicated a more sensitive assemblage than typical of large riverine environs in the Northwestern Great Plains ecoregion. Water quality was probably good in this reach. Although the hemoglobin-bearers were a diverse group (8 taxa), they made up only 3% of organisms. Thermal preference (19.5°C) calculated for this assemblage was higher than expected, but it is likely that the model employed here does not perform well for plains environs, since many taxa are not within the experience of the model. It seems likely that water quality was good at this site, and the thermal regime was probably appropriate for a plains river. Three caddisfly taxa were collected, which is the median value for this group in similar riverine systems. “Clinger” taxa were somewhat less diverse than expected, but accounted for 36% of the sampled invertebrates. Sediment deposition apparently did not obliterate stony substrate habitats in the reach. The FSBI value (2.04), however indicates a sediment-tolerant group of taxa. Overall taxa richness (43) was typical of Great Plains rivers; diverse instream habitats are indicated. Gatherers and filterers dominated the functional components of the assemblage, but scrapers and predators were also amply represented.

Low diversity and low abundance characterized the diatom assemblage at this site. No specific stressors were indicated, and no clear dominant was present among the identified taxa.

Otter Creek

Lentic conditions appeared to characterize this site; few rheophilic taxa were collected here. Damselflies were the most abundant taxonomic group. Of the 3 mayfly taxa that appeared in the sample, 2 were represented by single individuals. *Caenis latipennis*, however, was common among the collected animals. The HBI value (7.05) was high compared to the range of values calculated for fourth order streams in the Northwestern Great Plains region. Thermal conditions were warm; the temperature preference for the assemblage was 19.2°C. Eight hemoglobin-bearing taxa accounted for 19% of the animals in samples. Soft sediments are indicated by the dearth of caddisfly taxa (1) and the low abundance of "clingers" (9%). Macrophytes and soft sediments were probably the important contributors to habitat diversity in the reach. Gatherers and predators (mainly damselflies) were the major functional components of the assemblage.

This site supported a diverse diatom assemblage. Dominance was not clearly characteristic of any single taxon identified in this sample. Evidence for specific stressors was not apparent in the periphyton data.

Currant Creek

No targeted riffle sample was collected here; results are reported for a single reachwide sample. A few rheophilic taxa were taken, but most of the organisms present here were beetles, midges, and crustaceans. Mayflies were poorly represented in this sample; 2 taxa account for only 4% of sampled animals. Although the HBI was relatively low compared to other third order streams in the region, there were 7 hemoglobin-bearing taxa; these accounted for 12% of sampled animals. It seems likely that nutrient enrichment was a limitation to this assemblage. Thermal preference was calculated as 17.46°C, which is somewhat cooler than most streams in its class. The dominant taxon was the elmid *Dubiraphia* sp., which is typically associated with macrophytes. A single caddisfly was collected; this was *Hydroptila* sp., an indicator of filamentous algae. "Clingers" were not well-represented. Fine deposited sediment probably was the major component of the substrate composition. Overall taxa richness (34) fit well with the expected range for similar sites. The simple functional composition was dominated by gatherers.

Diatoms were diverse and abundant at this site. No single taxon emerged as dominant in this assemblage. Although sediment-tolerant taxa were moderately abundant, their contribution to the flora was not significant enough to suggest impairment.

Crooked Creek

The fauna sampled at this site is characteristic of a foothills trout stream, and has little in common with most of the plains-regions streams in this study. Eleven mayfly taxa were collected here, and the HBI value was comparable to values calculated for foothills environs. Two sensitive taxa were present; they were caddisflies in the Rhyacophila Rotunda Group and *Wormaldia* sp. Water quality was good in this reach. The thermal preference of the assemblage was calculated as 14.5°C, decidedly cold for a plains stream, and more similar to montane conditions. The ubiquitous mayfly *Baetis* sp. dominated the taxonomic composition of the sample; these were probably early instars, since specific identifications were not possible. Nine caddisfly taxa and 18 "clinger" taxa were counted. Stony substrates without sediment deposition apparently provided ample habitats. Large numbers of shredding stoneflies (*Malenka* sp. and *Amphinemura* sp.) suggest that organic debris from riparian vegetation was plentiful in the channel. High overall taxa richness implies diverse instream niches. Gatherers, primarily the ubiquitous *Baetis* sp., dominated the functional mix. Scrapers were notably scarce, suggesting dense riparian canopy cover.

Achnanthidium minutissimum was the dominant diatom taxon collected at this site, accounting for 49% of the organisms identified in the sample. Cold water temperatures, high dissolved oxygen concentrations, rapid flow, and low nutrient concentrations are suggested by the abundance of this taxon. Sediment may have influenced the composition of this assemblage, however. Sediment-tolerant taxa such as *Cocconeis pediculus* were significant contributors to the composition of the flora.

Stillwater River

In the sampled reach, the Stillwater River supports an invertebrate assemblage that bears little in common with other large plains-regions rivers. This cold water adapted fauna is similar to that of trout streams in the montane areas of the State. Thirteen mayfly taxa were counted, and the HBI value (4.85) was well within the range of riverine systems in the mountain or foothills ecoregions. Good water quality is indicated. The thermal preference of the assemblage was calculated as 17.0°C, considerably cooler than the median for large rivers in the Northwestern Great Plains. Cool water adapted taxa collected here include *Epeorus albertae*, *Attenella margarita*, *Arctopsyche grandis*, and *Brachycentrus occidentalis*, and others. These taxa suggest a transitional environment, with foothills influence the primary determinant of the fauna. Caddisflies and "clingers" were well-represented. Stony substrate habitats were not appreciably disturbed by sediment deposition. The FSBI value (4.76) is comparable to scores attained by similar-sized rivers in the foothills and mountains. Fifty-one taxa were collected; moderately high taxa richness suggests that instream habitats were diverse and mostly undisrupted. All of the functional groups expected in a cool water foothills river were present in appropriate abundances.

No specific stressors were indicated by the diatom data collected at this site. Seventy-nine percent of the diatoms identified at this site were the cold-water adapted *Achnanthidium minutissimum*. Diversity was very low. These findings suggest that the periphyton assemblage was naturally limited by rapid flow and low nutrients.

Ingersol Creek

The site sampled on Ingersol Creek was a cool water transitional site, with many of the expected components of a foothills assemblage. Eight mayfly taxa were collected here; the dominant taxon in the sample was *Baetis* sp., including *Baetis tricaudatus*, the ubiquitous taxon characteristic of foothills environments. Ephemerellid mayflies and *Paraleptophlebia* sp. were also present at the site. Other trout stream taxa collected here included *Malenka* sp., *Zapada cinctipes*, *Lara* sp., and *Hesperoperla pacifica*. The taxonomic pattern exhibited here, with *Baetis* sp., *Simulium* sp., and fingernail clams (*Pisidium* sp.) dominant, and large numbers of *Hydropsyche* sp., suggests that mild nutrient enrichment may influence the biota here. The HBI value (5.37) was higher than expected, indicating a moderately tolerant fauna. Cool thermal conditions are indicated by the thermal preference of the assemblage, which was calculated to be 15.4°C. Metric indicators of sediment deposition gave contrary results. Six caddisfly taxa were counted, and "clingers" were represented by 17 taxa, but the FSBI value (3.54) was low. Although the abundance of "clingers" makes it seem unlikely, sediment deposition cannot be ruled out here. Overall taxa richness was high; instream habitats were probably varied. Although all expected functional components were present, the mix was dominated by gatherers and filterers. This pattern is sometimes interpreted as evidence of degraded water quality.

Taxa that increase with sediment impairment in foothills and montane environs were abundant in the periphyton sample collected at this site. These taxa include *Navicula capitatoradiata* and *Cocconeis pediculus.* Nutrient enrichment may also be implicated by the abundance of *Navicula lanceolata* and *Cocconeis placentula*

Bear Creek

No targeted riffle sample was collected here. The reachwide sample was overwhelmed by oligochaetes, which accounted for 68% of the sampled animals. Since oligochaetes were only identified to this coarse level, it is not apparent whether these were hemoglobin-bearing types associated with hypoxic sediments, or whether they were taxa with affinities to filamentous algae. In either case, poor water quality is probably indicated by the abundance of these organisms. Only 3 mayfly taxa were counted. The HBI value (8.54) was the highest score calculated for any third order stream in the Northwestern Great Plains studied here. Nutrient enrichment could explain these findings. The thermal preference calculated for the assemblage was 17.3°C; oligochaetes were not included in the calculation. Fine sediments may have characterized the substrate. Caddisflies were represented by a few individuals in a single taxon, and 8 "clinger" taxa accounted for only 9% of the sampled organisms. Overall taxa richness (36) was within the narrow range observed for third order streams in the region. The functional composition of the assemblage was overwhelmed by gatherers.

Diatoms collected at this site were neither diverse nor abundant. Sediment-tolerant taxa were a significant portion of the assemblage. Nutrient stress was not evident.

Twelvemile Creek

No targeted riffle sample was collected from Twelvemile Creek. Only a few rheophilic taxa were present in the sample, suggesting that slow flow conditions characterized this site. The reachwide sample yielded 4 mayfly taxa, but only *Caenis* sp., the assemblage's dominant taxon, was represented by more than a few individuals. *Caenis* sp. accounted for 48% of the animals in the sample. The HBI value (7.03) indicated a tolerant assemblage. Nutrient enrichment cannot be ruled out. Warm water temperatures likely prevailed; the thermal preference of this assemblage was 18.5°C. Many taxa collected here are typically associated with macrophytes, which must have accounted for a major portion of the available instream habitats. Soft sediments are indicated by the absence of caddisflies, and by the scarcity of "clingers". Although 6 "clinger" taxa were counted in the sample, they accounted for no more than 4% of the assemblage. The FSBI value (3.67) indicated a sediment-tolerant community. Gatherers dominated the functional components of the sample. A few scrapers, primarily the gastropods *Gyraulus* sp. and *Physa* sp., were also present.

The diatom assemblage sampled at this site was diverse and balanced. Response to stressors was not evident. No single taxon was clearly dominant.

Squaw Creek

The fauna collected at this site had very little in common with the typical plains stream. Trout may have been supported in this cold water habitat. Twelve mayfly taxa were present in the sample, including *Cinygmula* sp. and *Epeorus* sp., taxa associated with cold foothills or mountain stream environments. The HBI value (3.91) indicated a moderately sensitive assemblage, and strongly implied that water quality was good in this reach. No fewer than 9 distinct stonefly taxa were supported here. Cold thermal conditions are indicated by the assemblage's temperature preference of 14.3°C. The midge *Boreochlus* sp., usually collected in high mountain streams and sometimes associated with glaciers, was present in the sample. Cold, clean water characterized this site. Sediment deposition did not limit access to stony substrate habitats. Ten caddisfly taxa and 26 "clinger" taxa were collected. Overall taxa richness was very high, suggesting that instream habitats were diverse and undisrupted. The functional composition of this assemblage was balanced between gatherers, filterers, and shredders. All of the other feeding groups expected in a montane setting were also present.

Taxa that increase with sediment stress in foothill and montane environs contributed significantly to the diatom assemblage at this site. Among these were the motile taxa *Navicula reichardtiana, Nitzschia inconspicua,* and *Nitzschia palea.* There was no other stressor response evident.\

Discussion

Classifications based on the ecological interpretations were not assigned to sites where taxonomic components indicated that lentic conditions were prevalent. Figure 31 graphs the extent of biological conditions as estimated by the narrative interpretations approach. Compared to MMI and O/E results, this approach estimated more widespread impairment in the plains ecoregions, and less extent of impairment in the Middle Rockies. More extensive impairment was estimated in the Northern Rockies by this approach than MMI or O/E. Similar to the MMI, the ecological interpretation approach identified all Canadian Rockies sites as unimpaired.

All 3 methods (MMI, O/E, and interpretations) gave impairment classifications that agreed in 45 out of 73 comparisons (62%). Montane regions achieved a higher rate of 3-way agreement among the methods; in those regions all methods gave the same impairment classification in 73% of cases. In the plains regions, methods agreed in only 43% of cases.

When MMI and O/E impairment classifications agreed for montane sites, there was a high probability (88%) that the narrative interpretations would also agree. This probability was lower among plains sites; where MMI and O/E agreed, narrative interpretations agreed in only 57% of cases.

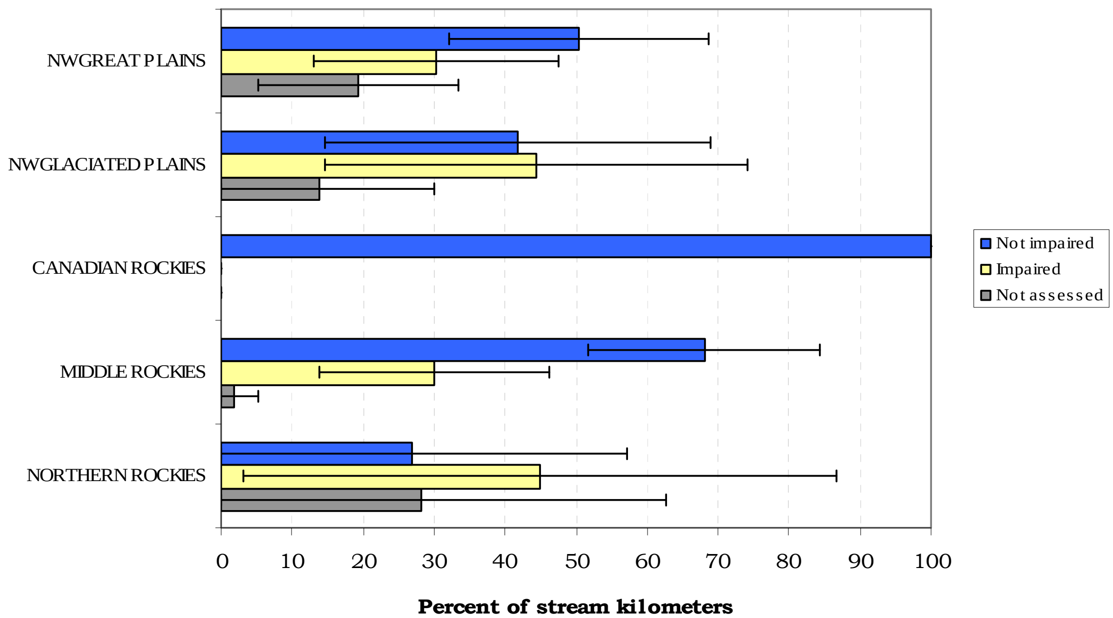

Figure 31. Extent of impairment classifications for Montana ecoregions based on ecological interpretations of macroinvertebrate data.

Appendix A summarizes the findings of the impairment classifications per site using the different approaches (narrative ecological interpretations of the macroinvertebrate and diatom samples, MMI and O/E, phosphorus, nitrogen and ammonia draft criteria, and sediment periphyton metric for the Middle Rockies ecoregion only.

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APPENDIX A

SAMPLE ID	SITE NAME	STRAHLER ORDER	ECOREGION	MACRO-INVERT-EBRATE SITE CLASS	MMI CONDITION	OE CONDITION	ECOL INTERP CONDITION	NITROGEN CONDITION	PHOSPHORUS CONDITION	AMMONIA CONDITION	PERIPHYTON SEDIMENT CONDITION (Middle Rockies only)
WMTP99-0503	BELT CREEK	3	17	MT	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED
WMTP99-0505	DUTCHMAN CREEK	3	17	LV	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	IMPAIRED	IMPAIRED	NOT IMPAIRED
WMTP99-0507	SIXMILE CREEK	3	17	MT	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	IMPAIRED	NOT IMPAIRED
WMTP99-0509	LITTLE SLEEPING CHILD CK	2	17	MT	IMPAIRED	IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	IMPAIRED	IMPAIRED	NOT IMPAIRED
WMTP99-0510	MUDDY CREEK	1	17	MT	IMPAIRED	NOT IMPAIRED	IMPAIRED	N.A.	NOT IMPAIRED	NOT IMPAIRED	IMPAIRED
WMTP99-0515	MOOSE CREEK	2	41	MT	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	IMPAIRED	N.A.
WMTP99-0516	KEEP COOL CREEK	3	17	LV	NOT IMPAIRED	NOT IMPAIRED	IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	IMPAIRED
WMTP99-0517	PINTLER CREEK	2	16	MT	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	N.A.	N.A.	N.A.	N.A.
WMTP99-0518	JACK CREEK	3	17	LV	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	N.A.	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED
WMTP99-0519	TONGUE RIVER	7	43	PL	NOT IMPAIRED	IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	N.A.
WMTP99-0521	SPRING PARK CREEK	1	17	MT	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	IMPAIRED	NOT IMPAIRED	NOT IMPAIRED
WMTP99-0523	TRIBUTARY TO LOCO CK	1	17	MT	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED
WMTP99-0524	MILK RIVER	3	42	PL	NOT IMPAIRED	IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	N.A.
WMTP99-0532	RUBY CREEK	3	17	MT	IMPAIRED	IMPAIRED	IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED
WMTP99-0535	BUCK CREEK	2	17	MT	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	IMPAIRED
WMTP99-0536	MIDDLE FORK POPLAR RIVER	3	42	PL	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	N.A.
WMTP99-0537	POWDER RIVER	1	43	PL	NOT IMPAIRED	IMPAIRED	IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	N.A.
WMTP99-0549	SPRING CREEK	3	43	PL	NOT IMPAIRED	NOT IMPAIRED	N.A.	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	N.A.
WMTP99-0555	POPLAR RIVER	4	42	PL	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	N.A.
WMTP99-0574	CABIN CREEK	4	43	PL	NOT IMPAIRED	IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	N.A.
WMTP99-0586	WEST FORK POPLAR RIVER	4	42	PL	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	N.A.

SAMPLE ID	SITE NAME	STRAHLER ORDER	ECOREGION	MACRO-INVERT-EBRATE SITE CLASS	MMI CONDITION	OE CONDITION	ECOL INTERP CONDITION	NITROGEN CONDITION	PHOSPHORUS CONDITION	AMMONIA CONDITION	PERIPHYTON SEDIMENT CONDITION (Middle Rockies only)
WMTP99-0600	MOOSE CREEK	3	41	MT	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	IMPAIRED	N.A.
WMTP99-0601	BLACKFOOT RIVER	6	17	LV	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	N.A.	NOT IMPAIRED	IMPAIRED	NOT IMPAIRED
WMTP99-0604	O'FALLON CREEK	4	43	PL	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	N.A.
WMTP99-0607	HUNGRY HORSE CREEK	3	41	MT	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	IMPAIRED	N.A.
WMTP99-0608	SOUTH FORK LITTLE JOE CK	2	15	MT	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	N.A.	NOT IMPAIRED	N.A.	N.A.
WMTP99-0609	FRED BURR CREEK	2	17	MT	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	N.A.	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED
WMTP99-0611	BIGHORN RIVER	7	43	PL	IMPAIRED	IMPAIRED	IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	N.A.
WMTP99-0613	MIDDLE FORK BEAVER CK	3	43	PL	NOT IMPAIRED	NOT IMPAIRED	IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	N.A.
WMTP99-0621	DRY GULCH CREEK	2	43	PL	IMPAIRED	IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	N.A.
WMTP99-0623	BOX ELDER CREEK	5	43	PL	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	N.A.
WMTP99-0628	FISH CREEK	4	43	PL	NOT IMPAIRED	IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	N.A.
WMTP99-0633	LITTLE BOULDER RIVER	3	17	MT	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	N.A.	NOT IMPAIRED	IMPAIRED	NOT IMPAIRED
WMTP99-0635	BIG MUDDY CREEK	4	42	PL	NOT IMPAIRED	IMPAIRED	N.A.	IMPAIRED	IMPAIRED	NOT IMPAIRED	N.A.
WMTP99-0642	LITTLE POWDER RIVER	5	43	PL	IMPAIRED	NOT IMPAIRED	N.A.	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	N.A.
WMTP99-0648	LITTLE POWDER RIVER	5	43	PL	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	N.A.
WMTP99-0653	FRENCHMAN CREEK	3	42	PL	NOT IMPAIRED	IMPAIRED	N.A.	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	N.A.
WMTP99-0697	OTTER CREEK	4	43	PL	NOT IMPAIRED	NOT IMPAIRED	N.A.	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	N.A.
WMTP99-0698	MCCORMICK CREEK	2	17	MT	IMPAIRED	IMPAIRED	IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	IMPAIRED	NOT IMPAIRED
WMTP99-0699	CURRANT CREEK	3	43	PL	NOT IMPAIRED	NOT IMPAIRED	IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	N.A.
WMTP99-0701	FISH CREEK	3	17	MT	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	N.A.	NOT IMPAIRED	IMPAIRED	NOT IMPAIRED
WMTP99-0702	SPAIN FERRIS DITCH	1	17	MT	IMPAIRED	IMPAIRED	IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	IMPAIRED	NOT IMPAIRED

SAMPLE ID	SITE NAME	STRAHLER ORDER	ECOREGION	MACRO-INVERT-EBRATE SITE CLASS	MMI CONDITION	OE CONDITION	ECOL INTERP CONDITION	NITROGEN CONDITION	PHOSPHORUS CONDITION	AMMONIA CONDITION	PERIPHYTON SEDIMENT CONDITION (Middle Rockies only)
WMTP99-0703	UNKNOWN	2	17	MT	IMPAIRED	IMPAIRED	IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED
WMTP99-0704	TRIBUTARY TO MOUNT CK	1	15	MT	IMPAIRED	IMPAIRED	IMPAIRED	N.A.	IMPAIRED	N.A.	N.A.
WMTP99-0705	WEST FORK LOLO CREEK	2	15	MT	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	N.A.	N.A.	N.A.	N.A.
WMTP99-0707	CROOKED CREEK	2	43	PL	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	N.A.
WMTP99-0709	STILLWATER RIVER	6	43	PL	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	N.A.
WMTP99-0712	SCHOOL SECTION COULEE	1	42	PL	IMPAIRED	NOT IMPAIRED	IMPAIRED	IMPAIRED	IMPAIRED	NOT IMPAIRED	N.A.
WMTP99-0713	WEST BOULDER RIVER	4	17	MT	IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED
WMTP99-0714	TONGUE RIVER	7	43	PL	NOT IMPAIRED	NOT IMPAIRED	IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	N.A.
WMTP99-0715	INGERSOL CREEK	2	43	PL	NOT IMPAIRED	NOT IMPAIRED	IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	IMPAIRED	N.A.
WMTP99-0716	BASIN CREEK	1	17	MT	IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED
WMTP99-0719	CLEAR CREEK	3	42	PL	NOT IMPAIRED	NOT IMPAIRED	IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	N.A.
WMTP99-0721	BIG HOLE RIVER	2	17	MT	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	IMPAIRED	NOT IMPAIRED
WMTP99-0722	LONE PINE CREEK	2	41	MT	NOT IMPAIRED	IMPAIRED	NOT IMPAIRED	IMPAIRED	NOT IMPAIRED	IMPAIRED	N.A.
WMTP99-0723	JERRY CREEK	3	17	MT	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	N.A.	NOT IMPAIRED	IMPAIRED	NOT IMPAIRED
WMTP99-0723	JERRY CREEK	3	17	MT	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	N.A.	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED
WMTP99-0723	JERRY CREEK	3	17	MT	IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	IMPAIRED
WMTP99-0724	BIG HOLE RIVER	5	17	MT	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	IMPAIRED	IMPAIRED	IMPAIRED	IMPAIRED
WMTP99-0724	BIG HOLE RIVER	5	17	MT	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	IMPAIRED	IMPAIRED	IMPAIRED
WMTP99-0727	MCHESSOR CREEK	2	17	MT	IMPAIRED	IMPAIRED	IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	IMPAIRED	NOT IMPAIRED
WMTP99-0729	HIGHWOOD CREEK	3	42	PL	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	N.A.

SAMPLE ID	SITE NAME	STRAHLER ORDER	ECOREGION	MACRO-INVERT-EBRATE SITE CLASS	MMI CONDITION	OE CONDITION	ECOL INTERP CONDITION	NITROGEN CONDITION	PHOSPHORUS CONDITION	AMMONIA CONDITION	PERIPHYTON SEDIMENT CONDITION (Middle Rockies only)
WMTP99-0731	WILLOW CREEK	4	42	PL	NOT IMPAIRED	NOT IMPAIRED	IMPAIRED	NOT IMPAIRED	IMPAIRED	NOT IMPAIRED	N.A.
WMTP99-0733	BEAR CREEK	3	43	PL	IMPAIRED	NOT IMPAIRED	IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	N.A.
WMTP99-0745	BROWNS CREEK	2	17	MT	IMPAIRED	IMPAIRED	IMPAIRED	N.A.	IMPAIRED	NOT IMPAIRED	NOT IMPAIRED
WMTP99-0747	CLARK FORK RIVER	7	15	MT	IMPAIRED	NOT IMPAIRED	IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	N.A.	N.A.
WMTP99-0748	TRIBUTARY TO PETERSON CK	3	17	MT	NOT IMPAIRED	IMPAIRED	IMPAIRED	IMPAIRED	IMPAIRED	IMPAIRED	NOT IMPAIRED
WMTP99-0749	JACKSON CREEK	2	17	MT	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	IMPAIRED	NOT IMPAIRED
WMTP99-0793	TWELVEMILE CREEK	3	43	PL	NOT IMPAIRED	NOT IMPAIRED	IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	IMPAIRED	N.A.
WMTP99-0794	BITTERROOT RIVER	6	17	LV	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED
WMTP99-0798	MILK RIVER	7	42	PL	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	N.A.
WMTP99-0801	TRIBUTARY TO DUNKLEBERG	1	17	MT	IMPAIRED	IMPAIRED	IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED
WMTP99-0803	BRACKET CREEK	3	17	MT	IMPAIRED	IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	IMPAIRED
WMTP99-0804	TULE CREEK	4	42	PL	NOT IMPAIRED	NOT IMPAIRED	IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	N.A.
WMTP99-0836	UNNAMED CREEK	1	41	MT	NOT IMPAIRED	IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	IMPAIRED	IMPAIRED	N.A.
WMTP99-0837	TRIB N FORK BLACKFOOT R	1	17	MT	IMPAIRED	IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED
WMTP99-0838	SQUAW CREEK	2	43	PL	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	N.A.
WMTP99-0839	UNKNOWN	2	17	MT	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED	NOT IMPAIRED