Cramer Fish Sciences

Montana Rivers and Streams Assessment

October 2013

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Table 1. Summary of nutrient category criteria for NRSA assessment (µg/L).

Introduction

Under the Clean Water Act (CWA), the U.S. Environmental Protection Agency (EPA) must periodically report on the condition of the nation's water resources by summarizing water quality information provided by the states. In this report, we summarize water quality data collected in 2008-2009 from 62 rivers and streams in the state of Montana as part of the National River and Stream Assessment (NRSA). These data were collected as part of a nationwide effort that surveyed the full variety of river and stream types. In this report, we interpret these data to determine the extent to which rivers and streams in Montana support a healthy biological condition and to assess the influence of environmental stressors that may be limiting attainment of healthy biological conditions.

Author's Note: Given the intended use of this report, and for consistency, we have incorporated many descriptions verbatim *from the National River and Stream Assessment Report (http://water.epa.gov/type/rsl/monitoring/riverssurvey/). Where appropriate, we added detail relevant to Montana. Otherwise, the summaries of NRSA data collected in Montana and their interpretation remain our original work product.*

Methods

Sample Design

EPA selected rivers and streams for the NRSA using a probability-based sampling design summarized in the EPA NRSA 2008-2009 Technical Report (EPA 2013). Rules were developed to ensure that the design yielded a sample that would support statistically valid conclusions. With input from the states, the following framework guided the sample selection process. Montana-specific information is noted.

- The sample frame was derived from the National Hydrography Dataset (NHD) version known as NHD-Plus. The following NHD-Plus classifications are included in the sample frame: connectors, canals and ditches, intermittent rivers and streams, and perennial rivers and streams. In Montana, 59,941 miles of

rivers and streams mapped by NHD-Plus are included in the sample frame.

- Sampling effort differed between wadeable streams (defined as Strahler stream order 1 through 4) and non-wadeable rivers (5 through 10). Note that "wadeable" and "non-wadeable" are used to designate Strahler stream order classes and do not imply that rivers or streams will be wadeable or non-wadeable according to state standards. In Montana, there are 51,938 miles of wadeable streams and 8,003 miles of non-wadeable rivers in the sample frame.
- In Montana, 41 samples were located along wadeable rivers and streams and 21 along non-wadeable rivers and streams. The sampling rate of wadeable rivers and streams is higher than in most states. Yet, this sampling rate is still lower than the proportion of wadeable stream length in the state. To account for this, a population weight was calculated by EPA for each sample site to reflect the proportion each represents in the sample frame. This population weight is used to calculate the unbiased statistics (means and variances) reported below.

Sample selection for the NRSA provided spatial distribution across the lower 48 states and 9 aggregated Omernik Level III ecoregions. In Montana, two aggregated ecoregions were encountered—Western Mountains and Northern Plains. These ecoregions are the basis for assessment criteria developed by EPA and for EPA's reporting of stream conditions. These ecoregions generally coincide with "coldwater" and "warmwater" stream designations used by Montana Department of Environmental Quality (MDEQ) as codified in the Administrative Rules of Montana (ARM) 17.30.600. All sites in the Western Mountains are designated as coldwater streams. However, in the Northern Plains ecoregion, there are many exceptions, especially along stream reaches flowing out of the Western Mountains that are classified as "coldwater" under the ARM, but are geographically located in the Northern Plains (Figure 1). To aid interpretation, summaries in this report distinguish between coldwater and warmwater streams in the Northern Plains. This combined designation of ecoregion and ARM classification will be referred to as a "stream group" in this report. A comprehensive list of Montana NRSA sites and their grouping is in Appendix A.

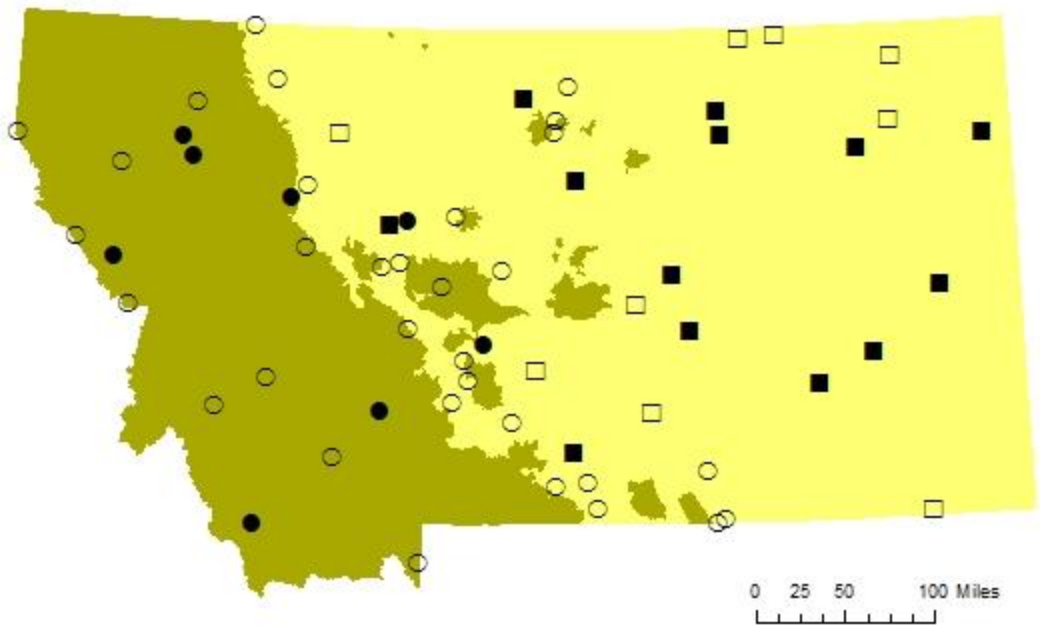


Figure 1. Location of NRSA rivers and streams sampled in Montana by aggregated ecoregion group (green=western mountains; yellow=northern plains), stream size (closed=non-wadeable; open=wadeable) and Montana ARM stream designation (circle=coldwater; square=warmwater).

Data Collection

Montana rivers and streams were sampled during the summers of 2008 and 2009 by a three- to four-person field crew. Data collection procedures are fully documented in the EPA NRSA Field Operations Manual (US EPA 2009). Generally, during each site visit crews laid out the sample reach (i.e., stretch of river or stream) and 11 transects to guide data collection. Indicators used to assess water quality, ecological integrity, and recreational value for non-wadeable and wadeable streams include:

- *Water chemistry* – using grab samples collected at the midpoint of the sampling reach at the center of the stream;
- *Periphyton assemblage* - collected from 11 locations systematically placed at each site and combined into a single composite sample;
- *Benthic macroinvertebrate assemblage* – collected from 11 locations

systematically placed at each site and combined into a single composite sample;

- *Fish assemblage* – collected at specified sites throughout the sampling reach;
- *Stream channel assessment* – measurements collected throughout the reach at specified locations associated with the 11 transect locations;
- *Riparian habitat assessment* – measurements collected throughout the reach at specified locations associated with the 11 transect locations;
- *Fecal indicator (enterococci)* – collected at the last transect one meter off bank;
- *Fish tissue* – target species collected throughout the sampling reach as part of fish assemblage sampling (collected at non-wadeable sites only).

Grab samples were sent to a lab for basic chemical analysis. Biological samples were sent to taxonomists for identification and enumeration. Crews recorded extensive data on field forms and documented information about the physical characteristics of each stream and the riparian area adjacent to its banks. Nationwide, about ten percent of the sites were revisited as part of the quality assurance plan for the survey. Data were reduced by EPA into data files containing raw measurements, calculated metric values, and sites classified into condition classes (i.e., good, fair, and poor). Results detailed in this report use data files posted on EPA's internal website in August 2013.

Biological Condition

Fish, benthic macroinvertebrates and algae are used as indicators of biological condition. Each group of organisms plays a different role in how rivers and streams function and is sensitive to different disturbances that result from human activities. Algae are the base of the food chain and capture light and nutrients to generate energy. They are sensitive to environmental stressors. Macroinvertebrates feed on algae and other organic material and are also an important food source for many other aquatic animals, such as fish; in turn, fish serve as an important source of food for people and wildlife. It is rare that these three assemblages are sampled at the same time over such a broad area. Collectively, they give us a robust understanding of the biological integrity of rivers and streams. Biological integrity has been defined as "the capability of

supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region" (Karr and Dudley 1981).

The composition and relative abundance of different taxa (i.e., classifications of groupings of organisms) that make up each group are used to assess the condition of each group. This is performed using well-established and tested indices described further below. In order to rate biological condition as "good", "fair", or "poor", metric values from NRSA sites are compared to those derived from samples collected at sites representing the best available physical, chemical, and biological habitat conditions given today's state of the landscape. These reference sites represent the "least disturbed condition" defined based on data from sites selected according to a set of explicit screening criteria which are used to define what is least-disturbed by human activities. In rating biological condition, distinct condition classes are drawn from the distribution of metric values found at these reference sites. Generally, "good" sites are as good as 75% of the reference sites and "poor" sites are worse than 95% of the reference sites.

Reference site criteria are summarized in the EPA NRSA 2008-2009 Technical Report (EPA 2013). Generally, they are selective for sites that have little influence from dams, agricultural areas, and urbanization *and* have low levels of riparian disturbance, low turbidity and percent fine substrate, low nitrogen and phosphorus concentrations, low chloride and sulfate concentrations, *and* high acid neutralizing capacity. Biological parameters were not used to select reference sites as that would introduce circular logic. Criteria differ between sites in the Western Mountains and those in the Northern Plains. Seventy-eight reference sites were available for use in the NRSA to represent the Northern Plains and 508 were available in the Western Mountains. Even though these reference data sets include samples collected outside of Montana, they were used as the basis of comparison for Montana samples collected within each ecoregion.

Key Stressors

Information on the ecological condition of streams is supplemented with measurements of key stressors that might affect their ecological condition. Stressors are the chemical, physical, and biological components of the ecosystem that have the potential to degrade biological integrity. Some of these are naturally occurring and some result only from human activities. Chemical indicators of stress measured in this assessment include: phosphorus, nitrogen, salinity, and acidity. Physical indicators include: streambed sediments, in-stream fish habitat, riparian vegetative cover, and riparian disturbance. Water quality impairment from toxic metals and high stream temperatures—both important stressors in Montana streams—were not evaluated in this assessment. In rating conditions indicated by these metrics, distinct condition classes are drawn from the distribution of metric values found at these reference sites. Generally, "good" sites are as good as 75% of the reference sites and "poor" sites are worse than 95% of the reference sites. Approaches to defining these thresholds may vary for a given metric and are discussed further below, as needed. As with the development of thresholds for biological condition described in the previous section, thresholds for environmental stressors are based on reference sites collected throughout the Northern Plains and Western Mountains ecoregions.

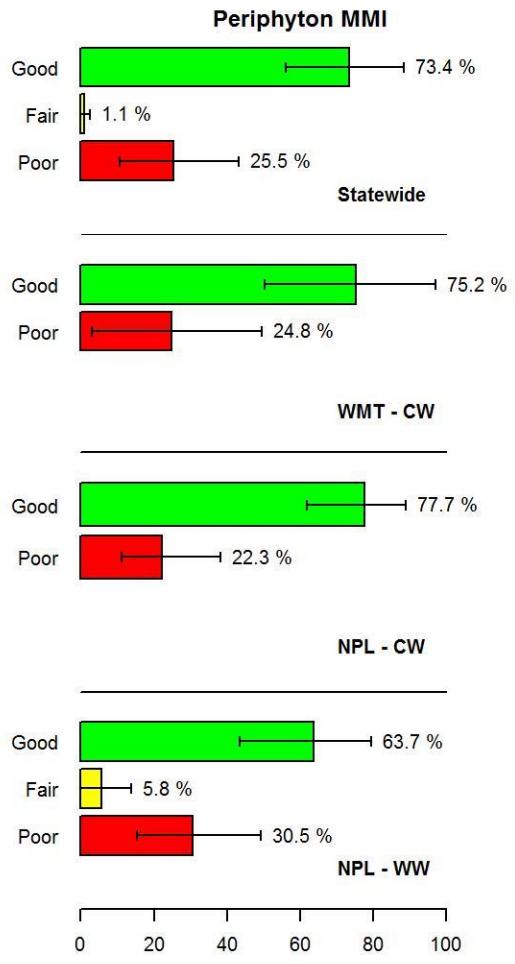
Health Indicators

NRSA also investigated two human health indicators: mercury in fish tissue and the pathogen indicator enterococci. For the NRSA, fish tissues were sampled and analyzed from a subsample of sites. This subsample focuses the assessment on waters that support fish of a size that are typically sought for human consumption. Enterococci are indicators of the presence of fecal material in water and, therefore, of the possible presence of disease-causing bacteria, viruses, and protozoa. Water samples were analyzed using a process known as quantitative polymerase chain reaction, or qPCR, a methodology that facilitates the detection of DNA sequences unique to these bacteria.

Results

Biological Condition

Periphyton are benthic algae that attach themselves to river and stream substrate and provide food for macroinvertebrates and fish. They are sensitive to physical, chemical, and biological stressors. The most common types of periphyton, diatoms, are abundant and display a range of autecological attributes. They are very useful indicators of biological condition. For the NRSA, scientists developed a Periphyton Multimetric Index (MMI) using an approach that uses the habitat affinities of periphtyon taxa sampled at NRSA sites to estimate expected condition at individual sites. That is, based on the types of periphyton sampled, this index tells us how good the biological condition at the site should be. Separate indices were developed for each of the aggregated ecoregions encountered in Montana. This index is based on different aspects of periphyton community structure: taxonomic diversity, pollution tolerance and sensitivity, and diatom habit. These metrics rate rivers and streams as good if they have high diversity, high relative abundances of sensitive taxa, low relative abundances of pollution tolerant taxa, and low abundances



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of motile diatoms (motile taxa do not attach themselves to substrate; an abundance of motile taxa indicates high levels of sediment), planktonic diatoms (also do not attach themselves to substrate) and stalked diatoms (which attach themselves to filamentous algae or macrophytes which grow in high nutrient loading conditions). Generally, these metrics distinguish good biological condition in rivers and streams having diverse, pollution intolerant benthic algae communities inhabiting water bodies with low nutrient loading and substrates with low levels of sediment. Very few sites will be found to be "fair" because the range of metric values defining "fair" is very narrow. The Periphyton MMI indicates that nearly three-quarters of Montana's river and stream length is in good condition (see Figure 2). Periphyton conditions are slightly better among coldwater sites than warmwater sites. Overall, periphyton conditions of Montana's rivers and streams are better than those found nationally.

Macroinvertebrates are organisms that are large (macro) enough to be seen with the naked eye and lack a backbone (invertebrate). Many macroinvertebrates eat benthic algae and are themselves food for fish. Examples of aquatic macroinvertebrates include insects in their larval or nymph form, crayfish, clams, snails, and worms. Ecologists have developed a Macroinvertebrate MMI for each ecoregion based on different aspects of macroinvertebrate community structure: taxonomic richness, taxonomic composition, diversity, feeding groups, habits, and pollution tolerance. In the Western Mountains (coldwater), rivers and streams were considered to be in good condition if they had higher relative abundance of EPT taxa (mayflies, stoneflies, and caddis flies), higher taxa richness (number of distinct taxa), high abundances of scrapers and clingers (which are adapted to maintaining their position on gravel size or larger substrate in swift currents), and low abundances of taxa tolerant to environmental degradation. In the Northern Plains ecoregion (warmwater and coldwater), rivers and streams are "good" if they have higher relative abundance of EPT taxa, higher taxa richness, higher abundance of scrapers (which feed on benthic algae and bacteria), and lower abundances of pollution tolerant species. Generally, these metrics distinguish good biological condition in streams having diverse, pollution intolerant benthic macroinvertebrate communities inhabiting substrates with low levels of fine sediment.

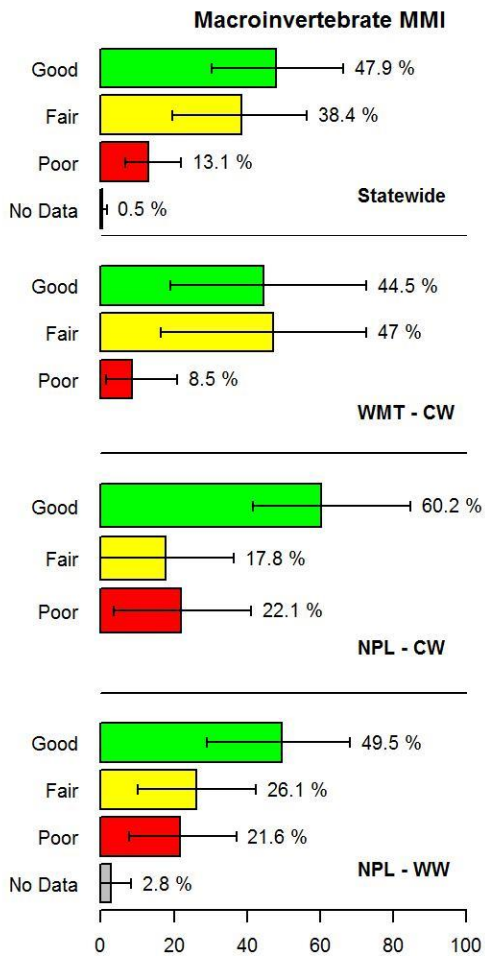
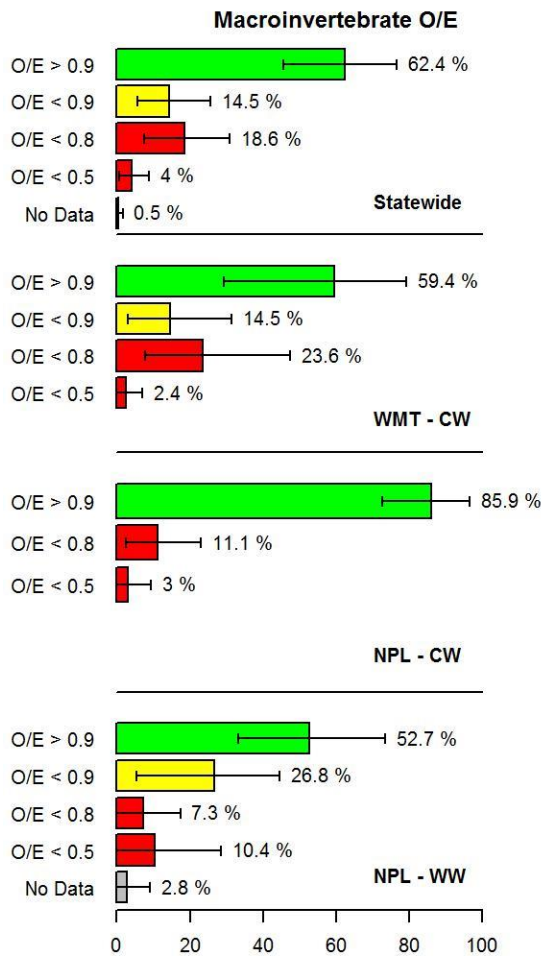


Figure 3. Biological condition of Montana's rivers and streams based on the Macroinvertebrate Multimetric Index. This index combines metrics of benthic community structure and function into a single index for each region. Stream groupings represent a combination of geographic location within an aggregated Omernik Level III ecoregion and stream designations according to the Administrative Rules of Montana 17.30.600: WMT-CW = Western Mountains-Coldwater; NPL-CW = Northern Plains-Coldwater; NPL-WW = Northern Plains-Warmwater.

The Macroinvertebrate MMI indicates that nearly half of Montana's river and stream length is in good condition (Figure 3). A greater percentage of coldwater streams located in the Northern Plains are in good condition compared to the other stream groups. Overall, conditions of Montana's rivers and streams based on this metric are better than those found nationally.

The NRSA used another metric to rate the biological condition of streams based on the macroinvertebrate assemblage. The Macroinvertebrate Observed/Expected Ratio of Taxa Loss (or O/E Taxa Loss) measures taxa that have been lost at a site. The taxa expected at individual sites (E) are predicted from a model developed from data collected at least-disturbed sites. By comparing the list of taxa observed (O) at a site with those expected to occur, the proportion of expected taxa that have been lost can be quantified as the ratio of O/E. O/E taxa loss models are calibrated for the specific natural conditions in each area for which they are used. For the NRSA, analysts developed O/E taxa loss models to predict the extent of taxa loss in each aggregated ecoregion. O/E Taxa Loss values range from 0 (none of the expected taxa are present) to slightly greater than 1 (more taxa are present than expected). Each tenth of a point less than 1 represents a 10% loss of taxa at a site, so a score of 0.9 indicates that 90% of the expected taxa are present and 10% are missing. Over 60% of

the statewide river and stream length showed very low levels of taxa loss (Figure 4). This is lower than the rates of taxa loss found nationally. In general, coldwater streams in Montana have lower rates of taxa loss than warmwater streams, and taxa loss is lowest in coldwater steams in the Northern Plains.



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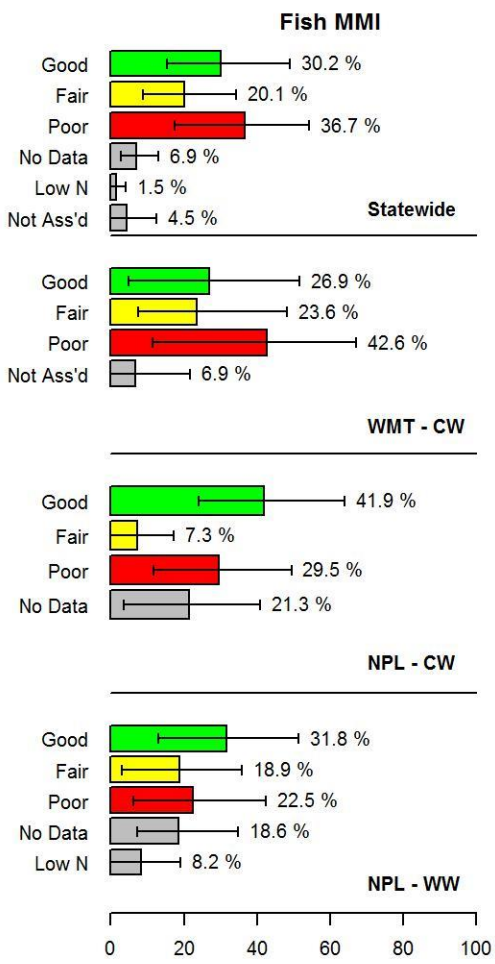
Fish are gill-bearing, skulled aquatic species that derive much of their food from macroinvertebrates and algae. They are also culturally important to humans and to other creatures for food. Their condition is an important indicator of river and stream health. NRSA scientists developed a Fish MMI for each ecoregion encountered in Montana. These indices were based on a variety of metrics including taxa richness, taxonomic composition, pollution tolerance, habitat and feeding groups, spawning habits, the number and percent of taxa that are migratory, and the percent of taxa that are native. These metrics tend to rate rivers and streams as good if they contain relatively high abundances of long-lived species that favor higher water quality, high abundances of species that require clean substrate for spawning, high abundances of native species, high abundances of herbivores and invertivores, and low abundances of species that are tolerant of environmental degradation. As shown in Figure 5, the NRSA Fish MMI indicates that 30% of Montana's rivers and streams are in good condition for this indicator, 20% are in fair condition, and 38% are in poor condition compared to least-



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disturbed conditions at reference sites. Introduced species, which are more tolerant of degraded stream habitat, may be contributing to the relatively high fraction of sites classified as poor. About 12% of the streams were not assessed for various reasons. A greater percentage of coldwater streams located in the Northern Plains is in good condition compared to the other stream groups. Overall, trends are very similar to those found nationally.

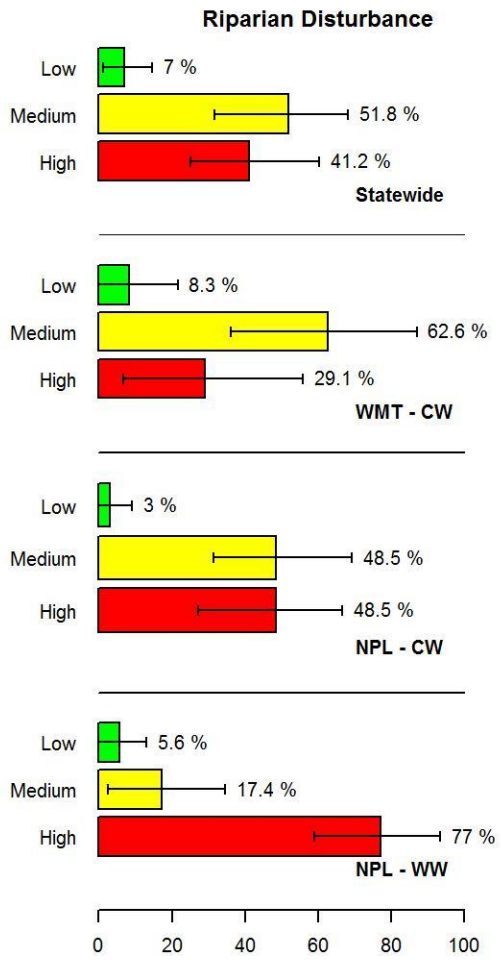
The statistical performance of these indicators has been validated nationally and they have a demonstrated ability to discriminate biological condition. Yet, biological indicators probably could be refined if they were developed using reference sites from solely within Montana's stream groups. As it is, the NRSA relies on rating thresholds based on reference sites collected through the greater plains and west climatic regions, respectively. Arguably, thresholds based on samples from biogeographically different regions may not be fully representative for Montana. The same could be said for any state. Furthermore, comparisons to national results are tempered by the variability exhibited by these metrics (shown as 95% confidence limits on the bar plots). Statistics are calculated from fewer samples within Montana than nationally; hence, confidence limits are larger. Because of the magnitude of this variability, there may be some differences that may not be statistically significant.

Despite these shortcomings, these metrics show a level of biological condition in Montana's rivers and streams that exceeds national trends. Such a result is plausible given lower levels of human disturbance found within the state compared to that in other more populated states with more intensive land use practices.

Among these results, one consistent trend emerges that warrants further discussion. That is, across trophic levels, a greater proportion of coldwater streams located in the Northern Plains are classified in good condition compared to either of the two other stream groups. Part of this can be due to the fact that metrics from these streams, which are coldwater and salmonid-bearing, are being compared to thresholds developed for warmwater, non-salmonid streams typically found in the plains and prairies landscapes. Biological conditions in coldwater streams might be expected to be inherently better than in warmwater streams when rated on a common scale. Therefore, the proportions of good biological conditions reported for these streams might be artificially high. However, this trend may indicate that biota may be responding to real differences in habitat quality in coldwater vs. warmwater streams in the Northern Plains. That is, besides inherent differences, these results may be reflecting the fact that habitat degradation may be greater among the warmwater streams. Even with the discrepancy in scales, better habitat conditions in coldwater streams in the Northern Plains could be supporting more healthy and robust biological communities than in their warmwater counterparts. Such differences will be explored further in the next section. Nevertheless, it is important to stress that despite this confounding factor, biological conditions in Montana streams tend to rate better than those found nationally, regardless of which stream group they belong to. This distinction between biological conditions in coldwater and warmwater streams in the Northern Plains is unique to Montana and likely to other states along the Rocky Mountain front.

Physical Stressors

Four physical stressors were assessed as indicators in the NRSA: excess streambed sediments, in-stream fish habitat, riparian (streamside) vegetative cover, and riparian disturbance. The closer harmful human activities are to a river or stream, the more impact they will have on it. The NRSA uses a direct measure of riparian human disturbance that tallies 11 specific forms of human activities and their proximity to the river or stream in 22 riparian plots along the water body. Examples of human disturbance include roads, pavement and cleared lots, buildings, pastures and rangeland, row crops, dams, and logging or mining operations. Disturbance occurring within the water body or on its banks were weighted higher than those occurring in adjacent riparian areas or beyond. The same disturbance criteria were applied to define high, medium, and low riparian disturbance in streams and rivers nationwide. In Montana, nearly all sites rated with low riparian disturbance had zero observed forms of human disturbance and most sites rated with high riparian disturbance had the equivalent of about two forms of disturbance observed in all riparian plots. Using this index, a low percentage (<10%) of Montana's rivers and streams are rated with low riparian disturbance (Figure 6). This is well below the proportion of rivers and streams with low disturbance found nationally. Increasing levels of high riparian



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disturbance are evident from Western Mountains coldwater sites east to Northern Plains warmwater sites. Over three-quarters of warmwater sites have high levels of riparian disturbance typified by human activity occurring in close proximity to the river or stream. This far exceeds the national rate. In eastern Montana, much of this disturbance is due to agriculture. In comparison, a low proportion of coldwater streams have high levels of riparian disturbance; this is also greater than that found nationally.

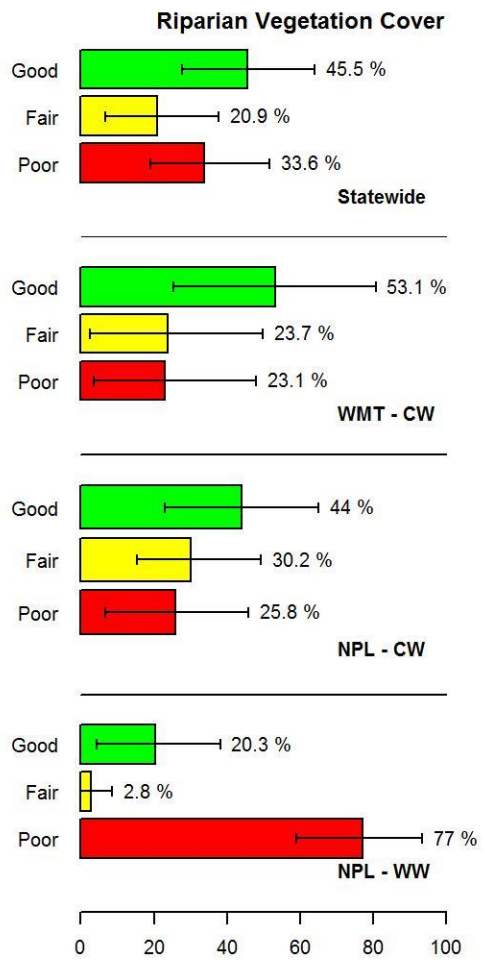

Figure 7. Riparian vegetative cover in Montana's rivers and streams (EPA/NRSA). Stream groupings represent a combination of geographic location within an aggregated Omernik Level III ecoregion and stream designations according to the Administrative Rules of Montana 17.30.600: WMT-CW = Western Mountains-Coldwater; NPL-CW = Northern Plains-Coldwater; NPL-WW = Northern Plains-Warmwater.

These trends in riparian disturbance likely influence similar trends in vegetation cover. A river or stream can be buffered from the effects of human disturbance in the watershed by varied, multi-layered vegetation in the land corridor that surrounds it. Healthy, intact vegetative cover in these riparian areas can help reduce nutrient and sediment runoff from the surrounding landscape, prevent streambank erosion, provide shade to reduce water temperature, and provide leaf litter and large wood (such as branches and logs) to serve as food, shelter, and habitat for aquatic organisms. Riparian disturbance can adversely affect this. The NRSA uses a measure of riparian vegetative cover that sums the amount of cover provided by three layers of riparian vegetation: the ground layer, woody shrubs, and canopy trees. Because the amount and complexity of riparian vegetation differs naturally within and among ecoregions, lower-than-expected riparian vegetative cover was assessed by comparison with expected values at least-

disturbed sites estimated within ecoregions. The definition of poor and good riparian vegetation cover was set as that below and above the reference mean minus or plus 1.65 * the SD of reference sites. Statewide, about 45% of rivers and streams are in good condition (see Figure 7). This is lower than the rate found nationally. Warmwater streams have a very high rate of poor vegetation cover, correlating with high rates of riparian disturbance. Coldwater streams have better riparian vegetation cover.

Trends in riparian disturbance likely also influence trends in instream habitat. The healthiest and most diverse communities of fish and macroinvertebrates are found in rivers and streams that have complex and varied forms of habitat, such as boulders, undercut banks, tree roots, and logs within the stream banks. Human use of rivers and streams and their adjacent riparian areas often results in the removal or loss of much of this habitat, which in turn affects the biological condition of the stream. The NRSA uses a habitat complexity measure that sums the amount of in-stream fish habitat and concealment features such as undercut banks, boulders, large pieces of wood, and cover from overhanging vegetation within the water body and its banks. Because this measure differs naturally within and among ecoregions, low in-stream fish habitat complexity was assessed by comparison with expected values at least-disturbed sites adjusted for factors such as geography and climate within ecoregions. Thresholds were

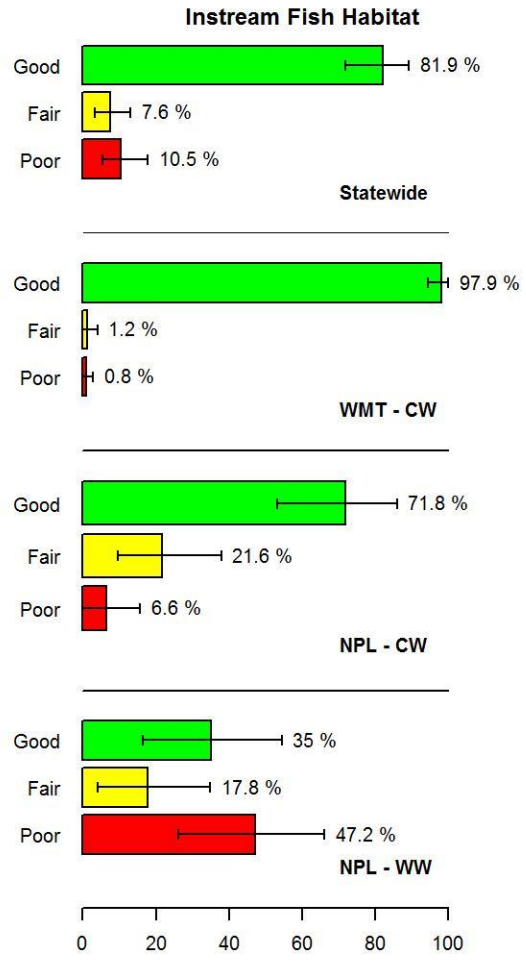

Figure 8. Instream fish habitat in Montana's rivers and streams (EPA/NRSA). Stream groupings represent a combination of geographic location within an aggregated Omernik Level III ecoregion and stream designations according to the Administrative Rules of Montana 17.30.600: WMT-CW = Western Mountains-Coldwater; NPL-CW = Northern Plains-Coldwater; NPL-WW = Northern Plains-Warmwater.

set for this metric analogous to the methods used for riparian vegetation cover. Statewide, over 80% of rivers and streams are in good condition (see Figure 8). However, there are differences among stream groups, similar to that observed for riparian vegetation. Nearly all streams in the Western Mountains are in good condition and a high percentage of coldwater streams in the Northern Plains are also in good condition. But, only about half of warmwater rivers and streams are in good condition.

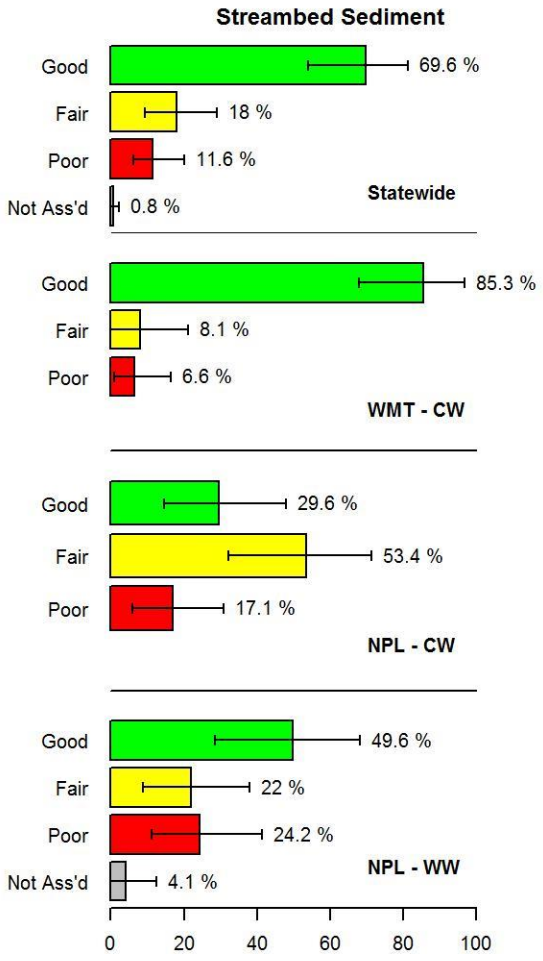

Figure 9. Streambed sediment conditions in Montana's rivers and streams (EPA/NRSA). Stream groupings represent a combination of geographic location within an aggregated Omernik Level III ecoregion and stream designations according to the Administrative Rules of Montana 17.30.600: WMT-CW = Western Mountains-Coldwater; NPL-CW = Northern Plains-Coldwater; NPL-WW = Northern Plains-Warmwater.

Numerous land use practices can lead to increased hillslope erosion and mass wasting leading to delivery of sediments to streams. Channel alterations due to instream activities or altered hydrology can also increase the amount of sediment in streams. As this sediment settles on the streambed, the interstitial spaces between gravel and cobble can fill with fine sediment—adversely impacting periphyton, macroinvertebrates, and fish that depend on clean substrates. For the NRSA, scientists assessed excess streambed sediment by measuring the ratio between particle size of observed sediments to the size of sediments each river or stream can move during its flood stage. This ratio, also known as relative bed stability (RBS), differs naturally between the coldwater and warmwater regions because of differences in geology, topography, hydrology, and vegetation. A high RBS indicates sediment removal (little excess sediment) while increasingly lower RBS values indicate increasing excess sediment. The definition

of poor condition was set as those sites with logarithm of RBS (LRBS) below the reference mean LRBS minus 1.65 * the SD of reference sites. Sites in good condition with respect to this indicator were those with LRBS above the reference mean LRBS minus 0.67 * the SD of reference sites. In Montana, about 70% of river and stream length are in good condition (see Figure 9). This is slightly greater than the proportion of rivers and streams found nationally. Over 85% of Western Mountains rivers and streams are in good condition; this is greater than the rate found nationally. However, in comparison, only 30 to 50% of rivers and streams in the Northern Plains are in good condition; this is lower than the national rate. Streambed sediments are slightly greater in the coldwater streams in the Northern Plains than in their warmwater counterparts.

Overall, these results show that there is a consistent correlation between increasing levels of high riparian disturbance, west to east, and decreasing riparian and instream habitat conditions. The cause and effect of riparian perturbation on habitat quality is well-established and is the basis for riparian protection measures throughout the US. Among many effects, riparian disturbance by definition leads to decreased vegetation cover, decreased inputs of large woody debris and nutrients, increased soil disturbance and erosion, and decreased ability of the buffer to limit sediment delivery. Through the NRSA monitoring, we are seeing this relationship demonstrated on a state-wide scale. Generally, the Western Mountains have the lowest levels of riparian disturbance and the greatest levels occur along warmwater streams in the Northern Plains. Coincidently, physical habitat conditions are best and worst in these stream groups, respectively. Within the Northern Plains, coldwater streams have the lower levels of riparian disturbance than warmwater streams. And, coincidently, physical habitat conditions are better in coldwater streams. Overall, this gradient in riparian disturbance and physical habitat conditions, west to east, is likely meaningful. Generally, habitat conditions in Montana's coldwater streams are better than in warmwater streams.

Chemical Stressors

Four chemical stressors were assessed as indicators in the NRSA: total phosphorus, total nitrogen, salinity, and acidification. These stressors were selected because of national or regional concerns about the extent to which they might be affecting the quality of the biological communities in rivers and streams, and to allow comparison with earlier monitoring efforts. Scientists developed thresholds for interpreting the data for these indicators from a set of least-disturbed reference sites for each climatic region. Total nitrogen and phosphorus were classified using a method similar to that used for biological condition classes. For nutrients, the value at the 25th percentile of the reference distribution was selected for each region to define the least-disturbed condition class. The 5th percentile of the reference distribution defines the most disturbed condition class. For setting nutrient class boundaries, only reference sites from the screened WSA dataset were used. These thresholds, along with Montana state standards for each ecoregion, are summarized in Table 1. Generally, Montana standards coincide with EPA-derived thresholds distinguishing fair and poor conditions.

Table 1. Summary of nutrient category criteria for NRSA assessment (µg/L).

Ecoregion	Threshold	Total N	Total P
Western Mountains	State Standard[1]	275-325	25-30
	Good-Fair	131	14
	Fair-Poor	229	36
Warmwater	State Standard[1]	1300	110-150
	Good-Fair	948	91.8
	Fair-Poor	1570	183

1 – MDEQ Circular DEQ-12, Version 6.7, Table 12A-1, Level III Ecoregion Standards

Phosphorus and nitrogen are essential nutrients in aquatic environments, but tend to occur naturally at low concentrations. Therefore, even small increases can affect water quality and biological condition. At high concentrations, they can stimulate excess growth of algae and large aquatic plants which can lead to low dissolved oxygen levels and degraded habitat for benthic macroinvertebrates and fish. Algae blooms can

produce toxins that are harmful to human and animal health. At the statewide level, about two-thirds of rivers and streams are in good condition for total phosphorus and nearly 90% are in good condition for total nitrogen (**Error! Reference source not ound.**). The poorest nutrient conditions were found in the Western Mountains; nearly 40% exceeded the threshold of 229 µg/L. Otherwise, the proportion of poor total phosphorus conditions in the other stream groups was less than 10%. Poor total nitrogen conditions occurred infrequently throughout the state. With the exception of total phosphorus in the Western Mountains, nutrient conditions are better than those found nationally.

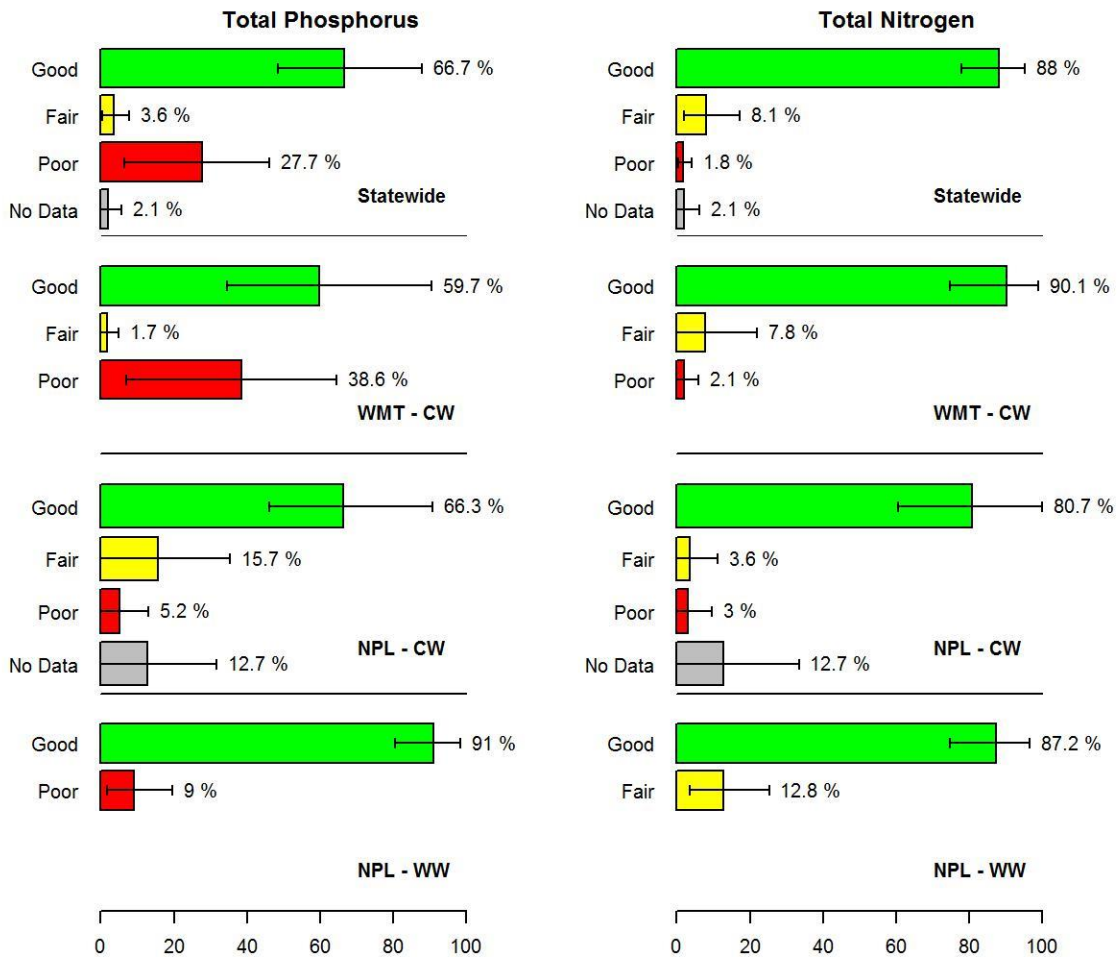

Figure 10. Total phosphorus and nitrogen concentrations in Montana's rivers and streams (EPA/NRSA). Percent of river and stream length in good, fair, and poor, condition based on phosphorus and nitrogen concentrations compared to least disturbed regional reference sites. Stream groupings represent a combination of geographic location within an aggregated Omernik Level III ecoregion and stream designations according to the Administrative Rules of Montana 17.30.600: WMT-CW = Western Mountains-Coldwater; NPL-CW = Northern Plains-Coldwater; NPL-WW = Northern Plains-Warmwater.

Salts can be toxic to freshwater plants and animals and can make water unsafe for drinking, irrigation, and livestock watering. Excess salinity can occur in areas where evaporation is high and can be made worse by repeated use of water for irrigation or water withdrawals. It can also occur from stormwater and wastewater discharges. Conductivity (a measure of water's ability to pass an electrical current) was used as a measure of salinity. Salinity conditions are good in nearly all Western Mountain rivers and streams (Figure 11). This rate of nearly 99% is slightly higher than the rate found nationally. Nearly 80 percent of coldwater streams in the Northern Plains are also in good condition. This, too, is also a relatively high rate, but lower than the national rate. Among warmwater sites, salinity conditions are good about half the time. This is much lower than found nationally. The geology of the Northern Plains, water moving through the soil profile as a result of farming systems (e.g., irrigation), and climate are responsible for the development of saline seeps in the region that contribute to surface water salinity. This is fairly common in the Northern Plains (Brown et al. 1983). Statewide, about 80% of rivers and streams are considered in good condition for salinity. This is slightly lower than the rate found in rivers and streams nationally, due primarily to the lower rate of good salinity conditions found among warmwater rivers and streams in the Northern Plains.

Atmospheric acid deposition and acid mine drainage are two primary concerns for acidification of the nation's rivers and streams. In Montana, both sources can occur but of greatest concern would be acid drainage from abandoned mines. This is known to occur locally and be locally important, but it does not occur at a high enough frequency to be detected by an extensive survey such as NRSA. That is, acidification of Montana's rivers and streams does occur and when it does it can be damaging to the aquatic environment, but the 62 samples collected during NRSA does not adequately characterize this impact. Using a probabilistic sampling design such as NRSA, these degraded streams would likely not be picked by chance. According to the NRSA survey, all Montana rivers and streams are in good condition for acidification (Figure 12). This is comparable to rates found nationally.

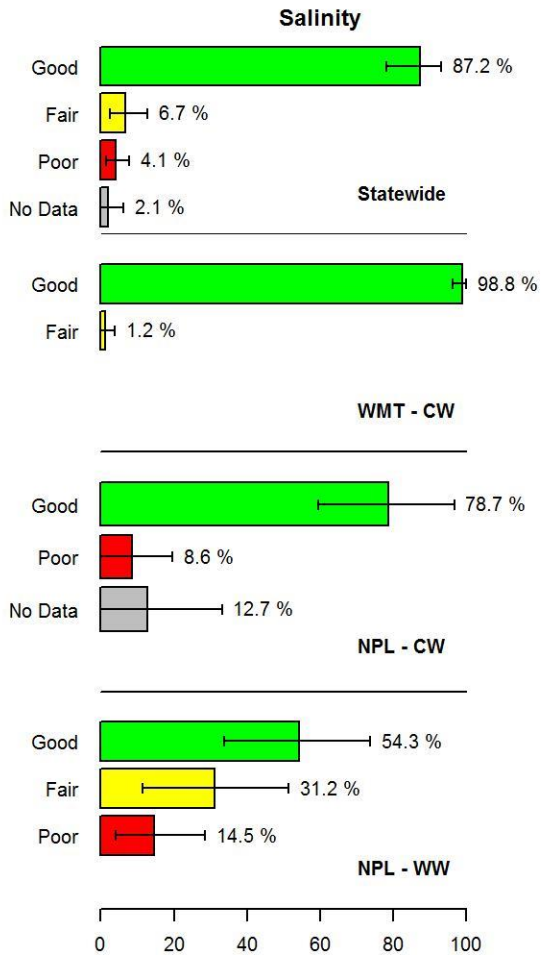

Figure 11. Salinity conditions in Montana's rivers and streams (EPA/NRSA). Thresholds are based on conditions of least disturbed regional reference sites. Indicator based on electrical conductivity. Stream groupings represent a combination of geographic location within an aggregated Omernik Level III ecoregion and stream designations according to the Administrative Rules of Montana 17.30.600: WMT-CW = Western Mountains-Coldwater; NPL-CW = Northern Plains-Coldwater; NPL-WW = Northern Plains-Warmwater.

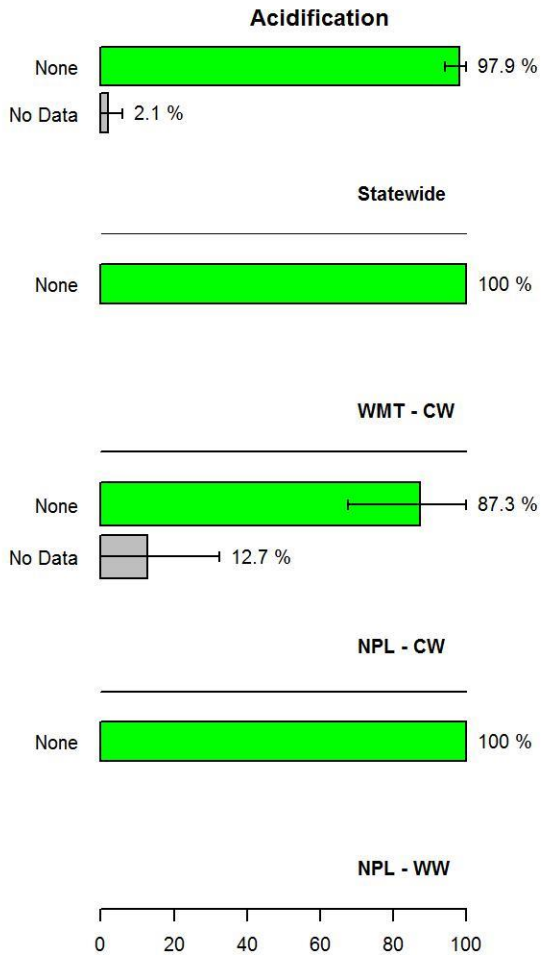

Figure 12. Acidification in Montana's rivers and streams (EPA/NRSA). Stream groupings represent a combination of geographic location within an aggregated Omernik Level III ecoregion and stream designations according to the Administrative Rules of Montana 17.30.600: WMT-CW = Western Mountains-Coldwater; NPL-CW = Northern Plains-Coldwater; NPL-WW = Northern Plains-Warmwater.

Health Indicators

Two human health indicators were assessed in the NRSA: mercury in fish tissue and the pathogen indicator enterococci. The human health fish tissue indicator focused on a subsample of fifth-order and larger rivers. Given that levels of mercury in fish tissue vary but tend to increase with size and trophic level, this focus was intended to address both fish taken for subsistence and for sportfishing and produce assessment results that could be comparable across all the waters sampled. The sampled population is the portion of the target subpopulation for which we can determine whether mercury levels were above or below the human-health-based screening value. Subsampled sites are indicated in the site listing in Appendix A. Two tissue samples were collected from Western Mountains rivers; eight samples were taken from rivers in the Northern Plains (two in rivers designated coldwater and six in warmwater rivers). Samples were analyzed for total mercury and compared to EPA's 300 parts per billion human-health-based water quality criterion for mercury. Of the two samples collected from coldwater rivers, one exceeded this standard (northern pike minnow from the Clark Fork). Of the eight samples collected from warmwater streams, one exceeded this standard (channel catfish from the Tongue River). Given the low sampling rate, we did not infer the proportion of fifth-order and larger rivers exceeding this standard.

Enterococci are bacteria that live in the intestinal tracts of warm-blooded animals, including humans, and therefore indicate possible contamination of streams and rivers by fecal waste. Enterococci are typically not considered harmful to humans, but their presence in the environment may indicate that other disease-causing agents such as viruses, bacteria, and protozoa may also be present. Sources of fecal indicator bacteria such as enterococci include wastewater treatment plant effluent, leaking septic systems, stormwater runoff, sewage discharged or dumped from recreational boats, domestic animal and wildlife waste, improper land application of manure or sewage, and runoff from manure storage areas, pastures, rangelands, and feedlots. There are also natural, non-fecal sources of fecal indicator bacteria, including plants, sand, soil, and sediments, that contribute to a certain background level in ambient waters and vary

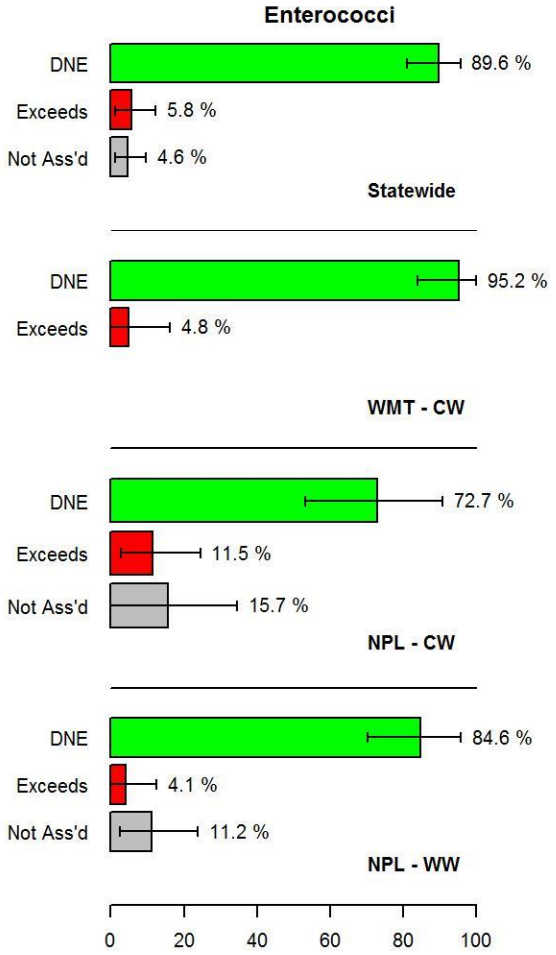

Figure 13. Enterococci human health thresholds exceedance in Montana's rivers and streams (EPA/NRSA). Percent of rivers and streams length exceeding or not exceeding EPA human health thresholds for enterococci. Stream groupings represent a combination of geographic location within an aggregated Omernik Level III ecoregion and stream designations according to the Administrative Rules of Montana 17.30.600: WMT-CW = Western Mountains-Coldwater; NPL-CW = Northern Plains-Coldwater; NPL-WW = Northern Plains-Warmwater.

based on local environmental and meteorological conditions. For the NRSA, water samples were analyzed using a process known as quantitative polymerase chain reaction, or qPCR, a methodology that facilitates the detection of DNA sequences unique to these bacteria. Analysts compared the NRSA results to a new EPA qPCR threshold for protecting human health in ambient waters designated for swimming (1,000 calibrator cell equivalents per 100 milliliter). This threshold is lower than that used in the national assessment; therefore, comparisons to national rates cannot be made. Nevertheless, few samples exceeded this human-health standard statewide (Figure 13). Exceedance is greatest in the Northern Plains, and is highest among coldwater streams in this ecoregion despite a relatively higher percentage of streams not being tested.

Discussion

Synthesis of the NRSA results also provides an opportunity to assess the influence of stressors on the biological condition of Montana's rivers and streams. One way is to evaluate the relative extent of each stressor. That is, assess how extensive any particular stressor is (e.g., how many miles of rivers and streams have excess phosphorus concentrations). Nationwide, the greatest extent of poor conditions were found for total phosphorus (40% of rivers and streams had poor conditions), total nitrogen (28%), riparian cover (24%), and riparian disturbance (20%). This trend was more or less consistent across the nation. In Montana, total phosphorus, riparian disturbance, and riparian cover also have the greatest extent of poor conditions throughout the state (Figure 14). However, there are meaningful differences between ecoregions. In the Western Mountains, the relative extent of poor total phosphorus conditions is greater than the relative extent of physical habitat stressors. In the Northern Plains, the

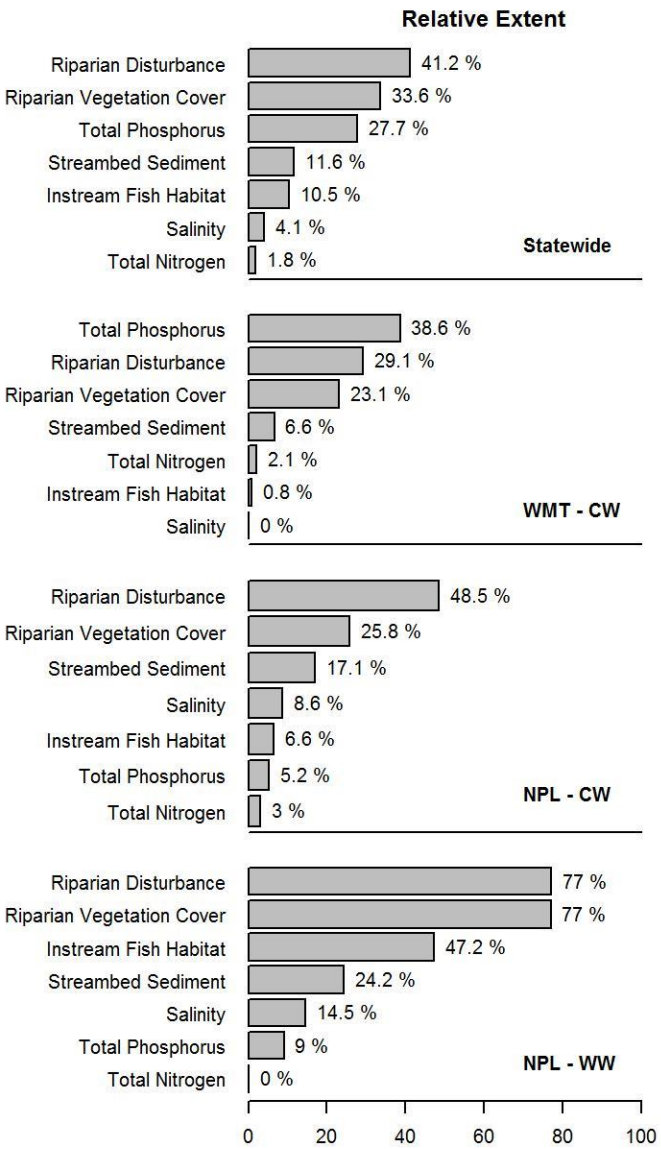

Figure 14. Relative extent of stressors in Montana's rivers and streams (EPA/NRSA). Stream groupings represent a combination of geographic location within an aggregated Omernik Level III ecoregion and stream designations according to the Administrative Rules of Montana 17.30.600: WMT-CW = Western Mountains-Coldwater; NPL-CW = Northern Plains-Coldwater; NPL-WW = Northern Plains-Warmwater.

relative extent of riparian disturbance and low riparian vegetation cover is greater. Notably, the extent of poor conditions in warmwater streams in the Northern Plains is greater than that found nationwide, especially the high levels of riparian disturbance and poor riparian vegetation cover. The extent of poor stream conditions in the other stream groups is more or less comparable to the extent of poor conditions found nationally.

To evaluate the severity of the impact when a stressor occurs we used a metric named "relative risk". Relative risk is the ratio of the likelihood of finding poor biological conditions in a river or stream when stressor conditions are poor to the likelihood of poor biological conditions when stressor conditions are good. A relative risk value that exceeds 1 indicates that the stressor is more likely to be associated with poor biological conditions than good conditions. A relative risk value less than 1 indicates that the stressor likely does not have an effect on biological condition. After calculating this metric, we found the following situations where poor stressor condition led to an increased likelihood of poor biological condition (stressors are listed in order, highest relative risk to lowest relative risk greater than 1):

- Western Mountains - Coldwater
    - Periphyton: total nitrogen
    - Macroinvertebrates: instream sediment, riparian cover, total nitrogen
    - Fish: streambed sediment, riparian vegetation cover
- Northern Plains - Coldwater
    - Periphyton: total nitrogen, total phosphorus, streambed sediment
    - Macroinvertebrates: total nitrogen, total phosphorus, riparian disturbance
    - Fish: riparian vegetation cover, riparian disturbance
- Northern Plains - Warmwater
    - Periphyton: salinity, total phosphorus
    - Macroinvertebrates: salinity, streambed sediment
    - Fish: instream fish habitat

Several of these stressors had very high relative risk values, indicating that when the stressor occurred at very high levels, biological conditions would be poor. These included: poor streambed sediments leading to poor macroinvertebrate and fish conditions in the Western Mountains; poor total nitrogen conditions leading to poor periphyton and macroinvertebrate conditions in coldwater streams in the Northern Plains; and poor salinity conditions leading to poor fish conditions in warmwater rivers and streams in the Northern Plains. It's notable that despite these stressors having relatively limited extent (see Figure 14), poor biological conditions are always associated with them. Poor habitat conditions due to these stressors do not appear to happen as often as others, but when they do occur, biological conditions suffer.

Overall, these results indicate that there is room for improving the biological condition of Montana streams by improving habitat conditions. But, with the exception of those instances of high relative risk (above), improvement needs to occur on several fronts. In the Western Mountains, results indicate that emphasis placed on improving physical conditions and water chemistry could be beneficial. Riparian vegetation cover had a high relative risk for macroinvertebrates and fish and, although not exceeding 1, it represented the second highest relative risk factor affecting periphyton. Improving riparian vegetation cover could improve conditions at all trophic levels. Poor riparian conditions affect nearly one-third of Western Mountains rivers and streams, so there is a lot of opportunity for improvement. In comparison, water chemistry is not as limiting. Total nitrogen, while having a high relative risk, is limited in extent. And, total phosphorus, while having the greatest relative extent, has very low relative risk. Nonetheless, marginal improvements are possible through improving water chemistry.

In the Northern Plains, improving riparian conditions, instream habitat, and water chemistry all appear to be important to improving biological conditions. In coldwater streams, improving nutrient conditions and instream sediment could be very important to improving biological conditions in the lower trophic levels. But these risk factors have lower relative extent. Poor riparian conditions are more extensive. There are more opportunities for reducing riparian disturbance and improving riparian vegetation cover.

These could have benefits to fish and macroinvertebrates. In warmwater streams, attention to all facets of environmental stress appears to be warranted. High riparian disturbance occurs along over three-quarters of warmwater streams. While not identified as directly leading to a greater likelihood of poor biological conditions, it is arguable that disturbance likely affects physical stressors and water chemistry—factors that do have high relative risk. Agricultural land use is common along these streams and could be accounting for increased salinity (e.g., Brown et al. 1982) and for poor nutrient conditions as well as for poor instream fish habitat and sedimentation.

Overall, it is important to put these findings in their proper context. Despite these risk factors, biological conditions in Montana streams tend to rate better than those found nationally. Most notably, biological conditions at the lower trophic levels are much better than those found nationally; the condition of the fish assemblage is more or less comparable. However, this is no reason to downplay the affects environmental stressors are having on Montana's rivers and streams. This report gives a broad overview of the nature and extent of factors most limiting to biological conditions. It offers useful suggestions about habitat factors to focus on for improving biological conditions. There are areas with room for improvement. But, such results can only provide important background for understanding the health of Montana rivers and streams. It can only be through watershed-level, site-specific investigation that meaningful remedies can be developed. Information in this report is just a start.

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Appendix A: Rivers and Streams Sampled in Montana in the NRSA

Stream Group[1]	Stream Size[2]	Site ID	Stream Name	Sample Date	Latitude	Longitude
NPL - CW	NW	FW08MT039	South Fork Musselshell River	7/15/2008	46.45774768	-110.3713081
NPL - CW	NW	FW08MT043	Missouri River above Great Falls*	9/16/2008	47.45160978	-111.3012823
NPL - CW	NW	FW08MT058	Sun River*	6/30/2009	47.61666091	-112.6810588
NPL - CW	W	FW08MT002	Bear Creek near Belfry	7/29/2008	45.14160685	-109.039941
NPL - CW	W	FW08MT004	Highwood Creek	7/17/2008	47.49900796	-110.7164261
NPL - CW	W	FW08MT014	Squaw Creek	7/1/2008	47.08177722	-111.5943272
NPL - CW	W	FW08MT019	Clear Creek	7/22/2009	48.27114172	-109.5269269
NPL - CW	W	FW08MT023	Little Timber Creek	7/24/2008	45.83768591	-110.045797
NPL - CW	W	FW08MT030	Shields River	7/21/2008	46.16676666	-110.5490957
NPL - CW	W	FW08MT036	Willow Creek	6/10/2009	48.56932334	-112.9000922
NPL - CW	W	FW08MT044	Hay Coulee	9/8/2009	45.43382265	-107.7781915
NPL - CW	W	FW08MT052	Willow Creek	6/11/2009	48.99086339	-113.198807
NPL - CW	W	FW08MT060	Little Bighorn River	7/30/2008	45.03420574	-107.5853158
NPL - CW	W	FW08MT066	Rock Creek	8/26/2009	45.34771317	-109.1693839
NPL - CW	W	FW08MT071	Unnamed	8/20/2008	47.11536955	-111.3767773
NPL - CW	W	FW08MT088	Clear Creek	7/21/2009	48.54946815	-109.3916757
NPL - CW	W	FW08MT090	Deep Creek	8/19/2009	47.72171679	-112.4911162
NPL - CW	W	FW08MT091	Sage Creek	8/4/2009	47.05425104	-110.163839
NPL - CW	W	FW08MT094	Flathead Creek	8/25/2009	45.99350064	-110.7352848
NPL - CW	W	FW08MT098	East Rosebud Creek	9/30/2009	45.30787397	-109.5258136
NPL - CW	W	FW08MT103	Bozeman Fork Musselshell River	8/24/2009	46.32795499	-110.6049339
NPL - CW	W	FW08MT111	West Fork Clear Creek	9/10/2009	48.18045069	-109.5509106
NPL - CW	W	FW08MT124	Short Canyon Creek	8/28/2009	45.00147924	-107.6834348
NPL - WW	NW	FW08MT025	Missouri River at Culbertson*	9/15/2009	48.07661344	-104.3912468
NPL - WW	NW	FW08MT029	Musselshell River	7/8/2008	46.56603822	-107.9657348
NPL - WW	NW	FW08MT031	Missouri River	9/15/2008	47.41435002	-111.4986355
NPL - WW	NW	FW08MT032	Tongue River at Niles City*	7/29/2009	46.35962704	-105.8140482
NPL - WW	NW	FW08MT033	Beaver Creek	9/9/2009	48.34598235	-107.5838059
NPL - WW	NW	FW08MT041	Yellowstone River*	7/30/2009	46.8678342	-104.9952025
NPL - WW	NW	FW08MT045	Box Elder Creek	7/10/2008	47.0151948	-108.1650054
NPL - WW	NW	FW08MT047	Big Sandy Creek	6/16/2009	48.457665	-109.9263753
NPL - WW	NW	FW08MT048	Rosebud Creek	7/7/2008	46.11059188	-106.4503921
NPL - WW	NW	FW08MT049	Missouri River (Fort Peck Reach)*	9/16/2009	48.00521118	-105.9092292
NPL - WW	NW	FW08MT050	Stillwater River*	9/24/2008	45.59731978	-109.3116046
NPL - WW	NW	FW08MT061	Beaver Creek	6/28/2009	48.14732714	-107.5489961
NPL - WW	NW	FW08MT063	Missouri River*	7/20/2009	47.79247326	-109.2767963
NPL - WW	W	FW08MT006	Frenchman Creek	6/23/2009	48.91180622	-107.308237
NPL - WW	W	FW08MT008	Fish Creek	7/23/2008	46.25086868	-109.769586
NPL - WW	W	FW08MT012	Tule Creek	5/20/2009	48.22390983	-105.5177517

NPL - WW	W	FW08MT013	Twelve Mile Creek	9/25/2008	45.91293536	-108.4087977
NPL - WW	W	FW08MT053	Poplar River	9/16/2009	48.72954904	-105.4411635
NPL - WW	W	FW08MT056	Rock Creek	6/24/2009	48.9432344	-106.8565292
NPL - WW	W	FW08MT059	Pondera Coulee	5/19/2009	48.14320727	-112.1246251
NPL - WW	W	FW08MT080	Ranch Creek	7/13/2009	45.05170882	-105.2142905
NPL - WW	W	FW08MT093	Unnamed	9/9/2009	46.78491673	-108.5938921
WMT - CW	NW	FW08MT022	Clark Fork*	7/8/2009	47.06636155	-114.7698502
WMT - CW	NW	FW08MT024	Swan River	8/6/2008	48.07746729	-114.0187155
WMT - CW	NW	FW08MT035	Medicine Lodge Creek	8/25/2008	44.97626082	-112.9965913
WMT - CW	NW	FW08MT042	Swan River	8/5/2008	47.90948388	-113.8707
WMT - CW	NW	FW08MT062	Jefferson River*	9/22/2008	45.90936211	-111.5668902
WMT - CW	W	FW08MT001	Tributary to Tenderfoot Creek	7/16/2008	46.93088969	-110.8698447
WMT - CW	W	FW08MT005	Pintler Creek	9/9/2008	45.90723297	-113.4809371
WMT - CW	W	FW08MT007	West Fork Lolo Creek	9/29/2008	46.68544062	-114.5589588
WMT - CW	W	FW08MT010	Lone Pine Creek	8/17/2009	47.21185412	-112.4959016
WMT - CW	W	FW08MT015	South Fork Little Joe Creek	7/7/2009	47.2076157	-115.220465
WMT - CW	W	FW08MT017	Hungry Horse Creek	7/6/2009	48.35356432	-113.8808058
WMT - CW	W	FW08MT020	West Fork Elk Creek	9/30/2008	48.00504903	-116.0016672
WMT - CW	W	FW08MT038	Bassoo Creek	10/1/2008	47.83706182	-114.7376506
WMT - CW	W	FW08MT051	Noble Fork	8/26/2008	45.53162435	-112.1075066
WMT - CW	W	FW08MT054	Lost Creek	9/10/2008	46.15890312	-112.9050686
WMT - CW	W	FW08MT055	Mule Creek	7/14/2008	46.5855868	-111.2657088
WMT - CW	W	FW08MT087	Madison River	7/27/2009	44.69396024	-111.0906576

Notes:
1 – Stream groupings represent a combination of the sites geographic location within an aggregated Omernik Level III ecoregion and stream designations according to the Administrative Rules of Montana 17.30.600: NPL-CW=Northern Plains – Coldwater; NPL-WW=Northern Plains – Warmwater; WMT-CW=Western Mountains – Coldwater.
2 – Stream size is determined by EPA using Strahler stream order: NW=Non-wadeable (Strahler stream order 1 through 4; W=Wadeable (Strahler stream order 5 and greater). Stream size designations may not concur with wadeable and non-wadeable stream designations according to State of Montana standards.
* - Site subsampled for assessment of mercury in fish tissue.