Water Quality Condition of Wyoming Perennial Streams and Rivers

Results of the First (2004-2007) and Second (2008-2011) Statewide Probability Surveys

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EXECUTIVE SUMMARY

The Wyoming Department of Environmental Quality-Water Quality Division's (WDEQ/WQD) first and second statewide probabilistic surveys of perennial streams and rivers were conducted during 2004-2007 and 2008-2011, respectively. Results from these surveys provide an objective current status and summary of trends in the biological condition of Wyoming's perennial streams and rivers and identifies the most important potential stressors. Information obtained from these probabilistic surveys also allows Wyoming to fulfill State obligations under §305(b) of the federal Clean Water Act. These surveys represent a more focused and representative effort to evaluate the biological condition of Wyoming's perennial streams and rivers relative to findings from a previous analysis as part of the Environmental Monitoring and Assessment Program (EMAP-West). EMAP-West was a regional probabilistic survey implemented by the United States Environmental Protection Agency (USEPA) during 2000-2003, to evaluate the biological condition of perennial streams and rivers in 12 western states, including Wyoming.

WDEQ/WQD's statewide surveys includes all non-headwater (>1st Strahler order) perennial streams and rivers that are not located in national parks, United States Forest Service wilderness areas and the Wind River Reservation. This equates to approximately 17,513 miles (based on the most accurate NHD+ digital stream coverage) of perennial streams and rivers or almost one-half of the total miles of perennial streams and rivers in Wyoming. Biological condition was evaluated at both the statewide scale and separately for three climatic regions of the State: mountain, plains and xeric.

According to the most recent statewide survey conducted in 2008-2011, 58% of the perennial streams and rivers in Wyoming were in the least-disturbed biological condition or comparable to reference expectations. This percentage is statistically similar to that estimated during 2004-2007 (53%) and the period 2000-2003 (52%). Approximately 18% of Wyoming's perennial stream and river length is considered most-disturbed, implying an appreciable deviation from reference expectations associated with anthropogenic stressors. This estimate is similar to the first statewide survey (22%) though represents a significant reduction since the 32% of most-disturbed perennial stream miles documented during EMAP-WY.

Based on the second statewide survey, 81% of perennial streams in the mountains climatic region were in the least-disturbed biological condition – a significant increase from 66% in the first statewide survey and 51% for EMAP-WY. The percentage of perennial streams in the least-disturbed condition for the plains was 39% (similar to the 41% in the first statewide survey) and 53% in the Xeric. The percentage of least-disturbed stream miles in the xeric during the second survey was similar to the first statewide survey of 48% and EMAP-WY (66%), though the decrease from EMAP-WY to the first statewide survey was significant. The percentage of perennial streams in the most-disturbed biological condition was 4% in the mountains – a significant reduction from the 18% in the first statewide survey and 33% during EMAP-WY. The percentage of perennial stream miles in the plains with a most-disturbed biological condition remained similar between the first (33%) and second (24%) statewide surveys. Approximately 25% of the perennial streams in the xeric region were in the most-disturbed biological condition, which is statistically equivalent to the 19% from the first statewide survey and 26% during EMAP-WY. A combination of drought-induced effects, record high flows and historical and current anthropogenic disturbances are presumed responsible for the less favorable biological conditions and their temporal trends within the xeric and plains regions.

Channel instability and total suspended solids (TSS) were consistently the most widespread

stressors for both statewide surveys that influence biological condition. Based on the most recent statewide survey, channel instability was among the top two most common stressors in all three climatic regions. Riparian disturbance was the second most common stressor in the mountain and the most common stressor in the xeric region, whereas TSS was the second most common stressor in the plains. Nutrient enrichment was the least important stressor both statewide and within climatic regions.

Wyoming fairs better than the western United States (based on EMAP-West) with regard to the least-disturbed (58% vs. 51% West-wide) and most-disturbed (18% vs. 27% West-wide) biological condition. Not only was channel instability a common stressor that affects approximately 41% of perennial streams in Wyoming but it also affects 26% of perennial streams west-wide. Riparian disturbance was found to be the number one stressor west-wide (47%) though this stressor ranked third most common (36%) in Wyoming according to the most recent statewide survey.

Wyoming's perennial streams also fair far better than the national estimates of least-disturbed (58% vs. 28% national) and most-disturbed (18% vs. 42% national) biological condition (based on USEPA's 2004-2005 National Wadeable Streams Assessment). Whereas total phosphorus was the most common stressor nationally (31%), it was considered a potential stressor in only 14% of Wyoming's perennial streams. Riparian disturbance and channel instability (25%) were the second and third most common stressors nationally and both were less than that estimated in Wyoming.

WDEQ/WQD has phased out statewide probabilistic surveys for the foreseeable future and replaced them with a rotating basin probabilistic design that was implemented in 2010 as part of the State's ten year (2010-2019) monitoring strategy. Wyoming's probabilistic rotating basin approach establishes an order of rotation and sampling years among five 'superbasins', which are conglomerates of several river basins. Information from each of the five superbasin probabilistic surveys will be used in the future to evaluate and report on the water quality condition of Wyoming streams within each superbasin and statewide once all superbasins have been completed.

INTRODUCTION AND OBJECTIVES

The federal Clean Water Act (CWA) §305(b) requires States to describe the water quality condition of all their surface waters. To help fulfill these State obligations to the CWA, the United States Environmental Protection Agency (USEPA) has advocated the use of a cost-effective approach known as probability designs to monitor and assess trends in surface water quality condition. Probability designs yield unbiased statistically-derived estimates of the condition of surface waters based on a representative sample of the resource with a known level of statistical confidence or certainty. Probability designs are very efficient because they require sampling relatively few locations to make valid scientific statements about the condition of waters at the State or regional scale.

From 2000 to 2004, a large regional probability survey known as the Western Pilot Environmental Monitoring and Assessment Program (EMAP-West) was implemented by the USEPA to evaluate the ecological status of perennial streams and rivers in 12 western states, including Wyoming (Stoddard et al. 2005). Following this study, the United States Geological Survey (USGS) in cooperation with the Wyoming Department of Environmental Quality-Water Quality Division (WDEQ/WQD) produced a report on the ecological status of Wyoming's perennial streams and rivers from data collected as part of EMAP-West for the 2000-2003 period (hereafter referred to as EMAP-WY) (Peterson et al. 2007).

To expand on the assessment conducted by Peterson et al (2007) and to help fulfill State requirements under the CWA, the WDEQ/WQD conducted its first statewide probability survey of perennial streams and rivers from 2004 to 2007. A second statewide probability survey was implemented from 2008 to 2011. The objectives of these two probability surveys were to:

- Determine the biological condition of Wyoming perennial streams and rivers
- Determine which stressors have the most influence on biological condition
- Evaluate trends in biological condition and stressors over time with comparisons to findings from EMAP-WY

PROBABILITY SURVEYS AND WYOMING'S INTEGRATED REPORT

In addition to requiring States to describe the water quality condition of all their waters including designated use support determinations, CWA §303(d) directs each State to develop a list of all waters which do not fully support their designated uses and require development of a Total Maximum Daily Load (TMDL). Assessments of pollutant problems and their impact to designated use-support are incorporated into Wyoming's Integrated 305(b) and 303(d) Report (hereafter Integrated Report) that is submitted to the USEPA biannually. Findings from Wyoming's probability surveys appear similar to those reported in Wyoming's Integrated Report, however, it is important to emphasize the differences in the scope of these reports and how they are used.

Probability surveys provide a systematic, broad-scale and quantitative estimate of biological condition of perennial streams and rivers in Wyoming. Probability surveys are intended to represent all perennial streams of the State. Conversely, Wyoming's Integrated Report summarizes only the available data and information for assessed streams and is not intended to estimate overall condition of all waters of the State. The Integrated Report summarizes data and information collected using a variety of sampling methods; water quality standards and interpretation of methods; and time periods. The Integrated Report describes water quality issues identified by the WDEQ/WQD's Monitoring Program and other entities, and summarizes designated use support determinations including those waters that do not fully support their designated uses (i.e. 303(d) list).

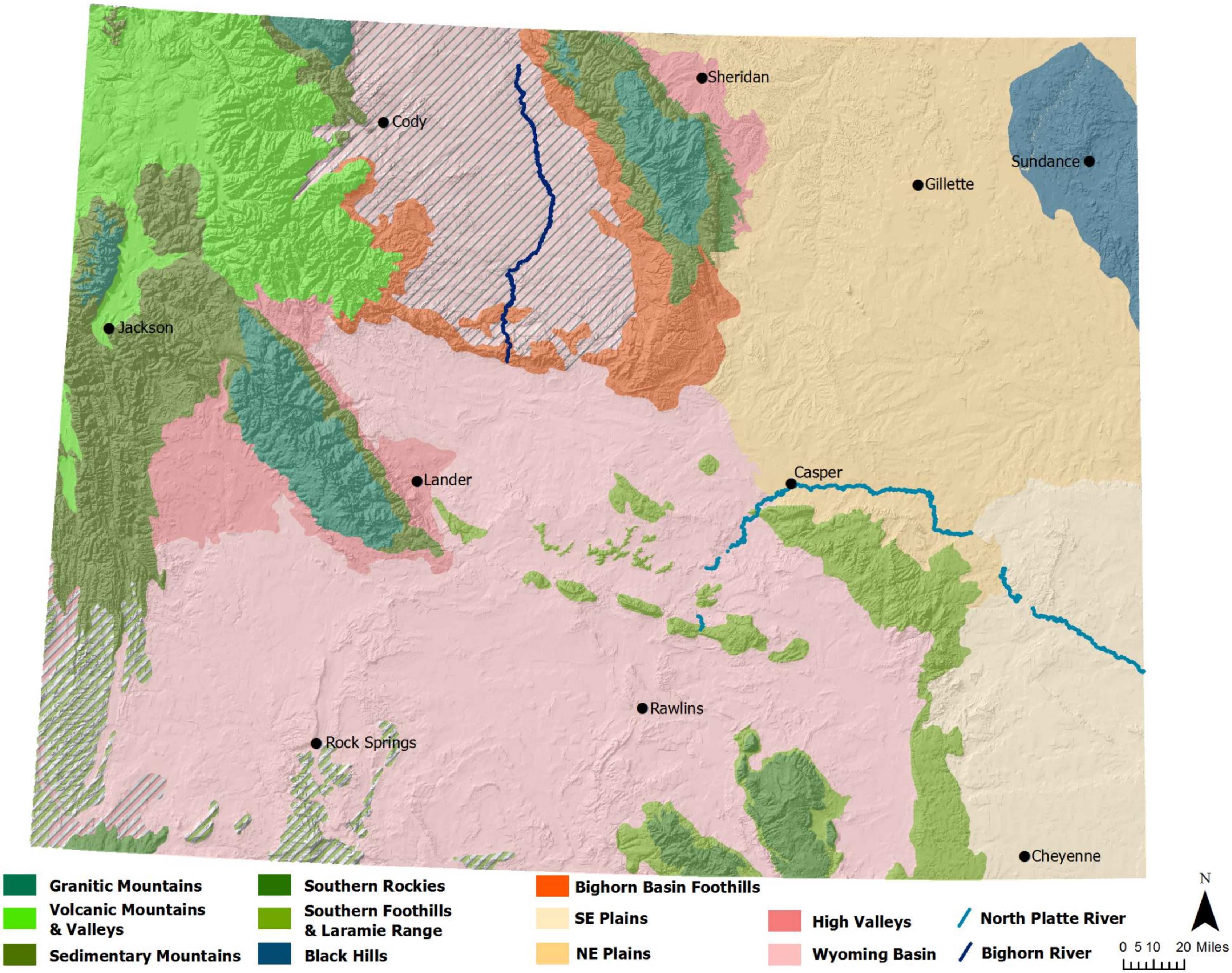
Findings from probability surveys are summarized in Wyoming's Integrated Report. However, data collected as part of the probability surveys are not intended to be used to make designated use-support determinations, including 303(d) listings. Rather, probability surveys may be used to prioritize future targeted sampling.

STUDY AREA

Wyoming is ecologically diverse, with much of this diversity attributable to variability in geology, climate, topography, and other environmental features of the State (Chapman et al. 2003 and Knight 1994). The State of Wyoming straddles the continental divide and encompasses 97,100 mi^2. Wyoming is characterized by abrupt topographic relief and numerous types of exposed granitic, volcanic, and sedimentary bedrock. Elevation ranges from 3,081 to13,802 ft with a mean of 6,660 ft. Average annual precipitation ranges from 6 to 59 in, which is mostly in the form of rain in the plains regions and snow in the mountain and intermountain basins. Air temperature in Wyoming varies widely due to the great topographic relief of the State. For example, mean daily maximum and minimum temperatures for July range from 90°F to <75°F and 55°F to 32°F, respectively.

Wyoming is divided into eleven bioregions (Figure 1): Bighorn Basin Foothills, Black Hills, Granitic Mountains, High Valleys, NE Plains, SE

Figure 1 - Wyoming bioregions, large river segments and selected municipalities. Reference data are not available or limited for cross-hatched areas though assumed to have similarities to the bioregion of the same color.



Plains, Sedimentary Mountains, Southern Foothills & Laramie Range, Southern Rockies, Volcanic Mountains & Valleys and the Wyoming Basin (Hargett 2011). Bioregions are geographic classifications that represent groups of streams with similar habitat, chemical and biological characteristics. These bioregions are then aggregated into three climatic regions: mountains, plains and xeric.

The mountain climatic region includes the Bighorn Basin Foothills, Black Hills, Granitic Mountains, Sedimentary Mountains, Southern Foothills & Laramie Range, Southern Rockies and the Volcanic Mountains & Valleys. This climatic region consists of several ranges of the southern and middle Rockies including the Absaroka, Beartooth, Bighorn, Black Hills, Laramie, Medicine Bow, Salt River, Sierra Madre, Teton and Wind River mountain ranges. The mountains of Wyoming are composed of low foothills to steep-crested high mountains largely covered by coniferous forest, aspen groves, subalpine meadows and/or alpine tundra. Many of the major perennial rivers and streams in Wyoming originate in the mountains and provide water resources for the more arid plains and xeric climatic regions. Recreation, logging and summer livestock grazing are common land uses.

The mixed-grass and short-grass prairies of the eastern one-third of the State (encompassed by the NE Plains, SE Plains and a portion of the High Valleys bioregions) make up the plains climatic region. This semi-arid climatic region consists of rolling plains interrupted by buttes and badlands. Soils are derived from sedimentary formations such as shale and sandstone and dissolved solids concentrations in streams of the region can be naturally elevated. Many of the perennial streams and rivers that course through the plains have a mixture of spring and montane snow-melt origins. Livestock grazing, irrigated agriculture and energy development are common land uses in the region. Natural flow regimes for some streams and rivers in the plains are appreciably altered by man-made flow alterations such as reservoirs, diversions and trans-basin inputs predominantly for irrigated agriculture and flood control.

The remainder of the State (Wyoming Basin and portions of the High Valleys bioregions) is considered the xeric climatic region, which is a high desert elevated plateau that consists of sagebrush, greasewood and saltbush shrublands. Nearly surrounded by forest-covered mountains, the xeric region is drier than the plains. Most perennial streams and rivers in the xeric region have a mixture of spring and montane snow-melt origins. Similar to the plains, man-made dams, diversions and trans-basin inputs have altered the natural flow regimes of some perennial streams and rivers in the xeric region. Much of the region is used for livestock grazing, energy development and irrigated agriculture.

SURVEY DESIGN

The total length of all waterways (perennial, intermittent, ephemeral, canals) in Wyoming is 108,767 miles based on the digitized 1:100,000 scale USEPA River Reach File Version 3 (RF3) and 113,522 miles according to the 1:100,000 scale enhanced National Hydrography Dataset (NHD+). Approximately 35,151 (32%) miles in RF3 and 37,623 (33%) miles in NHD+ are represented by perennial streams and rivers. It is important to note that the locations and total length of perennial streams and rivers represented by the RF3 or NHD+ may not be entirely accurate due to the coarse scale from which the coverages were derived. In reality, the total length of perennial streams and rivers in Wyoming is likely less than that represented by both digitized frames once factors including anthropogenic alterations and fragmented flow regimes are considered.

The design for Wyoming's statewide probability surveys is based on the approach developed by Stevens and Olsen (2004 and 1992) and previously implemented in USEPA's EMAP, EMAP-West and EMAP-WY (Messer et al. 1991, Overton et al. 1990, Peterson et al. 2007, Stoddard et al. 2005). Site locations that represent a known proportion of the target population (in this case perennial streams and rivers) were computer generated randomly from the digitized stream network sample frames using a Generalized Random Tessellation Stratified (GRTS) Design.

The GRTS design assigns weights to user-specified categories such as Strahler order, ecoregion, year and other geographic variables based on their extents within the sample frame. The weight assignments are integral to GRTS designs so that combined, randomly selected sites fully represent the variety of streams in the sample frame. Each randomly selected site thus represents a known proportion of total stream miles within the sample frame. From this information, estimates of stream length and associated biological condition and stressor extents within different landscape categorizations can be calculated.

For the first statewide survey, the stratified survey design for Wyoming selected sites from perennial, non-headwater (>1st Strahler order) rivers and streams that are not located in national parks, United States Forest Service wilderness and the Wind River Reservation within the RF3 sample frame. The second statewide survey followed the same basic stratified design though utilized the more accurate NHD+ for the sample frame. This equated to a target population of approximately 17,147 miles of perennial streams and rivers for the first statewide probability survey and 17,513 miles in the second survey (almost one-half the total miles of perennial streams and rivers in Wyoming). The random site selection was performed with Geographic Information Systems (GIS) by the USEPA's Health and Environmental Effects Research Laboratory in Corvallis, Oregon.

The statistical procedures used in selecting site locations from sample frames using GRTS are fully described in Stevens and Olsen (2004 and 1992) and only a brief description is provided here. To select monitoring site locations, the following procedures were used:

1) Determine the sample frame (e.g. RF3 for NHD+) with the accompanying GRTS stratified design.
2) A grid is placed over the sample frame to form stream segment units.
3) All stream segment units are joined along one line according to a randomized order. For example, there were 17,147 stream miles in the sample frame for the first statewide survey and thus the line is conceptually of the same length.
4) The line of stream segments is subdivided into equally sized segments according to the desired number of sample sites.
5) Reverse hierarchical ordering is applied to these segments along the line.
6) A random starting point is selected along the line. Sample sites are then selected at this fixed distance along the line.
7) The actual latitude and longitude of the monitoring site is determined through an interpolation from the known latitude and longitude coordinates at the start and end of each segment.

Sample size for the first statewide survey was based on a multi-density categorization of sample year and Strahler order for a total of 60 primary sites to be sampled on perennial streams and rivers. These 60 sample sites were selected so that an approximately equal number of sites could be sampled in each year and among 2nd, 3rd, 4th and 5th+ order perennial streams. For the second statewide survey, the WDEQ/WQD determined that sampling would not be implicitly structured by year but rather based on a categorization of aggregated level III ecoregions (Olsen and Peck 2008) combined with Strahler order. The result was an approximate equal number of sites distributed among four aggregated ecoregions (mountains, northern plains, southern plains and xeric) and among 2nd, 3rd, 4th and 5th+ order streams. Since this sample size categorization did not include sample year and the more accurate NHD+ was used as the sample frame, only 40 primary sites sampled on perennial streams and rivers were needed for a sufficient sample size. Following the same designs, populations of oversample sites were generated for each survey. Oversample sites were used as replacements when primary sites could not be sampled due to access denial, inaccessibility or they were non-target (e.g. ephemeral, intermittent, canal, wetland, etc.). Sites were sampled in the order of selection by the GRTS design for both surveys and for the first survey, also within the year designated for sampling.

Results of the two statewide surveys are presented at two levels of geographic resolution similar to EMAP-WY: statewide and three climatic regions (mountains, plains, xeric).

EMAP-West/EMAP-WY implemented a slightly different GRTS design that was based on the RF3 sample frame though did not exclude first-order streams or those located in national parks, wilderness or tribal reservations. Additionally, the climatic region boundaries used for the two statewide surveys were marginally adjusted from those used in EMAP-WY to accommodate the use of Wyoming's bioregion classifications. The majority of these small adjustments were focused on mountain/foothill areas previously considered xeric under EMAP-WY that have been included as part of the mountain region with the two statewide surveys.

DATA COLLECTION

All data collection was conducted during baseflow conditions. Chloride, *Escherichia coli*, nitrate+nitrite-N, total phosphorus, sulfate and total suspended solids (TSS) were analyzed from grab samples collected at the base of a riffle at each site (WDEQ/WQD 2012). Instantaneous water temperature, dissolved oxygen, pH and specific conductance were measured directly in the field (WDEQ/WQD 2012).

Benthic macroinvertebrates were collected from a representative riffle within each monitoring site following standard procedures in WDEQ/WQD (2012). Eight randomly selected samples (each 1 ft^2) were collected from the representative riffle with a Surber sampler (500-μm mesh collection net), filtered with a 500-μm mesh sieve and combined into a single composite sample. At low-gradient sites where riffles were absent, benthic macroinvertebrates were collected from multiple habitats (WDEQ/WQD 2012). The multi-habitat sample was a composite of 20 discrete 'jab' samples (each approximately 1.3 ft^2) collected with a dip net, from multiple habitats weighted proportionally based on representation, within a 100 - 300 ft reach Organisms were preserved in the field with 99% isopropanol or ethyl alcohol. Sample processing followed methods described in WDEQ/WQD (2012) and included removal of large and rare organisms followed by a 500-organism fixed-count subsampling procedure. Most taxa were identified to genus or species.

Substrate particle size and mean embeddedness within riffles where benthic macroinvertebrates were collected were estimated by measuring at least 100 randomly selected particles using a modification of the Wolmann pebble count method (WDEQ/WQD 2012). Mean riffle embeddedness is the degree to which coarse materials are covered or surrounded by very fine gravels, sands and silts. Surveys were also performed at permanent cross-sections within representative riffles to calculate existing channel dimensions for Rosgen channel classification (Rosgen 1996) and to evaluate relative departure from general expected conditions. Wolman pebble counts (100 count) were conducted reachwide to characterize substrate composition and for use in Rosgen channel classification. Additional semi-quantitative evaluations of streambank stability and cover, human influences within the riparian zone, stream bank and riparian zone condition and channel stability were measured at all sites (considering their inherent potential) following approved procedures in WDEQ/WQD (2012). Twelve human activities (logging, mining, buildings, roads, landfills, riprap, pavement, pipes, lawn, row crops, pasture and grazing) were evaluated for presence/absence, proximity and relative influence to water quality conditions. Combined, these physical parameters were used to make conservative inferences on the degree of riparian disturbance and the relative stability of the channel.

All sites were evaluated as to the degree and relative extent the natural stream hydrology was affected by flow diversions or flow augmentation. The number and type of surface water diversions or inputs upstream of the site in addition to information on water operations in the watershed were used to determine whether flow alterations were present in the watersheds. Sources of this information included but were not limited to the Wyoming State Engineers Office and the U.S. Bureau of Reclamation. In addition, sites where reservoirs (as depicted on a USGS 1:100,000 scale map) affected 50% or more of the upstream watershed were noted as reservoir influenced. Lastly, a site was noted as effluent dependent (WDEQ/WQD 2007) if the flow at the site for the majority of the year was known to be primarily attributable to the permitted discharge of waste or production water. Information on permitted discharges was obtained from the WDEQ/WQD's Wyoming Pollutant Discharge Elimination System program.

All chemical, physical and biological data collected from 2004 to 2011 that did not meet quality assurance/quality control standards (WDEQ/WQD 2001) were either excluded or noted in this report. Otherwise, all remaining data were determined to be complete and accurate.

SETTING EXPECTATIONS OF STREAM AND RIVER CONDITION

INDICATORS OF BIOLOGICAL CONDITION

To assess the biological condition of the State's streams and rivers requires the establishment of minimum biological thresholds. Wyoming uses a reference condition approach to develop minimum biological condition thresholds for different regions in the State that are derived from benthic macroinvertebrate data collected at a network of over 200 minimal or least-impacted reference sites. Benthic macroinvertebrates are one of the most common indicators used to assess the biological condition of streams and rivers. Aquatic life other than fish use-support in Wyoming is typically evaluated using two biological indicator models, the Wyoming Stream Integrity Index (WSII) and the WY RIVPACS, each of which were developed using Wyoming's reference dataset. Both models were also used to assess the biological condition of Wyoming's perennial streams and rivers for this study. Because results from the WSII and WY RIVPACS provide strong inference about water quality conditions over a multi-year period, they are extremely important tools for evaluating the ecological condition of Wyoming's perennial streams and rivers.

WYOMING STREAM INTEGRITY INDEX (WSII) is a statewide regionally-calibrated macroinvertebrate-based multimetric index designed to assess biological condition in Wyoming streams (Hargett 2011). Index scores for the WSII are calculated by summing the standardized values of selected metrics (composition, structure, tolerance, functional guilds) derived from the riffle-based macroinvertebrate sample. The selected metrics are those that best discriminate between reference and degraded waters. The assessment of biological condition is made by comparing the index score for a site of unknown biological condition to expected values that are derived from an appropriate set of regional reference sites that are minimally or least impacted by human disturbance. WSII index values that fall within the range of expected, or reference values, imply high biological condition, whereas values lower than that observed at reference sites imply biological degradation. Index scores are codified into one of three narrative aquatic life use-support categories of 'full-support', 'indeterminate' and 'partial/non-support' based on numeric thresholds for each of Wyoming's eleven bioregions and two reservoir-regulated large river segments.

WYOMING RIVER INVERTEBRATE PREDICTION AND CLASSIFICATION SYSTEM (WYRIVPACS) is a statewide macroinvertebrate-based predictive model that assesses stream biological condition by comparing the riffle-based macroinvertebrate community observed at a site of unknown biological condition with that expected to occur under reference condition (Hargett 2012). The expected macroinvertebrate taxa are derived from an appropriate set of reference sites that are minimally or least impacted by human disturbance. The deviation of the observed from the expected taxa, a ratio known as the O/E value, is a measure of compositional similarity expressed in units of taxa richness and thus a community level measure of biological condition. O/E values near 1 imply high biological condition while values <1 imply some degree of biological degradation. O/E values are codified into one of three narrative aquatic life use categories of 'full-support', 'indeterminate' and 'partial/non-support'.

The 'full-support' and 'partial/non-support' categories derived from the WSII and WY RIVPACS represent the 'least-disturbed' and 'most-disturbed' biological conditions, respectively (Table 1). Sites that fall between these two categories are retained as 'indeterminate'.

The WSII and WY RIVPACS were designed to evaluate only riffle-based benthic macroinvertebrate samples and thus are limited in their application to samples collected with multi-habitat sampling procedures. However, recent studies indicate that riffle-based and multi-habitat samples provide similar estimates of biological condition when evaluated at the regional scale (Gerth et al. 2006, Peterson et al. 2007, Rehn et al. 2007). Therefore, multi-habitat collected samples were evaluated with the WSII and WY RIVPACS, however, the aquatic life use narrative categories for each model were not used to assign a biological condition. Instead, model scores for each multi-habitat sample were compared to a range of model scores derived from multi-habitat samples collected at appropriate regional reference sites. Multi-habitat samples with model scores ≥75th percentile of reference conditions were considered 'least disturbed'. Multi-habitat samples with model scores <75th percentile of reference conditions defaulted to 'indeterminate' unless other information (e.g. numeric criterion exceedences, professional judgment) suggested a 'most disturbed' condition.

The biological condition in large perennial rivers where inflows are largely controlled by reservoir operations is expected to be quite different and commonly lower compared to the generally un-regulated streams (Nestler et al. 1986, Petts 1984, Poff et al. 1997, Stanford et al. 1996, Walburg et al. 1980 and Ward and Stanford 1995) from which the WY RIVPACS and bioregional indices of the WSII were developed. To address this issue, only large river multimetric indices for the reservoir-regulated Bighorn and North Platte Rivers, developed as part of the WSII, were applied to riffle-based samples collected on these same waterbodies. Scores from these large river indices were codified into one of three narrative aquatic life use-support categories of 'least-disturbed', 'indeterminate' and 'most-disturbed' (Table 1). Numerical expectations for the narrative categories were empirically derived from available data on these regulated reaches to represent the best-attainable conditions.

The biological condition of effluent dependent streams is almost entirely dependent on the quality and quantity of wastewater in addition to any physical changes to the channel as a result of the effluent discharges. The chemical and physical conditions of effluent dependent streams limit potential biological condition comparable to

Table 1 – Stressor thresholds used to establish condition categories for stream and rivers within bioregions and climatic regions. Values represent the (least-disturbed condition) / (most disturbed condition) except for sulfate where only most-disturbed values are provided according to the embedded matrix.

		Climatic Region											
		Mountain							Plains			Xeric	
		Bioregion											
	Variable	Bighorn Basin Foothills	Black Hills	Granitic Mountains	Sedimentary Mountains	Southern Foothills & Laramie Range	Southern Rockies	Volcanic Mountains & Valleys	High Valleys (east)	NE Plains	SE Plains	High Valleys (west)	Wyoming Basin
Water Chemistry	Conductivity (µS/cm)	≤ 500 / > 1000							≤ 1000 / > 2000			≤ 500 / > 1000	
	TSS (mg/L)	3 / 17	3 / 9	3 / 7	3 / 8	3 / 10	3 / 7	3 / 17	3 / 9	3 / 34	3 / 11	3 / 9	3 / 18
	Nitrate+Nitrite-N (mg/L)	0.100 / 0.674	0.100 / 0.637	0.100 / 0.203	0.100 / 0.200			0.100 / 0.150	0.100 / 0.172	0.100 / 0.612	0.100 / 0.550	0.100 / 0.172	0.100 / 0.200
	Total Phosphorus (mg/L)	0.01 / 0.04							0.04 / 0.30			0.04 / 0.18	
	Chloride (mg/L)	< 230 / ≥ 230											
	Sulfate (mg/L)												
	pH	> 6.5 and < 9.0 / < 6.5 or > 9.0											
	Escherichia coli (cfu/100 mL)	< 126 / > 630											
Biological Condition	WSII	> 60.9 / < 40.6	> 46.1 / < 30.7	> 60.3 / < 40.2	> 52.3 / < 34.8	> 66.7 / < 44.5	> 48.8 / < 32.6	> 69.3 / < 46.2	> 48.8 / < 32.5	> 58.4 / < 38.9	> 55.1 / < 36.7	> 48.8 / < 32.5	> 39.9 / < 26.2
	WSII Large River	Bighorn River (> 0.62 / < 0.32) North Platte River (> 0.60 / < 0.34)											
	WY RIVPACS	> 0.85 / < 0.63	> 0.88 / < 0.59	> 0.88 / < 0.65	> 0.82 / < 0.68	> 0.88 / < 0.68	> 0.89 / < 0.62	> 0.87 / < 0.65	> 0.86 / < 0.69	> 0.75 / < 0.52	> 0.78 / < 0.51	> 0.86 / < 0.69	> 0.82 / < 0.64
Physical Stability / Habitat	Mean Riffle Embeddedness	< 50% / ≥ 50%											
	Mean Streambank Stability	≥ 70% / < 70%											
	Channel Bed Instability (excess sediment and/or degradation)	Most-disturbed when Mean Riffle Embeddedness ≥ 50% or Mean Streambank Stability < 70% or at least one of the following documented in the reach: bimodal reachwide particle distribution, accelerated lateral channel migration, channelization, new and extensive unvegetated bar development, channel incision or channel classified as an unexpected Rosgen F or G											
	Mean Streambank Cover	≥ 70% / < 70%											
	Bareground	≤ 40% / > 40% (within 30 feet of the channel)											
	Riparian Disturbance	Most-disturbed when Mean Streambank Cover < 70% or Bareground > 40%. Otherwise, at least four of the following indicators must be documented within 30 feet of the channel (unless otherwise noted) to receive a rating of PRESENT: wall/dike/revetment/rip-rap/dam, buildings, pavement/cleared land, road/railroad, pipes/diversion structures, landfill/trash, park/lawn, row crops up to bank, logging operations, gas/oil/mineral mining activity, grazing, low riparian vegetation vigor, no diverse age-class or composition in riparian vegetation, dominant stream bank vegetation comprised of upland or facultative upland species, extensive hoof shear/trampling, < 10% woody riparian vegetation or < 10% overhanging vegetation											

Sulfate (mg/L):

	Cl < 5 mg/L	5 ≤ Cl < 25 mg/L	25 mg/L ≤ Cl	
HD < 100 mg/L	500 mg/L	500 mg/L	500 mg/L	Cl = Chloride
100 ≤ HD ≤ 500 mg/L	500 mg/L	SO4 = [-57.478 + 5.79(HD) + 54.163 (Cl)] * 0.65	SO4 = [1276.7 + 5.508(HD) - 1.457(Cl)] * 0.65	HD = Hardness
HD > 500 mg/L	500 mg/L	2000 mg/L	2000 mg/L	

naturally perennial non-effluent dependent streams. Consequently, the use of the WSII and WY RIVPACS is limited in the assessment of biological condition for effluent dependent systems. Biological condition of effluent dependent systems was only rated as most-disturbed if data indicated an exceedence of an applicable numeric criterion protective of aquatic life or there were indicators of other unexpected stressors that could influence biological condition. Otherwise, biological condition was derived based on best professional judgment and/or knowledge of a particular known expectation for a given effluent dependent system.

With the exception of large river indices and special considerations for effluent-dependent waters and multi-habitat samples, results from the WSII and WY RIVPACS were incorporated into Wyoming's aquatic life use-support decision matrix (WDEQ/WQD 2008). This matrix was used to determine overall biological condition using the three categories of least-disturbed, indeterminate and most-disturbed.

INDICATOR OF RECREATIONAL CONDITION

Although this report focuses almost exclusively on the biological condition of lotic perennial systems, *Escherchia coli* were also collected as part of the first and second probability surveys to evaluate the overall recreational condition of the same target population. *E. coli* is a fecal coliform bacterium commonly found in the intestines of warm-blooded animals and humans and is used as an indicator of potential public health risk of recreational waters in Wyoming (WDEQ/WQD 2007). Elevated concentrations of *E. coli* increase the risk that the public may contract pathogens through recreational use of the water. Anthropogenic sources of *E. coli* are human or warm-blooded animal fecal material conveyed via multiple pathways that include septic systems, wastewater effluent, storm drains, overland runoff from agricultural areas and direct deposit in or near the stream. Wyoming's *E. coli* geometric mean criterion of 126 cfu/100 mL that is protective of primary contact recreation was used to represent the least-disturbed recreational condition threshold for streams and rivers in the State (WDEQ/WQD 2007). Conversely, Wyoming's numeric *E. coli* geometric mean criterion of 630 cfu/100 mL protective of secondary contact recreation (WDEQ/WQD 2007), represents the most-disturbed recreational condition threshold.

STRESSORS TO BIOLOGICAL CONDITION

For the purposes of this study, stressors are chemical and physical factors that negatively affect the biological condition of a stream or river, particularly when influenced by human activities (Stoddard et al. 2005). Wyoming has water quality standards and criteria to protect designated aquatic life uses of streams and rivers (WDEQ/WQD 2007). For parameters such as pH and chloride, Wyoming's respective numeric criteria protective of aquatic life were used to evaluate conditions statewide and for each climatic region. The water quality condition was considered least-disturbed when the numeric criterion was met. Conversely, water quality condition was considered most-disturbed when the numeric criterion was exceeded.

For stressors without numeric criteria, values that represent the $5^{th}/25^{th}$ or $75^{th}/95^{th}$ percentiles of western United States reference streams, developed for USEPA's EMAP-West study (Stoddard et al. 2005), were used. These expectations were utilized to maximize comparability of findings from the two statewide surveys to those from EMAP-WY (Peterson et al. 2007). For parameters that were not considered by Stoddard et al. (2005), the percentile distributions ($5^{th}/25^{th}$ for least disturbed and 95^{th} for most-disturbed) of reference site values within each of the eleven Wyoming bioregions were used to establish the least and most-disturbed thresholds for each stressor. These values were established only for the objectives of this study and are not to be viewed as future numeric criteria. Temperature and dissolved oxygen were not evaluated as stressors for this study because of their diurnal fluctuations that are not accurately represented by the instantaneous measurements collected as part of this project. Stressors used in this report, their descriptions and the established expectations are described below.

CHEMICAL STRESSORS

NUTRIENTS – Parameters such as nitrate+nitrite-N (commonly referred to as nitrate) and total phosphorus are essential to the biological productivity of streams and rivers, though are generally found in low concentrations naturally and are therefore considered limiting constituents for plant and algal growth. However, excess contributions of nutrients associated with human activities, otherwise known as nutrient enrichment, can cause problems that range from annoyances to serious health concerns (USEPA 2000a). Nutrient concentrations in streams may be increased above ambient concentrations through fertilization of agricultural and residential land, animal and human wastes and elevated soil or bank erosion (USEPA 2000a). Nutrient enrichment to a stream or river may stimulate excessive plant or algal growth (algal blooms) and lead to detrimental changes in dissolved-oxygen concentrations (hypoxia), pH, or habitat quality (Munn and Hamilton 2003, Peterson et al. 2007). Nuisance levels of plant and algal growth interfere with aesthetic and recreational uses of streams and rivers. Blooms of certain blue-green algae produce toxins that can affect animal and human health (USEPA 2000a).

Excess nutrients may either run off the land during storms and snow-melt or infiltrate below the soil layer into groundwater aquifers. Once in groundwater aquifers, the nutrients may take years to decades before reaching a stream. Excess nutrients can enter the stream through decomposition of excess accumulations of organic material in the channel. The WDEQ/WQD currently has no numeric water quality criteria for total phosphorus or nitrates protective of aquatic life. The WDEQ/WQD does however maintain a minimum nitrate human-health criterion of 10,000 µg/L on waters designated for drinking water use (WDEQ/WQD 2007).

Nutrient enrichment can stimulate excessive growth of algae and aquatic macrophytes.

The USEPA (2000b, 2000c, 2001a, 2001b) has developed recommended minimum nitrate concentrations thought protective of aquatic life for ecoregions of the western United States. However, their application for this study was precluded by the fact that laboratory detection limits in the analysis of nitrate samples for this project were generally above the recommended concentrations. In addition, the representativeness of USEPA's recommended thresholds to expected conditions in Wyoming is questionable. No thresholds for nitrate were developed by Stoddard et al. (2005). Therefore, nitrate thresholds were derived using conservative 5th and 95th percentiles of nitrate concentrations among Wyoming reference sites for each bioregion, that represented the least and most-disturbed conditions, respectively (Table 1). Total phosphorus thresholds for the three climatic regions were derived from Stoddard et al. (2005) (Table 1).

TOTAL SUSPENDED SOLIDS - TSS is the concentration of both inorganic and organic materials suspended in the water column. Natural TSS concentrations are seasonally variable and normally highest during spring snowmelt runoff and after thunderstorms. Elevated TSS concentrations may affect aquatic life through alterations to feeding mechanisms, reduced photosynthesis by algae and macrophytes, physical abrasion, streambed scouring and increased water temperatures. Elevated concentrations of suspended solids can also interfere with agricultural, municipal and industrial uses of the water. Human activities such as construction, mining, logging, irrigation drainage and potential sources of nutrients described earlier may contribute to elevated TSS beyond ambient concentrations. There is no federal or Wyoming criterion for TSS protective of aquatic life nor are there TSS thresholds developed by Stoddard et al. (2005). Therefore, least and most-disturbed TSS expectations for each Wyoming bioregion were derived from the 25th and 95th percentiles of TSS concentrations among Wyoming reference sites, respectively (Table 1).

Elevated TSS can interfere with gill function and feeding ability of aquatic life in addition to human uses of the water.

SALINITY - Specific conductance is an indicator of salinity or the concentration of dissolved salts. Dissolved salts may include ions of chloride, nitrate, phosphate, sulfate, selenium, magnesium, calcium, sodium and iron. Natural salinity of streams and rivers varies considerably and is primarily dependent on geology and soils of the watersheds. Elevated salinity causes negative effects to soils and drinking water. Aquatic life can also be affected with respect to physiological processes and to changes in the structure and functions of the community. Many ions that contribute to salinity are produced as byproducts of human activities such as irrigated agriculture, mineral and industrial development and road salt application. Elevated soil erosion can also increase the salinity of streams and rivers. There is no federal or Wyoming criterion for specific conductance protective of aquatic life. Therefore, salinity expectations for each of the three climatic regions were derived from Stoddard et al. (2005) (Table 1).

CHLORIDE - This is a naturally occurring constituent commonly found as a compound with sodium, potassium or magnesium and as noted previously can contribute to the salinity of a stream or river. Elevated concentrations of chloride can be toxic to aquatic life and can interfere with municipal and industrial processes. Human sources of chloride include sewage and industrial effluent, fertilizers, irrigation drainage and road salt application. The WDEQ/WQD has established a numeric chloride chronic criterion of 230 mg/L considered protective of aquatic life in all waters of Wyoming that can support game or non-game fisheries (WDEQ/WQD 2007). Chloride concentrations that exceed the 230 mg/L criterion would represent the most-disturbed condition for this stressor (Table 1).

SULFATE – As with chloride, sulfate occurs naturally in aquatic systems and generally originates from the decomposition of organic matter, atmospheric deposition or geologic weathering. Depending on the background concentrations of chloride and hardness, elevated concentrations of sulfate may be toxic to aquatic life (Soucek and Kennedy 2005). Anthopogenic sources of sulfate include sewage and industrial effluent (coal mines and oil treaters in particular) and agricultural runoff. There are currently no national or WDEQ/WQD water quality criteria for sulfate protective of aquatic life. However, the Illinois Environmental Protection Agency (ILEPA 2012) and Pennsylvania Department of Environmental Protection (PDEP 2012) have promulgated and drafted sulfate criteria, respectively, based on the study by Soucek and Kennedy (2005). Because the toxicity of sulfate varies with chloride and hardness and results from the Soucek and Kennedy (2005) study appear to be applicable nation-wide, these criteria, rather than percentiles based on distributions of sulfate from Wyoming reference sites, were used to set appropriate sulfate expectations in Wyoming. Sulfate concentrations that exceeded the chloride and hardness-dependent criteria described in Table 1 represented the most-disturbed condition for this stressor.

PH - The pH of a stream or river has important implications to the growth and survival of aquatic life since it affects the toxicity of constituents such as heavy metals and ammonia. Human sources that can contribute to alterations in pH from background include byproducts of industrial processes and indirectly from nutrient enrichment. The WDEQ/WQD has established a pH chronic criteria range of 6.5 to 9.0 as protective of aquatic life in all waters of Wyoming (WDEQ/WQD 2007). Values of pH < 6.5 or > 9.0 would be considered most-disturbed (Table 1).

PHYSICAL STRESSORS

RIPARIAN DISTURBANCE - The riparian zone, or the interface between a stream and upland vegetation, helps to protect streams from both natural and human disturbances when adequate vegetation is present. In many streams, this vegetation is vital to stream bank integrity, allowing stream banks to withstand the erosive forces of water at high flows. The vegetation also captures surface flows which facilitates groundwater recharge and reduces flooding while filtering sediment, nutrients and other constituents (Gregory et al. 1991). Aquatic life depends on riparian vegetation for habitat (e.g. roots and large woody debris) and shading which helps maintain cooler stream temperatures. Vegetation is also critical for providing food such as leaf litter for macroinvertebrates and terrestrial insects for fish. Anthropogenic disturbances to the riparian zone can negatively affect one or more of these processes. When severe, these disturbances can accelerate natural geomorphic processes and can threaten the physical stability of a stream, which in turn can limit its ability to support aquatic life. The degree of riparian disturbance was evaluated in this study by combining several semi-quantitative measures. Specifically, evaluations of human activity, mean percentage of riparian stream bank cover, percentage of bare ground and stream bank and riparian zone condition were estimated at each sampled site. Riparian disturbance was noted most-disturbed when either mean streambank cover was < 70% or bare ground represented > 40% of the riparian zone within 30 feet of the channel (Table 1) (Cowley 2002, USDA/NRCS 1998, USDI/BLM 1998, USEPA 1998). Riparian disturbance was also conservatively documented as most-disturbed when at least four of seventeen indicators noted in Table 1 were documented in the reach within 30 feet of the channel. At least four indicators were chosen to minimize false positive assignments of riparian disturbance.

Riparian disturbance can impact aquatic life through alterations to habitat.

EXCESS SEDIMENT - Excess sediment has been labeled the most important pollutant in United States streams and rivers (Waters 1995). In the latest USEPA summary of the Nation's water quality, excess sediment was again recognized as one of the top four stressors to streams and rivers and posed the greatest risk to the biological condition of the Nation's waters

(Paulsen et al. 2008, USEPA 2009). Excess sediment creates unstable physical conditions that can lead to channel aggradation or degradation. This pollutant can also smother fish eggs and fill interstitial spaces in stream beds where benthic organisms live, which can severely impact growth, reproduction, recruitment and survival. Excess sediment can also clog surface water diversion headgates and reduce channel capacity; raise the channel bed elevation (aggradation) potentially increasing flood stage and flood hazard and accelerate reservoir sedimentation and reduce storage. In addition to riparian disturbance, alterations to a natural flow regime that reduce stream competency or capacity can result in an accumulation of sediment.

Excess sedimentation often results in the development of un-vegetated mid-channel, transverse, delta and side bars (Barbour et al. 1999, Rosgen 2006 and 2008, Schumm 1977). Bimodal distributions in bed material (Rosgen 2006) and elevated riffle embeddedness (Sylte and Fischenich 2002) can be indicative of excess sedimentation.

Accelerated bank erosion is a common source of excess sediment that not only impacts aquatic life but can also interfere with water supply intakes, surface water diversions and accelerates reservoir filling.

ACCELERATED STREAM BANK EROSION - Stable stream banks are able to dissipate stream energy at high flows, minimizing alterations to channel dimension, pattern or profile while also capturing sediment and other pollutants (Waters 1995). Accelerated stream bank erosion generally occurs when riparian areas and stream banks are lacking adequate vegetation with well-developed root structures due to riparian vegetation removal, trampling, hoof shear, or recreational traffic and thus cannot retain soil and stabilize streambanks during high flows. Accelerated stream bank erosion may occur when stream banks exhibit high bank-height ratios where more of the bank surface is exposed above bankfull elevation and thus the bank is at greater risk for surface erosion, freeze/thaw, bank slumping and failure and mass erosion processes (Rosgen 2006). Accelerated stream bank erosion is a form of channel degradation that not only reduces in-stream aquatic habitat along the banks but also contributes excess sediment to a channel.

Channel incision and accelerated bank erosion can be triggered by alterations to channel boundary conditions such as from disturbances to the riparian zone.

CHANNEL INCISION - Accelerated stream bank erosion and excess sediment are sometimes associated with channel incision. Channel incision is abandonment of an active floodplain and a lowering of the channel bed with concomitant lowering of the water table. Channel incision may be triggered by a variety of historic and/or current causes, though is often associated with channel enlargement or straightening (channelization). Other causes of channel incision include reduced sediment load due to upstream dams, increased peak flows caused by anthropogenic activities and land use changes (Fischenich and Morrow 2000, Galay 1983).

CHANNEL INSTABILITY - Changes in sediment load or channel boundary conditions (e.g. slope, dimension, profile, planform, stream bank stability) can disrupt the dynamic equilibrium of streams that result in an accelerated rate of morphological changes (e.g. stream bank erosion, incision, lateral channel migration) that ultimately create instability of the channel and its habitat for aquatic life.

In short, accelerated stream bank erosion, channel incision and/or excess sediment create conditions of channel bed and bank instability (hereafter referred to as channel instability) that have major impacts on stream ecosystems. These impacts can include reduced aquatic habitat diversity and quality for spawning and rearing; reduced recruitment, growth and reproduction of aquatic life; altered food resources and in-stream cover; increased temperatures and ultimately a diminished and less diverse aquatic life community comprised of generalist, short-lived taxa tolerant to elevated levels of environmental stressors.

Channel instability was noted as most-disturbed when either mean riffle embeddedness was ≥50% or mean streambank stability was < 70% (Table 1). Though variable, the combined results from several studies suggest that a conservative threshold of at least 30% mean riffle embeddedness, may be suitable for detection of channel aggradation in cobble-bed streams (Sylte and Fischenich 2002). The mean riffle embeddedness that corresponded to the 95th percentile of the reference site distribution in Wyoming was 43%. Considering this information and accounting for the diversity of substrate composition among reference sites in Wyoming and a margin of sampling error, a conservative mean riffle embeddedness of ≥50% was selected as a threshold for the most-disturbed condition. Cowley (2002) suggests that 70% unaltered stream banks appear to be the minimum level that would maintain stable conditions. Channel instability was also documented as most-disturbed when one or more of the following indicators were documented in the reach: bimodal reachwide particle distribution, channelization, new and extensive unvegetated bar development, active channel incision or an unexpected Rosgen F or G channel classification (Table 1). Rosgen F and G channels are deeply entrenched, highly susceptible to changes in dimension, profile and planform and are general indicators of channel bed or bank instability in valley types where they are unexpected (Rosgen 1996).

Channel instability was further evaluated at the State and climatic region scale with respect to its three component sub-stressors: excess sediment, accelerated bank erosion and channel incision. Excess sediment was documented at a site when mean riffle embeddedness was ≥50%, the reachwide particle distribution was bimodal and/or new unvegetated bars were present and common. Accelerated bank erosion was documented at each site when the mean stream bank stability was <70%. A site would receive documentation of channel incision when one or more active headcuts were present and/or the stream had been channelized.

DATA ANALYSIS

All probability survey analyses were performed using modifications of the 'spsurvey.analysis' scripts developed in the R programming language (Version 2.4.1) by the USEPA's Office of Research and Development in Corvallis, Oregon or with STATISTICA (Version 10) (Statsoft 2011). The statistical procedures used in 'spsurvey.analysis' to extrapolate estimates of evaluated and assessed stream lengths and biological condition and stressor relative extents from collected data are fully described in Van Sickle et al. (2008 and 2006). Two-tailed Fischer exact (Zar 1984) and equivalence (Garrett 1997 and Rodger et al. 1993) tests were used to determine whether significant differences existed between the 1st and 2nd statewide survey results for biological condition, recreational condition and stressors to biological condition. Significant difference was determined at $P<0.05$.

DROUGHT CONDITIONS

Both the first and second statewide surveys were conducted during a multi-year drought that occurred over much of the western United States including Wyoming that began during the EMAP-WY period. According to the Wyoming Climate Atlas (Curtis and Grimes 2004) and information from the U.S. Drought Portal (USDP 2012), the ~10 year drought that began in 2000 was one of the second worst statewide droughts on record. The first statewide survey was conducted during the most severe period (2004-2007) of the drought. Drought conditions generally subsided throughout much of Wyoming in 2010 and 2011 with the onset of above average snowpack and rainfall coupled with increased soil moisture and cooler temperatures (USDP 2012).

Effects of the multi-year drought followed by above normal precipitation are reflected in recorded stream flows throughout Wyoming. Data collected at several USGS stream gage stations distributed throughout the three climatic regions of Wyoming show appreciable departures in annual flows during EMAP-WY and both statewide surveys relative to the mean annual flow for the periods of record at each gage (hereafter referred to as mean annual flow for simplicity) (Table 3). At the statewide scale, flows during EMAP-WY and the first statewide survey were on average -33% and -27% below the mean annual flow. Conversely, flows during the second statewide survey were approximately 25% above the mean annual flow. Flows in the mountain climatic region for calendar years 2000-2003, 2004-2007 and 2008-2011 averaged -32%, -18% and 23%, respectively, compared to the mean annual flow. This pattern of flows in the mountains steadily approaching and eventually exceeding mean annual flows from the EMAP-WY to second statewide survey periods was not evident in the plains and xeric climatic regions. Instead, flows in the plains and xeric regions relative to mean annual flows, were on average much lower during the first statewide survey (plains: -41%, xeric: -37%) compared to EMAP-WY (plains: -38%, xeric: -28%). This reduction in flows between EMAP-WY and the first statewide survey was coincident with the increased severity of the drought during the 2004-2007 calendar years. With general cessation of the drought, there was an average rebound in flows that exceeded mean annual flows (plains: 27%, xeric: 29%) between the first and second statewide surveys.

RESULTS

EXTENT OF RESOURCE

A total of 111 sites were evaluated as part of the first statewide probability survey that represented 17,147 perennial stream and river (hereafter referred to as just stream) miles or the target stream length. Approximately 30% (5,124 miles) of this target stream length was found to be non-target (Table 2, Figures 2 and 3). Non-target sites were those identified as ephemeral, intermittent, wetlands or human constructed channels such as irrigation canals. Four of these 33 non-target sites were sampled, though were later removed from further analysis upon confirmation of intermittent or ephemeral flow regimes. Approximately 16% (2,807 miles) of the target streams could not be assessed because access was denied or was inaccessible due to unsafe wading conditions or rugged terrain. Because this part of the target resource could not be assessed, the results from both statewide probability surveys cannot be applied to this unsampled portion. The remainder of the sampling frame represented the assessed targeted stream length for the first statewide survey – 9,215 miles (60 sites). This assessed targeted length represents 26% of the total

Figure 2 - Sites sampled as part of the first (2004-2007) and second (2008-2011) statewide probability surveys for Wyoming including climatic regions; and national parks, wilderness and Wind River Reservation boundaries.

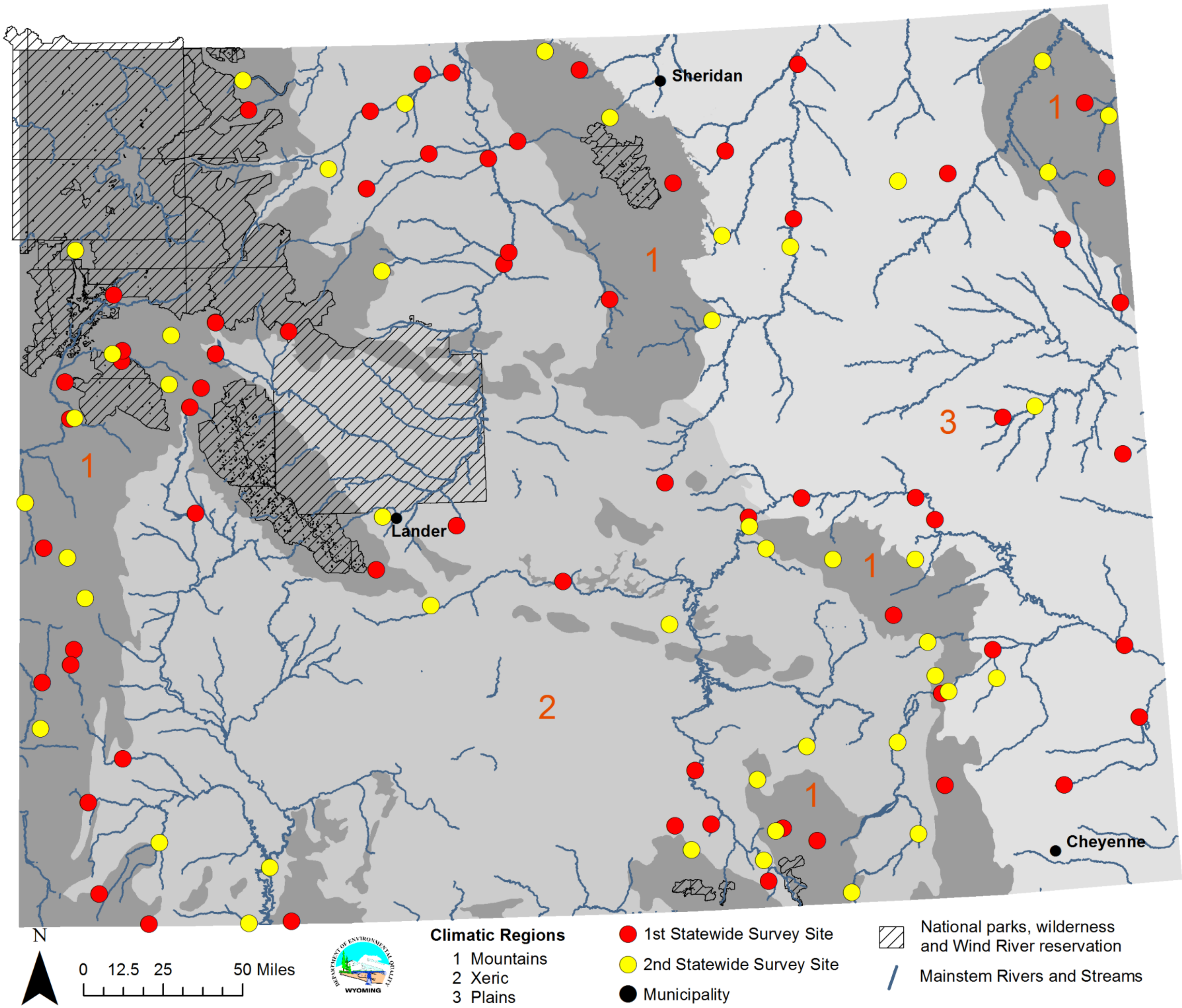


Table 2 – Sites sampled as part of the first (2004-2007) and second (2008-2011) statewide probability surveys. Sites with asterisks were considered non-target and removed from analysis.

Survey ID	Survey	StationID		WaterbodyName - Reach Name	Latitude	Longitude	Year Monitored	HUC 6 Basin	Elevation (ft)	Watershed Area (mi^2)	Climatic Region	BIOREGION
WYW03437-001	FIRST	WB0234	*	LITTLE MUDDY CREEK - HAUL ROAD	41.563703	-110.632508	2004	GREEN	6594	190.7	XERIC	WYOMING BASIN
WYW03437-002	FIRST	MRW0137		SUNLIGHT CREEK - STATION 6886	44.718392	-109.587567	2004	YELLOWSTONE	6886	85.8	MOUNTAIN	SEDIMENTARY MOUNTAINS
WYW03437-004	FIRST	WU0006		HENRYS FORK RIVER - BELOW GAGING STATION	41.007128	-110.268594	2004	GREEN	8360	56.0	XERIC	WYOMING BASIN
WYW03437-005	FIRST	WB220		NORTH PLATTE RIVER - THE OLD BOB PLACE	41.638478	-106.940186	2004	NORTH PLATTE	6580	3587.0	XERIC	WYOMING BASIN
WYW03437-006	FIRST	NGP0179		CLEAR CREEK - STATION 4245	44.453794	-106.558017	2004	POWDER	4245	376.4	PLAINS	NE PLAINS
WYW03437-007	FIRST	MRW0141		EAST FORK WIND RIVER - WILDERNESS BOUNDARY	43.702783	-109.358039	2004	BIGHORN	8530	37.7	MOUNTAIN	VOLCANIC MOUNTAINS & VALLEYS
WYW03437-008	FIRST	WB221		POISON SPIDER CREEK - BELOW IRON CREEK	42.780458	-106.535794	2004	NORTH PLATTE	5200	300.8	XERIC	WYOMING BASIN
WYW03437-009	FIRST	WHP40		LARAMIE RIVER - BELOW SYBILLE CREEK	42.108756	-105.086194	2004	NORTH PLATTE	4580	3291.0	PLAINS	SE PLAINS
WYW03437-010	FIRST	WB0233		BIGHORN RIVER - NOWATER	43.983622	-107.989619	2004	BIGHORN	4070	10302.5	XERIC	WYOMING BASIN
WYW03437-013	FIRST	MRW0143		FALL CREEK - ABOVE SNAKE CONFLUENCE	43.315669	-110.736853	2004	SNAKE	5920	47.1	MOUNTAIN	SEDIMENTARY MOUNTAINS
WYW03437-014	FIRST	NGP193		NORTH PLATTE RIVER - ANDERSON DAIRY	42.718478	-105.387147	2004	NORTH PLATTE	4780	18340.0	PLAINS	NE PLAINS
WYW03437-017	FIRST	MRW0139		SMITHS FORK - BLM	42.111219	-110.910483	2004	BEAR	6300	253.3	XERIC	HIGH VALLEYS
WYW03437-018	FIRST	WB0218		SHOSHONE RIVER - STATION 4317	44.699686	-108.808931	2004	BIGHORN	4317	1970.9	XERIC	WYOMING BASIN
WYW03437-019	FIRST	MRW0142		PACIFIC CREEK - DAVIS HILL	43.880875	-110.457764	2004	SNAKE	6880	143.0	MOUNTAIN	SEDIMENTARY MOUNTAINS
WYW03437-021	FIRST	NGP194		INDIAN CREEK - TABLE MOUNTAIN	42.953467	-104.199014	2005	CHEYENNE	4180	43.8	PLAINS	NE PLAINS
WYW03437-023	FIRST	MRW0148		GREEN RIVER - BIG BEND	43.365053	-109.985564	2005	GREEN	7780	173.3	MOUNTAIN	SEDIMENTARY MOUNTAINS
WYW03437-024	FIRST	WB0247		SWEETWATER RIVER - SODA	42.526508	-107.697047	2005	NORTH PLATTE	6040	1545.4	XERIC	WYOMING BASIN
WYW03437-026	FIRST	WB0249		SHELL CREEK	44.541700	-107.875900	2005	BIGHORN	4050	371.0	XERIC	WYOMING BASIN
WYW03437-027	FIRST	MRW0146		LITTLE POPO AGIE - MAXON BASIN	42.606961	-108.846381	2005	BIGHORN	8680	25.2	MOUNTAIN	GRANITIC MOUNTAINS
WYW03437-030	FIRST	WB0250		SOUTH FORK DRY CREEK	44.346500	-108.846300	2005	BIGHORN	5268	59.0	XERIC	WYOMING BASIN
WYW03437-031	FIRST	NGP0197		DONKEY CREEK	44.288100	-105.157100	2005	BELLE FOURCHE	4252	197.0	PLAINS	NE PLAINS
WYW03437-032	FIRST	SR43		SOUTH CHUGWATER CREEK - BALDY MOUNTAIN	41.508367	-105.433044	2005	NORTH PLATTE	7700	9.4	MOUNTAIN	SOUTHERN FOOTHILLS & LARAMIE RANGE
WYW03437-034	FIRST	WB0248		BIGHORN RIVER	44.036531	-107.958431	2005	BIGHORN	4030	10810.0	XERIC	WYOMING BASIN
WYW03437-035	FIRST	MRW0145		EAST DU NOIR CREEK - COFFIN BUTTE	43.751364	-109.817133	2005	BIGHORN	8120	25.4	MOUNTAIN	VOLCANIC MOUNTAINS & VALLEYS
WYW03437-036	FIRST	SR42		NORTH LARAMIE RIVER - TOLTEC	42.296011	-105.679119	2005	NORTH PLATTE	7510	8.0	MOUNTAIN	SOUTHERN FOOTHILLS & LARAMIE RANGE
WYW03437-038	FIRST	WB228		NORTH SPRING CREEK - RICH PLACE	41.389830	-106.856890	2005	NORTH PLATTE	6935	68.0	XERIC	WYOMING BASIN
WYW03437-039	FIRST	NGP0196		POWDER RIVER	44.828900	-106.062400	2005	POWDER	3485	6582.9	PLAINS	NE PLAINS
WYW03437-041	FIRST	NGP202		NORTH PLATTE RIVER - BROOKHURST	42.854384	-106.202005	2006	NORTH PLATTE	5075	12575.0	PLAINS	NE PLAINS
WYW03437-042	FIRST	WB0264		CROOKED CREEK	43.802458	-107.335248	2006	BIGHORN	4699	12.6	MOUNTAIN	BIGHORN BASIN FOOTHILLS
WYW03437-043	FIRST	MRW0154		SOUTH FORK FISH CREEK	43.451230	-109.913781	2006	SNAKE	8930	15.7	MOUNTAIN	SEDIMENTARY MOUNTAINS
WYW03437-045	FIRST	MRW0152		INDIAN CREEK - TALUS	42.261886	-110.717386	2006	GREEN	8038	7.4	MOUNTAIN	SEDIMENTARY MOUNTAINS
WYW03437-047	FIRST	NGP0209		POISON CREEK	43.948980	-104.467159	2006	CHEYENNE	4060	10.1	PLAINS	NE PLAINS
WYW03437-052	FIRST	WB0279		SPRING CREEK - MINNIES GAP	41.010507	-109.409650	2006	GREEN	6409	16.9	XERIC	WYOMING BASIN
WYW03437-053	FIRST	WHP42		HORSE CREEK - DUROC	41.754126	-104.226088	2006	NORTH PLATTE	4380	1235.3	PLAINS	SE PLAINS
WYW03437-054	FIRST	WB0265		SAGE CREEK	44.861554	-108.467090	2006	BIGHORN	3900	377.0	XERIC	WYOMING BASIN
WYW03437-056	FIRST	WB255		BEAR CREEK - BELOW HIGHWAY 230	41.117196	-106.527589	2006	NORTH PLATTE	7570	18.4	XERIC	WYOMING BASIN

Table 2 (cont.) – Sites sampled as part of the first (2004-2007) and second (2008-2011) statewide probability surveys. Sites with asterisks were considered non-target and removed from analysis.

Survey ID	Survey	StationID	WaterbodyName - Reach Name	Latitude	Longitude	Year Monitored	HUC 6 Basin	Elevation (ft)	Watershed Area (mi^2)	Climatic Region	BIOREGION
WYW03437-057	FIRST	NGP201	* LIGHTNING CREEK - SPLIT HILL	43.162297	-104.923319	2006	CHEYENNE	4300	306.1	PLAINS	NE PLAINS
WYW03437-059	FIRST	WB257	* MIDDLE FORK CASPER CREEK - BROAD MESA	42.955879	-107.041456	2006	NORTH PLATTE	5880	63.8	XERIC	WYOMING BASIN
WYW03437-061	FIRST	WB0296	HAMS FORK - ABOVE ALKALI CREEK	41.762144	-110.420558	2007	GREEN	6736	80.8	XERIC	WYOMING BASIN
WYW03437-062	FIRST	MRC0114	SHEEP CREEK	44.854944	-107.460383	2007	TONGUE	7605	1.2	MOUNTAIN	SEDIMENTARY MOUNTAINS
WYW03437-063	FIRST	MRW0158	FLAT CREEK - SADDLE BUTTE	43.483625	-110.765350	2007	SNAKE	6205	126.0	MOUNTAIN	VOLCANIC MOUNTAINS & VALLEYS
WYW03437-066	FIRST	WB0286	LITTLE JACK CREEK - HOMESTEAD	41.390958	-107.076678	2007	NORTH PLATTE	7380	28.3	XERIC	WYOMING BASIN
WYW03437-069	FIRST	NGP0211	STOCKADE BEAVER CREEK - MW RESERVOIR	43.641322	-104.135339	2007	CHEYENNE	3894	365.0	PLAINS	NE PLAINS
WYW03437-070	FIRST	MRC0115	NORTH CLEAR CREEK - LUCASTA CAMP	44.320067	-106.899850	2007	POWDER	6858	30.8	MOUNTAIN	GRANITIC MOUNTAINS
WYW03437-074	FIRST	WB0230	DRY CREEK - EMBLEM	44.499000	-108.442000	2007	BIGHORN	4441	331.6	XERIC	WYOMING BASIN
WYW03437-075	FIRST	MRE0023	REDWATER CREEK - SUGARLOAF MOUNTAIN	44.560800	-104.257000	2007	BELLE FOURCHE	4038	15.8	PLAINS	NE PLAINS
WYW03437-076	FIRST	WB0294	* EVANS CREEK - CHAPMAN	41.144736	-110.567858	2007	GREEN	7970	9.5	XERIC	WYOMING BASIN
WYW03437-082	FIRST	NGP0199	POWDER RIVER	44.126800	-106.149300	2005	POWDER	4024	4345.0	PLAINS	NE PLAINS
WYW03437-083	FIRST	MRW0144	CRYSTAL CREEK - SHORTY	43.578000	-110.411000	2004	SNAKE	7080	67.8	MOUNTAIN	SEDIMENTARY MOUNTAINS
WYW03437-086	FIRST	WB0258	SHOSHONE RIVER	44.864873	-108.280361	2006	BIGHORN	3700	2972.0	XERIC	WYOMING BASIN
WYW03437-088	FIRST	SR41	MIDDLE FORK LITTLE LARAMIE RIVER - BELOW JIM CREEK	41.291261	-106.223322	2005	NORTH PLATTE	9720	9.6	MOUNTAIN	SOUTHERN ROCKIES
WYW03437-089	FIRST	NGP195	LA PRELE CREEK - FORT FETTERMAN	42.824060	-105.497470	2005	NORTH PLATTE	4920	174.7	PLAINS	NE PLAINS
WYW03437-091	FIRST	MRW0140	CROOKED CREEK - HAT BUTTE	43.608875	-109.818947	2004	BIGHORN	7510	14.2	XERIC	HIGH VALLEYS
WYW03437-093	FIRST	MRW0149	SWIFT CREEK - USGS GAGE	42.726164	-110.899400	2005	SNAKE	6431	27.4	MOUNTAIN	SEDIMENTARY MOUNTAINS
WYW03437-094	FIRST	WB0270	GREYBULL RIVER - ABOVE HIGHWAY 16	44.467181	-108.065612	2006	BIGHORN	3816	1029.1	XERIC	WYOMING BASIN
WYW03437-095	FIRST	MRE0024	COLD SPRINGS CREEK	44.211000	-104.156000	2007	BELLE FOURCHE	5641	61.2	MOUNTAIN	BLACK HILLS
WYW03437-101	FIRST	MRW0151	HAMS FORK - 7694	42.192815	-110.737329	2006	GREEN	7694	63.3	MOUNTAIN	SEDIMENTARY MOUNTAINS
WYW03437-103	FIRST	MRW0153	SLATE CREEK - ABOVE HAYSTACK	43.625200	-110.405576	2006	SNAKE	7218	36.6	MOUNTAIN	SEDIMENTARY MOUNTAINS
WYW03437-105	FIRST	WHP43	NORTH PLATTE RIVER - ROCK RANCH	42.085795	-104.281328	2006	NORTH PLATTE	4110	20360.3	PLAINS	SE PLAINS
WYW03437-109	FIRST	WB0295	DUCK CREEK - PERCUSSION LANE	42.881397	-109.957792	2007	GREEN	7215	10.6	XERIC	HIGH VALLEYS
WYW03437-110	FIRST	SR44	LITTLE BRUSH CREEK - SLASH RIDGE	41.355117	-106.424439	2006	NORTH PLATTE	9500	4.0	MOUNTAIN	SOUTHERN ROCKIES
WYW03437-115	FIRST	WB0298	BEAVER CREEK - BRINGOLF ROAD	42.797144	-108.343731	2007	BIGHORN	5319	278.8	XERIC	WYOMING BASIN
WYW03437-120	FIRST	WHP0044	HORSE CREEK - FORK CAMP	41.473000	-104.712000	2007	NORTH PLATTE	5600	110.3	PLAINS	SE PLAINS
WYW03437-124	FIRST	SR0055	LARAMIE RIVER - BELOW WHEATLAND TUNNEL	41.926163	-105.416368	2007	NORTH PLATTE	6435	2042.5	MOUNTAIN	SOUTHERN FOOTHILLS & LARAMIE RANGE
WYS08706-002	SECOND	NGP0215	POWDER RIVER - FALXA ROAD	44.000616	-106.180410	2008	POWDER	4081	3839.0	PLAINS	NE PLAINS
WYS08706-005	SECOND	MRW0165	GROS VENTRE RIVER - WEST MINERS	43.612183	-110.466685	2008	SNAKE	6950	526.6	MOUNTAIN	SEDIMENTARY MOUNTAINS
WYS08706-006	SECOND	NGP0214	DONKEY CREEK - GOLF COURSE	44.268173	-105.475841	2008	BELLE FOURCHE	4439	42.4	PLAINS	NE PLAINS
WYS08706-007	SECOND	SR0056	LARAMIE RIVER - ABOVE SHELLROCK CREEK	41.047061	-106.032781	2008	NORTH PLATTE	7590	356.0	MOUNTAIN	SOUTHERN FOOHILLS & LARAMIE RANGE
WYS08706-009	SECOND	WB0297	* SULPHUR CREEK - HALF MOON	44.440717	-109.084140	2008	BIGHORN	5276	25.0	XERIC	WYOMING BASIN
WYS08706-012	SECOND	MRW0167	LA BARGE CREEK - MOUNT THOMPSON	42.496268	-110.645236	2008	GREEN	8300	13.4	MOUNTAIN	SEDIMENTARY MOUNTAINS
WYS08706-014	SECOND	SR0057	CENTENNIAL CREEK - SHARP HILL	41.278476	-106.984440	2008	NORTH PLATTE	8320	1.6	MOUNTAIN	SOUTHERN FOOHILLS & LARAMIE RANGE

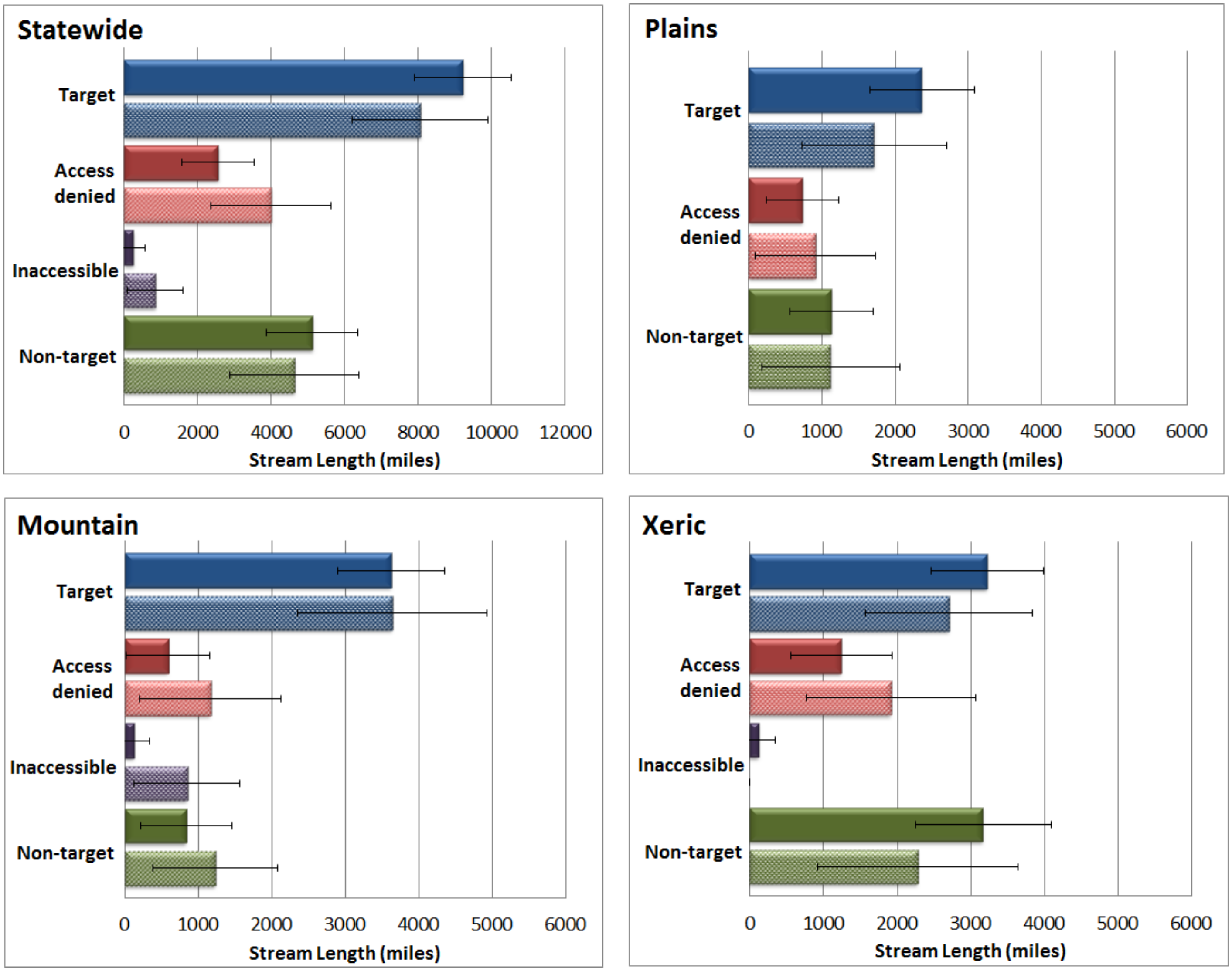
Table 2 (cont.) – Sites sampled as part of the first (2004-2007) and second (2008-2011) statewide probability surveys. Sites with asterisks were considered non-target and removed from analysis.

Survey ID	Survey	StationID		WaterbodyName - Reach Name	Latitude	Longitude	Year Monitored	HUC 6 Basin	Elevation (ft)	Watershed Area (mi^2)	Climatic Region	BIOREGION
WYS08706-015	SECOND	NGP0216	*	LIGHTNING CREEK - BELOW TWENTYMILE CREEK	43.201426	-104.718094	2008	CHEYENNE	4090	766.0	PLAINS	NE PLAINS
WYS08706-018	SECOND	MRE0025		INYAN KARA CREEK - DARK CANYON	44.259274	-104.523652	2008	BELLE FOURCHE	4370	175.0	MOUNTAIN	BLACK HILLS
WYS08706-019	SECOND	WHP0052		SYBILLE CREEK - NATWICK	41.978572	-105.075281	2008	NORTH PLATTE	4860	499.8	PLAINS	SE PLAINS
WYS08706-020	SECOND	WB0313		CURRANT CREEK - ABOVE WB107	41.257607	-109.535999	2008	GREEN	6010	48.9	XERIC	WYOMING BASIN
WYS08706-021	SECOND	MRW0166		TRUNK CREEK - SECTION 36	43.470155	-110.115206	2008	SNAKE	8953	1.0	MOUNTAIN	SEDIMENTARY MOUNTAINS
WYS08706-022	SECOND	NGP0213		CRAZY WOMAN CREEK - ZEZAS RANCH	44.068648	-106.607464	2008	POWDER	4500	287.0	PLAINS	HIGH VALLEYS
WYS08706-023	SECOND	WB0318		SAND CREEK - ARKANSAS FLATS	42.309417	-107.055625	2009	NORTH PLATTE	6085	60.0	XERIC	WYOMING BASIN
WYS08706-025	SECOND	WB0312		ENOS CREEK - 5860	43.968538	-108.762905	2008	BIGHORN	5860	35.1	MOUNTAIN	BIGHORN BASIN FOOTHILLS
WYS08706-027	SECOND	SR0066		WEST FORK LA BONTE CREEK - MANNING RIDGE	42.543797	-105.524205	2009	NORTH PLATTE	5360	46.3	PLAINS	NE PLAINS
WYS08706-028	SECOND	MRW0169		CORRAL CREEK - FITZPATRICK	42.681465	-110.754606	2009	SNAKE	8322	5.3	MOUNTAIN	SEDIMENTARY MOUNTAINS
WYS08706-029	SECOND	MRW0168		CRANDALL CREEK - BELOW RANGER STATION	44.854389	-109.620495	2009	YELLOWSTONE	6355	171.1	MOUNTAIN	SEDIMENTARY MOUNTAINS
WYS08706-030	SECOND	WB0325		MEDICINE BOW RIVER - TL RANCH	41.722113	-106.254127	2009	NORTH PLATTE	6890	236.0	XERIC	WYOMING BASIN
WYS08706-035	SECOND	SR0062		LARAMIE RIVER - SUGAR LOAF	41.934149	-105.371838	2009	NORTH PLATTE	6200	2045.9	MOUNTAIN	SOUTHERN FOOHILLS & LARAMIE RANGE
WYS08706-038	SECOND	WB0327		MIDDLE FORK POWDER RIVER - LEON DRAW	43.685675	-106.697567	2009	POWDER	4690	648.0	MOUNTAIN	BIGHORN BASIN FOOTHILLS
WYS08706-040	SECOND	WB0329		DEEP CREEK - ABOVE STRAWBERRY CONFLUENCE	42.436641	-108.515048	2009	NORTH PLATTE	7204	5.3	XERIC	HIGH VALLEYS
WYS08706-043	SECOND	SR0063		NORTH LARAMIE RIVER - MENTOR KNOB	42.163715	-105.480828	2009	NORTH PLATTE	6480	234.4	XERIC	WYOMING BASIN
WYS08706-044	SECOND	MRW0174		SALT RIVER - NORTH THAYNE	42.933240	-111.015393	2009	SNAKE	5855	360.2	MOUNTAIN	VOLCANIC MOUNTAINS & VALLEYS
WYS08706-045	SECOND	WB0326		WHISTLE CREEK - CEMETERY	44.730395	-108.583528	2009	BIGHORN	4070	97.1	XERIC	WYOMING BASIN
WYS08706-046	SECOND	SR0061		MILL CREEK - RYAN PARK	41.344282	-106.469289	2009	NORTH PLATTE	8800	1.9	MOUNTAIN	SOUTHERN ROCKIES
WYS08706-048	SECOND	MRE0026		BELLE FOURCHE RIVER - GANTZ	44.764300	-104.502421	2009	BELLE FOURCHE	3550	2831.7	PLAINS	NE PLAINS
WYS08706-051	SECOND	WB0354		LARAMIE RIVER - LAKE IONE	41.716625	-105.701731	2010	NORTH PLATTE	6985	1965.0	XERIC	WYOMING BASIN
WYS08706-052	SECOND	WB0332		BALDWIN CREEK - 5600	42.847401	-108.798584	2009	BIGHORN	5611	23.9	XERIC	HIGH VALLEYS
WYS08706-054	SECOND	MRC0121	*	WEST FOR BIG GOOSE CREEK - BELOW SAWMILL LAKES	44.630844	-107.280378	2010	TONGUE	7824	35.9	MOUNTAIN	GRANITIC MOUNTAINS
WYS08706-055	SECOND	WB0355		NORTH PLATTE RIVER - BESSEMER NARROWS	42.736710	-106.532412	2010	NORTH PLATTE	5190	10750.0	XERIC	WYOMING BASIN
WYS08706-057	SECOND	MRW0170		SNAKE RIVER - CAMP 4	44.085573	-110.697781	2009	SNAKE	6791	502.8	MOUNTAIN	VOLCANIC MOUNTAINS & VALLEYS
WYS08706-059	SECOND	SR0067		DEER CREEK - RENO HILL	42.567193	-106.030575	2010	NORTH PLATTE	7080	55.9	MOUNTAIN	SOUTHERN FOOHILLS & LARAMIE RANGE
WYS08706-060	SECOND	WB0375		ANTELOPE CREEK - BOULDER RIDGE	41.901074	-110.921616	2010	BEAR	6335	6.2	MOUNTAIN	SOUTHERN FOOHILLS & LARAMIE RANGE
WYS08706-061	SECOND	MRC0123		LITTLE BIGHORN RIVER - BOYD RIDGE	44.945405	-107.678582	2011	BIGHORN	5240	128.0	MOUNTAIN	SEDIMENTARY MOUNTAINS
WYS08706-062	SECOND	SR0068		NORTH PLATTE RIVER - SANGER RANCH	41.213843	-106.551483	2010	NORTH PLATTE	7230	2003.0	XERIC	WYOMING BASIN
WYS08706-063	SECOND	WB0374		SMITHS FORK - MUD SPRING	41.378328	-110.202397	2010	GREEN	6470	448.0	XERIC	WYOMING BASIN
WYS08706-064	SECOND	MRE0033		SAND CREEK - RANCH A	44.493341	-104.109424	2011	BELLE FOURCHE	3760	257.0	MOUNTAIN	BLACK HILLS
WYS08706-065	SECOND	MRW0188		HOBACK RIVER - HOBACK JUNCTION	43.318890	-110.705326	2011	SNAKE	5943	568.4	MOUNTAIN	SEDIMENTARY MOUNTAINS
WYS08706-067	SECOND	WB0321		LARAMIE RIVER - ABOVE UPRR TIE PLANT	41.294987	-105.610847	2010	NORTH PLATTE	7135	1005.0	XERIC	WYOMING BASIN
WYS08706-068	SECOND	WB0379		HENRYS FORK - 530 BRIDGE	41.004119	-109.667273	2011	GREEN	6067	520.0	XERIC	WYOMING BASIN
WYS08706-069	SECOND	MRW0187		NORTH FORK FISH CREEK - LAVA MOUNTAIN	43.694133	-110.099194	2011	SNAKE	8522	10.0	MOUNTAIN	SEDIMENTARY MOUNTAINS
WYS08706-071	SECOND	WB0352		BATES CREEK - SCHNOOR	42.632715	-106.437348	2010	NORTH PLATTE	5630	142.9	XERIC	WYOMING BASIN
WYS08706-075	SECOND	WB0353		DUCK CREEK - KENNEDY	42.008485	-105.448529	2010	NORTH PLATTE	6800	48.0	MOUNTAIN	SOUTHERN FOOHILLS & LARAMIE RANGE
WYS08706-078	SECOND	SR0069		PASS CREEK - COAD MOUNTAIN	41.581972	-106.565721	2010	NORTH PLATTE	7410	83.0	MOUNTAIN	SOUTHERN FOOHILLS & LARAMIE RANGE

Table 3 – Relative departures from mean annual flows at selected USGS stream gages during EMAP-WY and WDEQ/WQD's first and second statewide survey periods.

USGS Gage ID	USGS Gage Name	Climatic Region	Mean Annual Flow (cfs) 2000-2003 EMAP-WY	% Departure from Mean Annual Flow for Period of Record	Mean Annual Flow (cfs) 2004-2007 First Statewide Survey	% Departure from Mean Annual Flow for Period of Record	Mean Annual Flow (cfs) 2008-2011 Second Statewide Survey	% Departure from Mean Annual Flow for Period of Record	Mean Annual Flow (cfs) Period of Record	Period of Record
06188000	Lamar River nr. Tower Ranger Station YNP	Mountains	795.8	-8.9	777.3	-11.0	1085.6	24.3	873.7	1924-2011
06278300	Shell Creek abv. Shell Creek Reservoir	Mountains	22.5	-32.6	27.0	-19.2	36.9	10.5	33.4	1957-2011
06279940	North Fork Shoshone River at Wapiti, WY	Mountains	665.1	-20.9	660.8	-21.4	1059.7	26.0	841.2	1990-2011
06298000	Tongue River nr. Dayton, WY	Mountains	113.0	-36.2	132.7	-25.1	215.1	21.4	177.2	1920-2011
06309200	Middle Fork Powder River nr. Barnum, WY	Mountains	14.5	-50.5	21.7	-25.9	39.5	34.8	29.3	1962-2011
06620000	North Platte River nr. Northgate, CO	Mountains	227.5	-47.3	341.2	-21.0	605.5	40.3	431.7	1916-2011
06622700	North Brush Creek nr. Saratoga, WY	Mountains	36.0	-29.8	40.7	-20.7	84.1	63.9	51.3	1961-2011
06623800	Encampment River abv. Hog Park Creek	Mountains	80.7	-30.1	106.6	-7.6	170.7	47.9	115.4	1965-2011
09188500	Green River at Warren Bridge nr. Daniel, WY	Mountains	358.5	-27.4	389.2	-21.2	496.6	0.5	493.9	1932-2011
09196500	Pine Creek abv. Fremont Lake	Mountains	136.4	-21.1	151.3	-12.4	175.5	1.6	172.8	1955-2011
09210500	Fontenelle Creek nr. Herschler Ranch	Mountains	42.6	-40.2	63.4	-11.0	84.2	18.3	71.2	1952-2011
09220000	East Fork Smiths Fork nr. Robertson, WY	Mountains	29.9	-34.9	35.6	-22.4	54.4	18.5	45.9	1940-2011
09223000	Hams Fork blw. Pole Creek	Mountains	44.7	-53.0	76.2	-19.9	106.1	11.6	95.1	1953-2011
13010065	Snake River abv. Jackson Lake at Flagg Ranch	Mountains	733.5	-17.9	774.0	-13.3	1028.0	15.1	893	1984-2011
13018300	Cache Creek nr. Jackson, WY	Mountains	8.1	-35.7	9.6	-23.8	14.2	12.7	12.6	1963-2011
			Departure Range:	-8.9 to -53.0		-7.6 to -25.9		0.5 to 63.9		
			Mean Departure:	-32.4		-18.4		23.2		
06289600	West Pass Creek nr. Parkman, WY	Plains	8.8	-28.5	9.2	-25.2	15.9	29.3	12.3	1983-2011
06289820	East Pass Creek nr. Dayton, WY	Plains	10.4	-29.3	11.1	-24.5	19.5	32.7	14.7	1983-2011
06317000	Powder River at Arvada, WY	Plains	147.1	-45.4	147.1	-45.4	329.8	22.4	269.5	1931-2011
06324970	Little Powder River abv. Dry Creek	Plains	5.7	-73.9	17.4	-20.2	34.5	58.3	21.8	1973-2011
06386500	Cheyenne River nr. Spencer, WY	Plains	-	-	3.2	-93.4	33.6	-31.1	48.8	1949-2011
06425720	Belle Fourche River blw. Rattlesnake Creek	Plains	2.4	-7.7	1.9	-26.9	3.7	42.3	2.6	1976-2011
06426500	Belle Fourche River blw. Moorcroft, WY	Plains	13.4	-42.2	11.7	-49.6	32.0	37.9	23.2	1944-2011
			Departure Range:	-7.7 to -73.9		-20.2 to -93.3		22.4 to 58.3		
			Mean Departure:	-37.8		-40.7		27.4		
06218500	Wind River nr. Dubois, WY	Xeric	113.0	-32.7	111.2	-33.8	182.9	8.9	167.9	1946-2011
06280300	South Fork Shoshone River nr. Valley, WY	Xeric	313.6	-23.1	310.2	-24.0	499.2	22.4	408	1957-2011
06634620	Little Medicine Bow River at Boles Spring	Xeric	29.4	-28.6	19.9	-51.7	64.5	56.6	41.2	1985-2011
			Departure Range:	-23.1 to -32.7		-24.0 to -51.7		8.9 to 56.6		
			Mean Departure:	-28.2		-36.5		29.3		
			Statewide Departure Range:	-7.7 to -73.9		-7.6 to -93.3		0.5 to 63.9		
			Statewide Mean Departure:	-33.4		-27.0		25.1		

Figure 3 – Estimated target stream and river length relative to access denied, inaccessible and non-target lengths at the statewide and climatic region scales. Solid (top) bars represent the first survey (2004-2007) whereas patterned (bottom) bars represent the second survey (2008-2011). Error bars represent the 95% confidence intervals.



perennial stream length in RF3 and 54% of the targeted perennial stream length from the GRTS modified sample frame.

For the second statewide probability survey, a total of 78 sites were evaluated that represented 17,513 miles of target stream length. Approximately 26% (4,626 miles) of the target stream length were identified as non-target, 23% (3,986 miles) were denied access and 5% (846 miles) were inaccessible (Table 2, Figures 2 and 3). Five of the non-target sites were sampled though later identified as non-perennial or the collected data were considered non-representative. The remaining 8,055 miles (40 sites) were sampled and represented the assessed targeted stream length. This assessed targeted length represents 21% of the total perennial stream length in NHD+ and 46% of the targeted perennial stream length from the GRTS modified sample frame.

The difference in miles of targeted perennial stream length between the statewide surveys (17,147 versus 17,513 miles) is attributed to differences in the resolution of the sample frames (RF3 versus NHD+) and slight variations in the GRTS designs. An important finding from both statewide surveys is that a sizeable portion of the targeted perennial stream length was found to be non-target based on field determinations. This indicates that both RF3 and NHD+ overestimate perennial stream length (represented by the target, inaccessible and denied access lengths) in Wyoming by approximately 30%, similar to that reported west-wide by Stoddard et al. (2005). Overestimates of perennial stream length in Wyoming also varied by climatic region with means of 17% in the mountains, 29% in the plains and 37% in the xeric among both statewide surveys.

Of the 9,215 miles of assessed targeted streams in the first statewide survey, approximately 5% (427 miles) were identified as effluent dependent. Similarly, 5% (403 miles) of the 8,055 miles of assessed targeted streams represented by the second statewide survey were effluent dependent. All effluent dependent streams were located in the plains or xeric climatic regions.

The flow regimes of approximately 26% (2,381 miles) of the assessed targeted stream miles for the first statewide survey were reservoir influenced (≥50% of the respective watershed areas). Similarly, 16% (1,267 miles) of the assessed targeted stream miles for the second statewide survey were reservoir influenced.

Flow alterations represented by diversions or trans-basin inputs had varying influences on approximately 57% (5,235 miles) of the 9,215 miles of the assessed targeted streams for the first statewide survey. The second statewide survey revealed similar results with 69% (5,533 miles) of the 8,055 miles of assessed targeted streams influenced by flow alterations. The vast majority of flow alterations were identified within the plains and xeric climatic regions.

For both the first and second statewide surveys, more sampling sites on the assessed targeted streams were located in the mountains (24 and 22, respectively) and xeric (22 and 12, respectively) climatic regions rather than the plains (14 and 6, respectively) because of the higher occurrence of targeted perennial streams in those regions.

BIOLOGICAL CONDITION

Statewide, the WSII assessed 47% and 43% of perennial stream length as 'least-disturbed' during the first and second statewide surveys, respectively (Figure 4). Approximately 28% (first survey) and 26% (second survey) of statewide perennial stream miles were in the most-disturbed condition. 'Indeterminate' perennial stream length increased marginally from 25% in the first survey to 31% in the second. Among the three climatic regions, the mountains exhibited the largest percentage of least-disturbed stream miles with 54% and 56% in the first and second statewide surveys, respectively. The xeric region attained the lowest percentages of least-disturbed stream miles with 42% in the first survey and 36% in the second. Though similar to the xeric, the highest percentages of most-disturbed stream miles were located in the plains region with 41% and 61% in the first and second surveys, respectively.

The WY RIVPACS assigned a greater percentage of stream miles to the least-disturbed condition relative to the WSII with 60% in the first and 55% in the second statewide survey (Figure 5). A similar percentage of stream length statewide was in the most-disturbed condition between the first (12%) and second (13%) surveys. Similar to the results from the WSII, the mountain climatic region possessed the highest percentages of stream miles in the least-disturbed condition (first survey – 59%, second survey – 61%) compared to the other two climatic regions (Figure 5). Again, the highest percentages of most-disturbed stream miles were found in the plains region (first – 13%, second – 24%). However, the lowest percentages of least-disturbed streams were found in the xeric region (first – 63%, second – 43%) – similar to the WSII.

Information from both the WSII and WY RIVPACS ratings along with considerations for multi-habitat samples and effluent dependent systems, were incorporated into WDEQ/WQD's aquatic life use matrix to determine overall biological condition. Approximately 53% and 22% of the statewide assessed targeted perennial streams were in the 'least-disturbed' and 'most-disturbed' condition, respectively, for the first statewide survey (Figure 6). The percentage of perennial streams in the 'least-disturbed' condition remained statistically equivalent in the second statewide survey at 58% and compared to EMAP-WY (52%) (Table 4). The percentage of perennial stream miles in the 'most-disturbed' condition decreased slightly to 18% in the second statewide survey relative to the first statewide survey though was significantly less ($P < 0.05$) to that represented by EMAP-WY (32%) (Table 4).

Among the three climatic regions, the mountains attained the highest percentage of 'least-disturbed' stream miles which steadily increased ($P < 0.05$) from EMAP-WY (51%) to the first (66%) and second (81%) statewide surveys (Figure 6, Table 4). Similarly, the percentage of 'most-disturbed' stream miles in the mountains decreased substantially ($P < 0.05$) from 33% during EMAP-WY to 18% in the first survey and 4% in the second survey (Table 4). The percentage of 'most-disturbed' plains streams was equivalent between the first (33%) and second (24%) statewide surveys (Table 4). Likewise, plains perennial streams in the 'least-disturbed' biological condition were equivalent between the first (41%) and second (39%) surveys. Data collected in the plains for EMAP-WY were insufficient to make comparisons to WDEQ/WQD's two statewide surveys. The xeric region exhibited an equivalent percentage of 'most-disturbed' streams among the first (19%) and second (25%) statewide surveys and EMAP-WY (26%) (Table 4). Perennial streams in the xeric region assigned a 'least-disturbed' condition remained equivalent between the first (48%) and second (53%) surveys. There was however a notable decline ($P < 0.05$) in 'least-disturbed' condition in the xeric region from EMAP-WY (66%) to the first statewide survey (48%) (Table 4).

RECREATIONAL CONDITION

The recreational condition of Wyoming streams and rivers is shown in Appendix 1. For the first survey, 62% of the assessed targeted perennial streams was in the least-disturbed condition or exhibited instantaneous *E. coli* concentrations less than Wyoming's geometric mean criterion protective of primary contact recreation. The percentage of streams in the least-disturbed condition increased dramatically ($P < 0.05$) to 80% in the second survey (Table 5). Both the plains and xeric climatic regions showed similar increases ($P < 0.05$) in the least-disturbed condition between the first and second surveys,

Figure 4 – Biological condition of targeted perennial streams and rivers in Wyoming based on results from the Wyoming Stream Integrity Index (WSII). Solid (top) bars represent the first survey (2004-2007) whereas patterned (bottom) bars represent the second survey (2008-2011). Error bars represent the 95% confidence intervals.

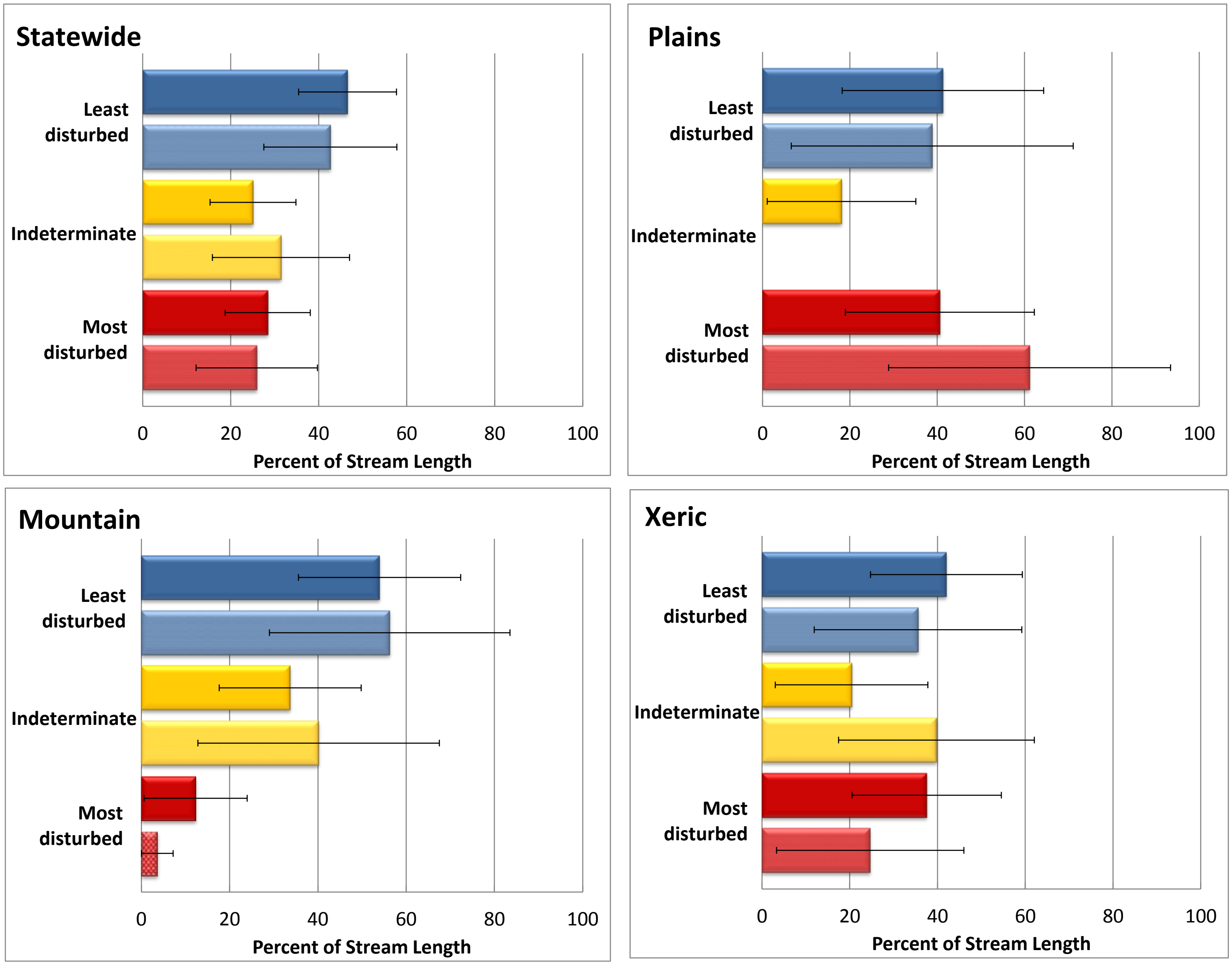


Figure 5 - Biological condition of targeted perennial streams and rivers in Wyoming based on results from the Wyoming River InVertebrate Prediction And Classification System (WY RIVPACS). Solid (top) bars represent the first survey (2004-2007) whereas patterned (bottom) bars represent the second survey (2008-2011). Error bars represent the 95% confidence intervals.

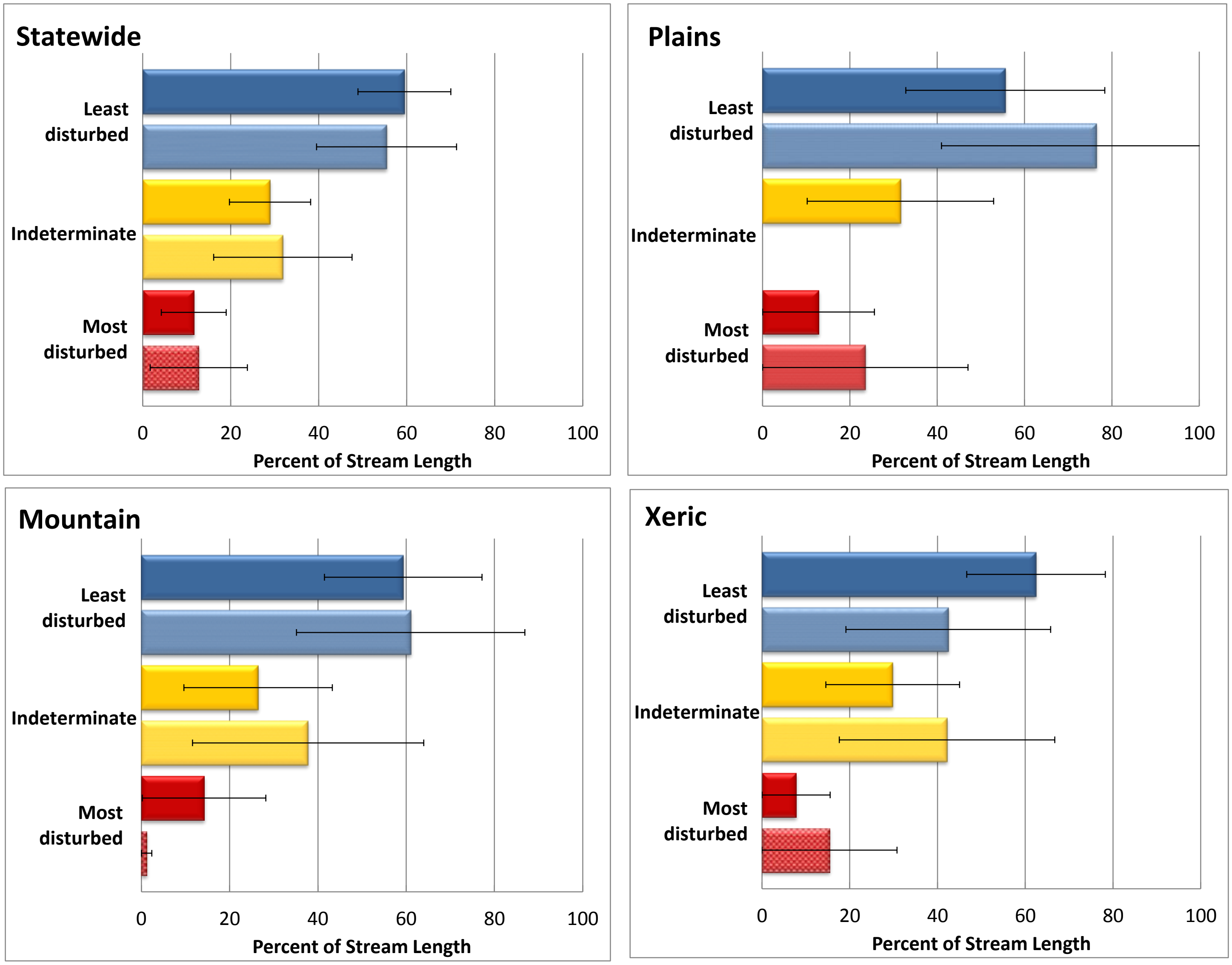


Figure 6 - Biological condition of targeted perennial streams and rivers in Wyoming based on WDEQ/WQD's aquatic life use matrix. Solid (top) bars represent the first survey (2004-2007) whereas patterned (bottom) bars represent the second survey (2008-2011). Error bars represent the 95% confidence intervals.

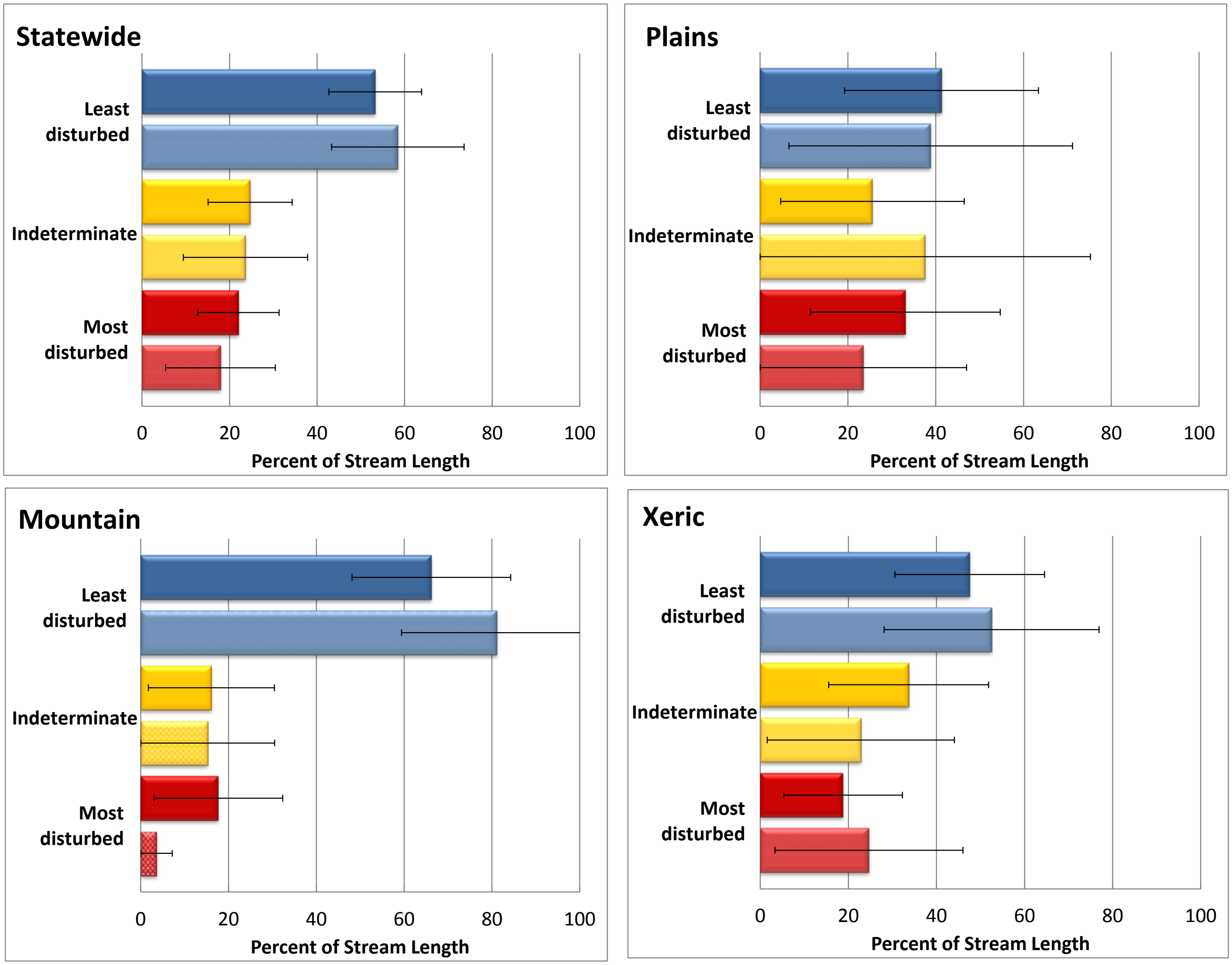


Table 4 – Biological condition estimates for EMAP-WY and WDEQ/WQD's first and second statewide surveys with associated trends and P-values for comparisons between surveys. Bold values are significant at $P < 0.05$.

Region	Biological Condition	EMAP-WY			First Statewide Survey			Second Statewide Survey	EMAP-WY to Second Statewide Survey	
		% of Stream Length	Trend	P value	% of Stream Length	Trend	P value	% of Stream Length	trend	P value
Statewide	Least-disturbed	52	NC	1.0000	53	NC	0.5694	58	NC	0.4774
	Most-disturbed	32	NC	0.1514	22	NC	0.5963	18	↓	**0.0332**
	Indeterminate	16	NC	0.1606	25	NC	1.0000	24	NC	0.2156
Mountains	Least-disturbed	51	↑	**0.0442**	66	↑	**0.0244**	81	↑	**<0.0001**
	Most-disturbed	33	↓	**0.0226**	18	↓	**0.0026**	4	↓	**<0.0001**
	Indeterminate	17	NC	1.0000	16	NC	1.0000	15	NC	0.8473
Xeric	Least-disturbed	66	↓	**0.0150**	48	NC	0.5717	53	NC	0.0836
	Most-disturbed	26	NC	0.3096	19	NC	0.3936	25	NC	1.0000
	Indeterminate	8	↑	**<0.0001**	34	NC	0.0827	22	↑	**0.0092**
Plains	Least-disturbed	-	-	-	41	NC	0.8853	39	-	-
	Most-disturbed	-	-	-	33	NC	0.2100	24	-	-
	Indeterminate	-	-	-	26	NC	0.0950	38	-	-

NC = No Significant Change, '-' Insufficient data

Table 5 – Stressor condition estimates for WDEQ/WQD's first and second statewide surveys with associated trends and P-values for comparisons between surveys. Bold values are significant at $P < 0.05$.

Stressor	Region	Stressor Condition	First Statewide Survey % of Stream Length	Trend	P value	Second Statewide Survey % of Stream Length
Escherichia coli		Least-disturbed	62	↑	**0.0078**	80
	Statewide	Most-disturbed	11	↓	**0.0489**	3
		Intermediate	27	NC	0.1239	17
		Least-disturbed	84	NC	1.0000	84
	Mountains	Most-disturbed	-	-	-	-
		Intermediate	16	NC	1.0000	16
		Least-disturbed	45	↑	**0.0027**	67
	Xeric	Most-disturbed	20	↓	**0.0119**	7
		Intermediate	35	NC	0.2190	26
		Least-disturbed	53	↑	**<0.0001**	100
	Plains	Most-disturbed	14	↓	**<0.0001**	0
		Intermediate	33	↓	**<0.0001**	0
Nitrate + Nitrite-N		Least-disturbed	74	NC	0.1681	83
	Statewide	Most-disturbed	20	↓	**0.0119**	7
		Intermediate	6	NC	0.3106	11
		Least-disturbed	84	↑	**0.0081**	96
	Mountains	Most-disturbed	10	↓	**0.0097**	1
		Intermediate	5	NC	0.4448	2
		Least-disturbed	63	↑	**0.0001**	87
	Xeric	Most-disturbed	37	↓	**0.0003**	14
		Intermediate	-	-	-	-
		Least-disturbed	72	↓	**0.0125**	54
	Plains	Most-disturbed	13	↓	**0.0002**	0
		Intermediate	16	↑	**<0.0001**	46
Total Phosphorus		Least-disturbed	66	↓	**0.0150**	48
	Statewide	Most-disturbed	13	NC	1.0000	14
		Intermediate	21	↑	**0.0190**	37
		Least-disturbed	75	↓	**<0.0001**	46
	Mountains	Most-disturbed	11	NC	0.6696	14
		Intermediate	14	↑	**<0.0001**	41
		Least-disturbed	56	NC	0.2576	47
	Xeric	Most-disturbed	14	NC	0.2640	21
		Intermediate	29	NC	0.7589	32
		Least-disturbed	67	NC	0.1460	56
	Plains	Most-disturbed	13	↓	**0.0002**	0
		Intermediate	20	↑	**0.0004**	44
Salinity		Least-disturbed	65	↓	**0.0449**	50
	Statewide	Most-disturbed	25	NC	1.0000	26
		Intermediate	10	↑	**0.0136**	24
		Least-disturbed	88	NC	0.4804	92
	Mountains	Most-disturbed	6	NC	0.1184	1
		Intermediate	6	NC	1.0000	7
		Least-disturbed	38	↓	**0.0311**	23
	Xeric	Most-disturbed	45	NC	0.0809	32
		Intermediate	17	↑	**<0.0001**	45
		Least-disturbed	71	↓	**0.0192**	54
	Plains	Most-disturbed	24	↑	**0.0018**	46
		Intermediate	6	↓	**0.0289**	0
TSS		Least-disturbed	38	NC	0.1308	27
	Statewide	Most-disturbed	30	NC	0.3688	37
		Intermediate	32	NC	0.6545	36
		Least-disturbed	69	NC	0.3722	62
	Mountains	Most-disturbed	11	NC	0.6696	14
		Intermediate	21	NC	0.7351	24
		Least-disturbed	12	NC	0.4804	8
	Xeric	Most-disturbed	55	NC	0.1571	44
		Intermediate	33	↑	**0.0434**	48
		Least-disturbed	24	NC	0.6089	20
	Plains	Most-disturbed	28	↑	**0.0003**	54
		Intermediate	48	↓	**0.0012**	25

NC = No Significant Change, '-' Insufficient data

Table 5 (cont.) – Stressor condition estimates for WDEQ/WQD's first and second statewide surveys with associated trends and P-values for comparisons between surveys. Bold values are significant at P < 0.05.

Stressor	Region	Stressor Condition	First Statewide Survey % of Stream Length	Trend	P value	Second Statewide Survey % of Stream Length
Chloride	Statewide	Least-disturbed	92	↑	**0.0068**	100
		Most-disturbed	8	↓	**0.0068**	0
	Mountains	Least-disturbed	100	NC	1.0000	100
		Most-disturbed	-	-	-	-
	Xeric	Least-disturbed	87	↑	**0.0002**	100
		Most-disturbed	13	↓	**0.0002**	0
	Plains	Least-disturbed	87	↑	**0.0002**	100
		Most-disturbed	13	↓	**0.0002**	0
Sulfate	Statewide	Least-disturbed	91	↑	**0.0032**	100
		Most-disturbed	9	↓	**0.0032**	0
	Mountains	Least-disturbed	94	↑	**0.0289**	100
		Most-disturbed	6	↓	**0.0289**	0
	Xeric	Least-disturbed	91	↑	**0.0032**	100
		Most-disturbed	9	↓	**0.0032**	0
	Plains	Least-disturbed	87	↑	**0.0002**	100
		Most-disturbed	14	↓	**0.0002**	0
Physical Stressors	Statewide	Riparian Disturbance	22	↑	**0.0423**	36
		Channel Instability	33	NC	0.3053	41
		Excess Sediment	29	NC	0.2925	37
		Accelerated Bank Erosion	8	↑	**0.0020**	25
		Channel Incision	9	↑	**0.0113**	23
	Mountains	Riparian Disturbance	23	NC	0.1445	14
		Channel Instability	14	NC	0.5634	18
		Excess Sediment	11	NC	0.2278	18
		Accelerated Bank Erosion	11	↓	**0.0184**	2
		Channel Incision	4	↑	**0.0238**	14
	Xeric	Riparian Disturbance	27	↑	**0.0001**	55
		Channel Instability	49	NC	1.0000	48
		Excess Sediment	44	NC	0.6705	48
		Accelerated Bank Erosion	9	↑	**<0.0001**	51
		Channel Incision	17	↑	**0.0208**	32
	Plains	Riparian Disturbance	15	NC	0.1528	24
		Channel Instability	41	↑	**0.0234**	58
		Excess Sediment	35	NC	0.4665	41
		Accelerated Bank Erosion	-	-	-	-
		Channel Incision	5	↑	**0.0115**	17

NC = No Significant Change, '-' Insufficient data

with the largest increase (47%) in the plains. The least-disturbed condition remained equivalent in the mountains with 84% in both surveys.

PHYSICOCHEMICAL STRESSORS TO BIOLOGICAL CONDITION

NUTRIENTS

Statewide, the percentage of stream length in the least-disturbed nitrate+nitrite-N condition remained similar between the first (74%) and second (83%) surveys (Appendix 2, Table 5). The extent of stream length in the most-disturbed nitrate condition declined significantly ($P < 0.05$) from 20% in the first survey to 7% in the second survey (Appendix 2, Table 5). Comparisons could not be made to EMAP-WY since nitrate+nitrite-N was not collected as part of that study. The highest percentage of streams in the most-disturbed nitrate+nitrite-N condition for both surveys occurred primarily in the xeric climatic region. However, the percentage of xeric streams in the most-disturbed nitrate+nitrite-N condition decreased 23% ($P < 0.05$) between the two surveys (Appendix 2, Table 5). The mountain and plains regions also exhibited marked decreases ($P < 0.05$) (9% - mountains, 13% - plains) in the most-disturbed nitrate+nitrite-N condition between surveys. For both the first and second surveys, no nitrate concentrations exceeded WDEQ/WQD's minimum nitrate human-health criterion of 10,000 µg/L protective of drinking water use.

There was a notable ($P < 0.05$) 18% decline in the percentage of streams that met the least-disturbed total phosphorus condition between the first (66%) and second (48%) surveys (Appendix 3, Table 5). Approximately 14% of streams statewide were in the most-disturbed total phosphorus condition for both surveys – comparable to the 20% identified with EMAP-WY (Appendix 3). The percentage of mountain streams in the most-disturbed total phosphorus condition was equivalent (Table 5) between the first (11%) and second (14%) surveys though was considerably less than the 36% documented with EMAP-WY. Conversely, a 13% decrease ($P < 0.05$) in the percentage of most-disturbed stream length for total phosphorus was noted in the plains region whereas there was no statistical difference in this condition within the xeric region (Appendix 3, Table 5). EMAP-WY identified most-disturbed total phosphorus conditions in almost 10% of perennial streams in the plains and 0% in the xeric regions.

SALINITY

Approximately 65% of streams for the first statewide survey were in the least-disturbed and 25% in the most-disturbed conditions (Appendix 4). The percentage of perennial streams in the least-disturbed condition dropped ($P < 0.05$) to 50% in the second survey even though the percentages of streams in the most-disturbed condition were statistically equivalent between the first (25%) and second (26%) surveys (Appendix 4, Table 5). Among the three climatic regions, the xeric (first survey: 45%, second survey: 32%) and plains (first survey: 24%, second survey: 46%) exhibited the highest percentages of most-disturbed streams for salinity for both surveys (Appendix 4). Between both statewide surveys, the percentage of streams in the most-disturbed salinity condition increased 22% ($P < 0.05$) in the plains though was equivalent in the xeric (Table 5). According to EMAP-WY, approximately 18% and 55% of stream miles in the xeric and plains regions, respectively, were affected by elevated salinity.

TOTAL SUSPENDED SOLIDS

Statewide, 30% of streams miles were in the most-disturbed condition and 38% in the least-disturbed condition for the first survey (Appendix 5). The second survey revealed that the percentage of stream miles in both of these categories (most-disturbed: 37%, least-disturbed: 27%) remained statistically equivalent to the first survey (Appendix 5, Table 5). Comparisons of TSS to EMAP-WY results could not be made as this constituent was not analyzed as part of that study. The highest percentages of stream miles in the most-disturbed TSS condition were in the xeric (55% - first survey, 44% - second survey) and plains (28% - first survey, 54% - second survey) regions (Appendix 5). The plains experienced a notable increase ($P < 0.05$) of 26% whereas the xeric was similar in the most-disturbed TSS condition between the two surveys (Appendix 5, Table 5).

CHLORIDE, pH and SULFATE

Comparison to Wyoming's numeric chronic criterion for chloride protective of fisheries uses revealed that statewide, 92% of stream miles in the State met the least-disturbed condition for chloride for the first survey. The remaining 8% of statewide stream miles represented the most-disturbed condition with equal representation in the xeric and plains climatic regions. The percentage of least-disturbed steam miles increased to 100% ($P < 0.05$) in all regions during the second survey (Table 5). All waters monitored for both statewide surveys were within Wyoming's pH criteria range protective of aquatic life uses. Both of these estimates are comparable to EMAP-WY where only 3% of statewide stream length was in the most-disturbed condition for chloride whereas all stream miles were within the least-disturbed pH condition.

During the first statewide survey, 9% of statewide stream miles were in the most-disturbed sulfate condition with the remaining 91% in the least-disturbed condition. Stream miles in the most-disturbed sulfate condition were more common in the plains region. Stream miles in the most-disturbed sulfate condition were often associated with the most-disturbed chloride condition, typically in effluent-dependent waters. As with chloride, the percentage of least-disturbed stream miles for sulfate increased to 100% ($P < 0.05$) in all regions for the second survey (Table 5).

PHYSICAL STRESSORS TO BIOLOGICAL CONDITION

RIPARIAN DISTURBANCE

Statewide, riparian disturbance exceeded the most-disturbed condition thresholds in 22% and 36% of stream length for the first and second surveys, respectively – an increase of 14% ($P < 0.05$) (Appendix 6, Table 5). However, these statewide estimates were less than the 47% identified by EMAP-WY. Between the two surveys for this stressor, the mountains and plains both experienced a negligible 9% decrease and the largest increase of 29% occurred in the xeric ($P < 0.05$) (Table 5). Riparian disturbance in the mountains (first survey: 23%, second survey: 14%) and plains (first survey: 15%, second survey: 24%), respectively, was less than EMAP-WY's 28% and 45%, respectively. Though riparian disturbance increased in the xeric region between WDEQ/WQD's two surveys (27% to 55%), both statewide survey percentages were considerably less than the 90% of xeric stream length identified with EMAP-WY.

CHANNEL INSTABILITY

Throughout Wyoming, a statistically equivalent 33% and 41% of stream length exhibited indicators of channel instability (excess sediment, accelerated bank erosion and/or channel incision) for the first and second surveys, respectively (Appendix 6, Table 5). The percentage of current statewide stream miles affected by channel instability rose 20% from the EMAP-WY survey. For both surveys, the highest proportion of streams with channel instability occurred in the xeric (first survey: 49%, second survey: 48%) and plains (first survey: 41%, second survey: 58%). Between both surveys, percentages of stream length with channel instability were statistically equivalent in the mountains and xeric though increased significantly (17%, $P < 0.05$) in the plains (Appendix 6, Table 5). According to EMAP-WY, channel instability was ~30% in the xeric region and >50% in the plains.

Partitioning channel instability into its three component sub-stressors revealed that a large proportion of statewide stream miles with channel instability problems (86% - first survey, 91% - second survey) were attributed to excess sediment (Appendix 7). Statewide and in all climatic regions, the percentage of streams with excess sediment remained statistically equivalent between both surveys (Table 5). Conversely, statewide accelerated bank erosion and channel incision increased ($P < 0.05$) 17% and 14%, respectively, between both statewide surveys (Appendix 7, Table 5). The significant increase in statewide accelerated bank erosion was primarily attributed to the large increase of 42% ($P < 0.05$) in the xeric region (Appendix 7, Table 5). Notable increases ($P < 0.05$) in channel incision were similar (10-15%) among all climatic regions between the first and second statewide survey. (Appendix 7, Table 5). Combined, these three sub-stressors exhibited their greatest relative extents within the xeric region during both statewide surveys (Appendix 7).

RANKING OF STRESSORS

Channel instability (first survey: 33%, second survey: 41%) and TSS (first survey: 30%, second survey: 37%) were consistently the top two most common stressors to perennial streams statewide for both surveys (Figure 7). This is in contrast to EMAP-WY where riparian disturbance (>50%) and habitat simplification (40%) were considered the top two statewide stressors for that period of record. Nutrients (nitrate+nitrite-N and total phosphorus) and chloride were the least common statewide stressors in both surveys, each affecting approximately 20% or less of statewide stream length (Figure 7). Within the plains climatic region, channel instability was the most common stressor among both surveys (first survey: 41%, second survey: 58%) (Figure 7). EMAP-WY revealed that habitat simplification (>75%) and channel instability were the most common (>50%) stressors in the plains region. Among both surveys, channel instability, TSS and riparian disturbance were the most widespread stressors affecting perennial streams and rivers of the xeric climatic region. Based on both surveys, an average 50%, 48% and 41% of stream miles in the xeric region were influenced by TSS, channel instability and riparian disturbance, respectively (Figure 7). Riparian disturbance (90%) and habitat simplification (>50%) were the most common stressors to xeric region streams during the EMAP-WY study. Considering both surveys, riparian disturbance was the predominant stressor in the mountain climatic region (first survey: 23%, second survey: 14%) (Figure 7). This is in contrast to EMAP-WY where habitat simplification (38%) and total phosphorus (36%) were the top two stressors in the mountain climatic region.

DISCUSSION

One of the challenges that States face with administration of the federal Clean Water Act is describing the overall water quality condition of their streams and rivers. The challenges lie in the data collection, analytical techniques, study design, consistency as well as limitations in resources to complete such endeavors. Probability surveys were designed specifically to address this important component of the Clean Water Act. Since the late 1980s, probability surveys have been implemented in one form or another at the national, State and regional scales. Their popularity has increased over time because they provide a statistically rigorous, objective and cost-effective approach to assess and track trends in the condition of waters.

Results from EMAP-WY (2000-2003) provided the first baseline evaluation on the ecological status of Wyoming's perennial streams and rivers. WDEQ/WQD subsequently implemented their first (2004-2007) and second (2008-2011) statewide surveys that were built upon the foundation laid by EMAP-WY and enhanced the ability to provide a representative picture of water-quality condition statewide, track trends in that condition and identify potential chemical and physical stressors to biological condition

Figure 7 – Relative extent of chemical and physical stressors that indicate the most-disturbed condition at the statewide and climatic region scales. Error bars represent the 95% confidence intervals.

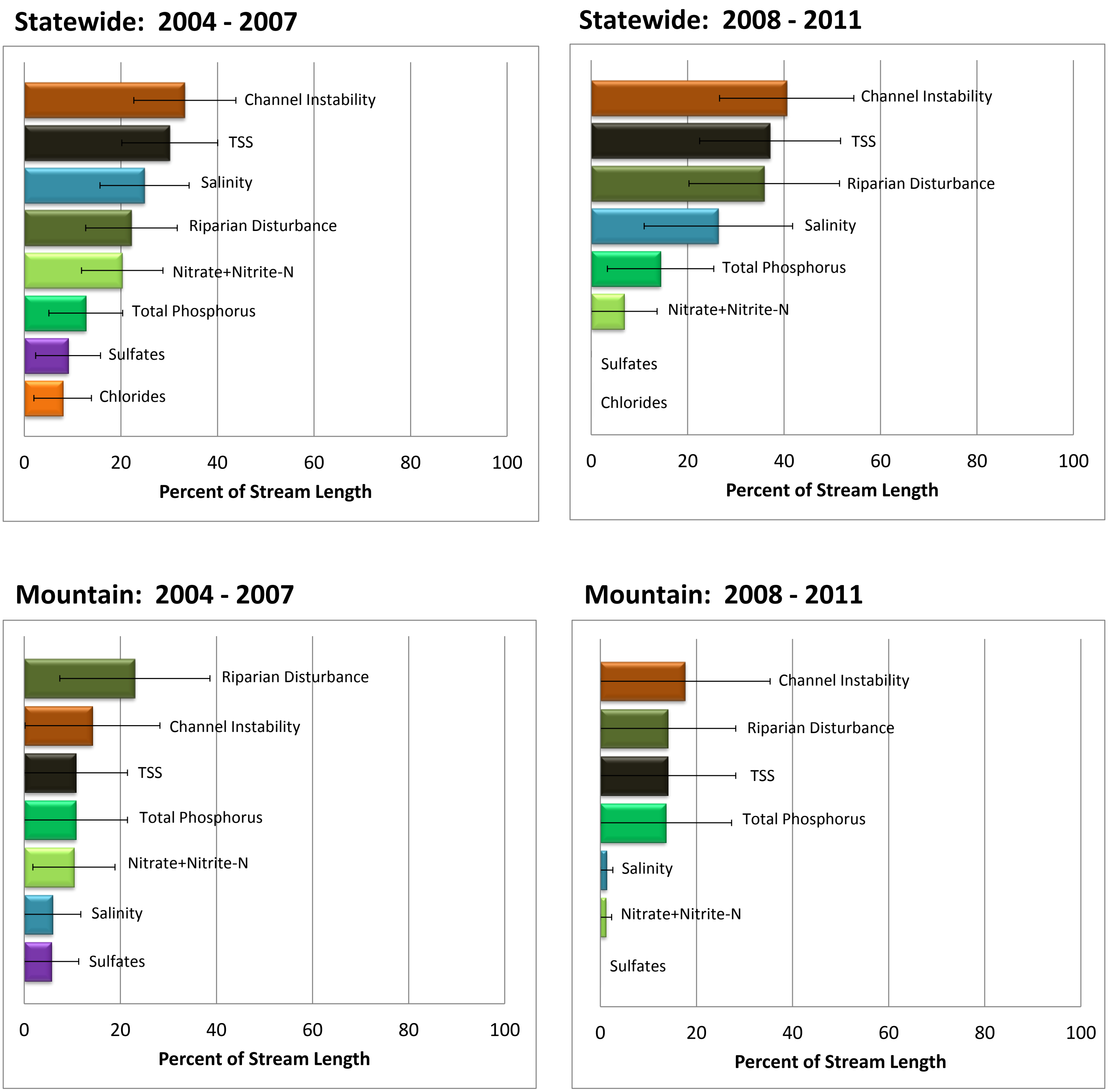
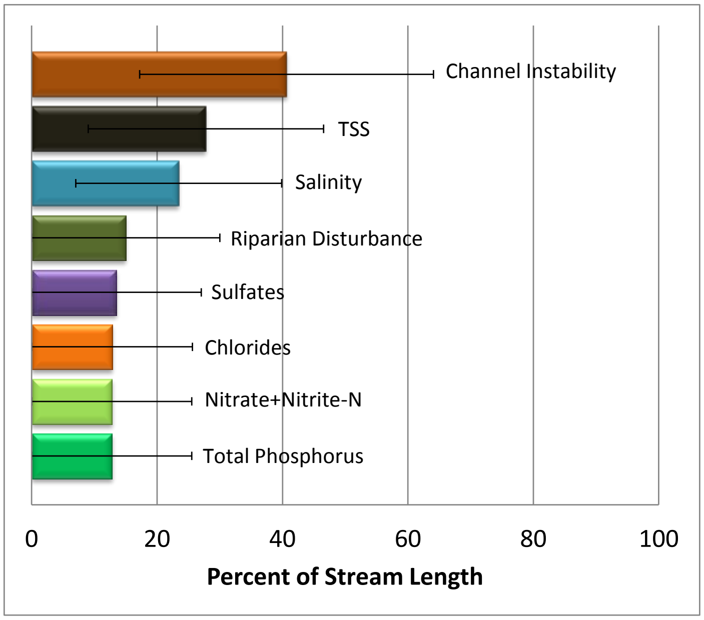
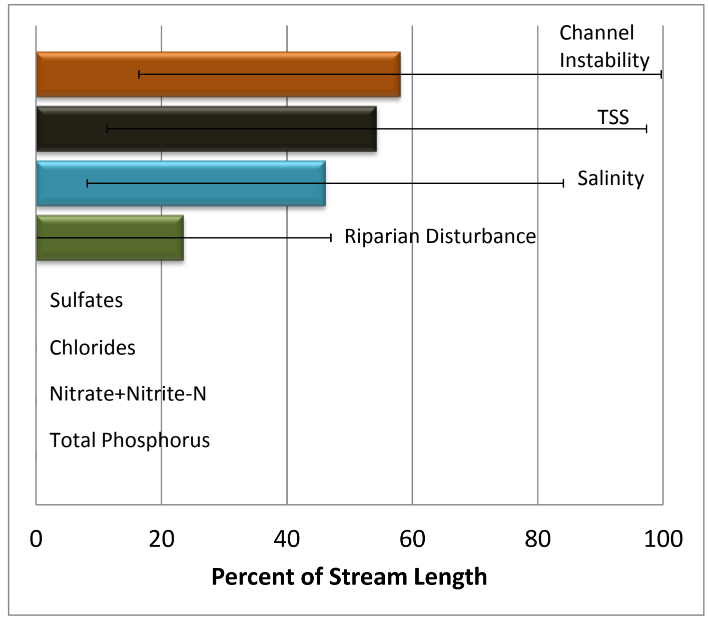


Figure 7 (cont.) - Relative extent of chemical and physical stressors that indicate the most-disturbed condition at the statewide and climatic region scales. Error bars represent the 95% confidence intervals.

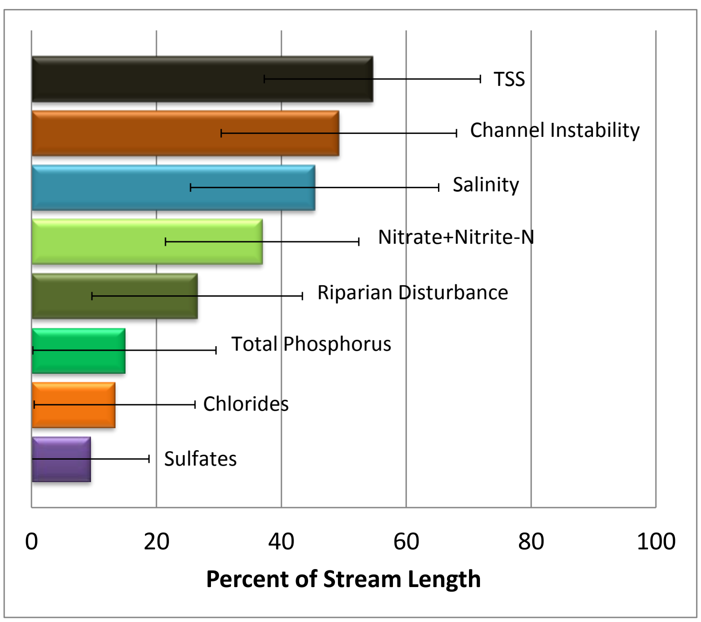
Plains: 2004 - 2007



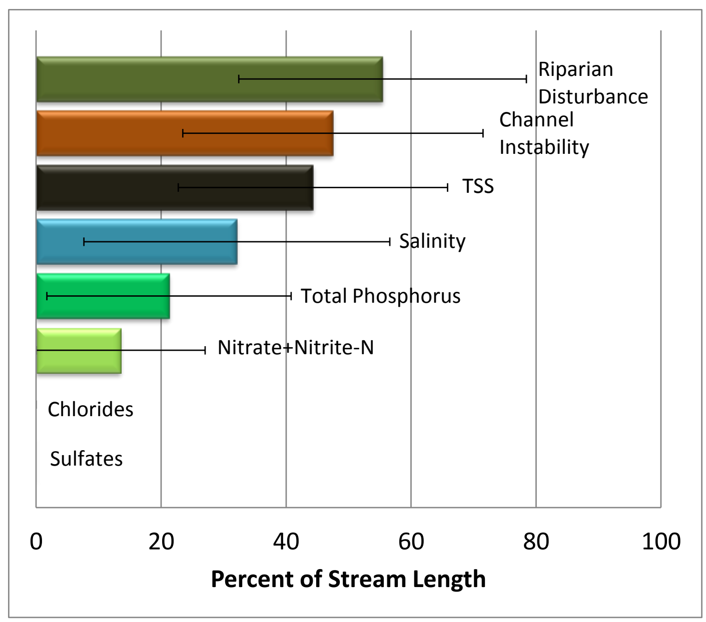
Plains: 2008 - 2011



Xeric: 2004 - 2007



Xeric: 2008 - 2011



without the need for a complete census of all perennial streams and rivers.

The water quality condition of Wyoming's perennial streams and rivers is favorable with over one-half (58%) of this resource currently considered least-disturbed with respect to biological condition whereas 18% are in the most-disturbed condition (Figure 8). At present, the targeted perennial streams and rivers of Wyoming's mountains are in much better condition biologically (81% least-disturbed) relative to those in the plains (39% least-disturbed) and xeric (53% least-disturbed) regions. Indeed, both the xeric (25%) and plains (24%) possess the highest percentages of perennial stream miles in the most-disturbed condition compared to those in the mountains (4%) (Figure 8).

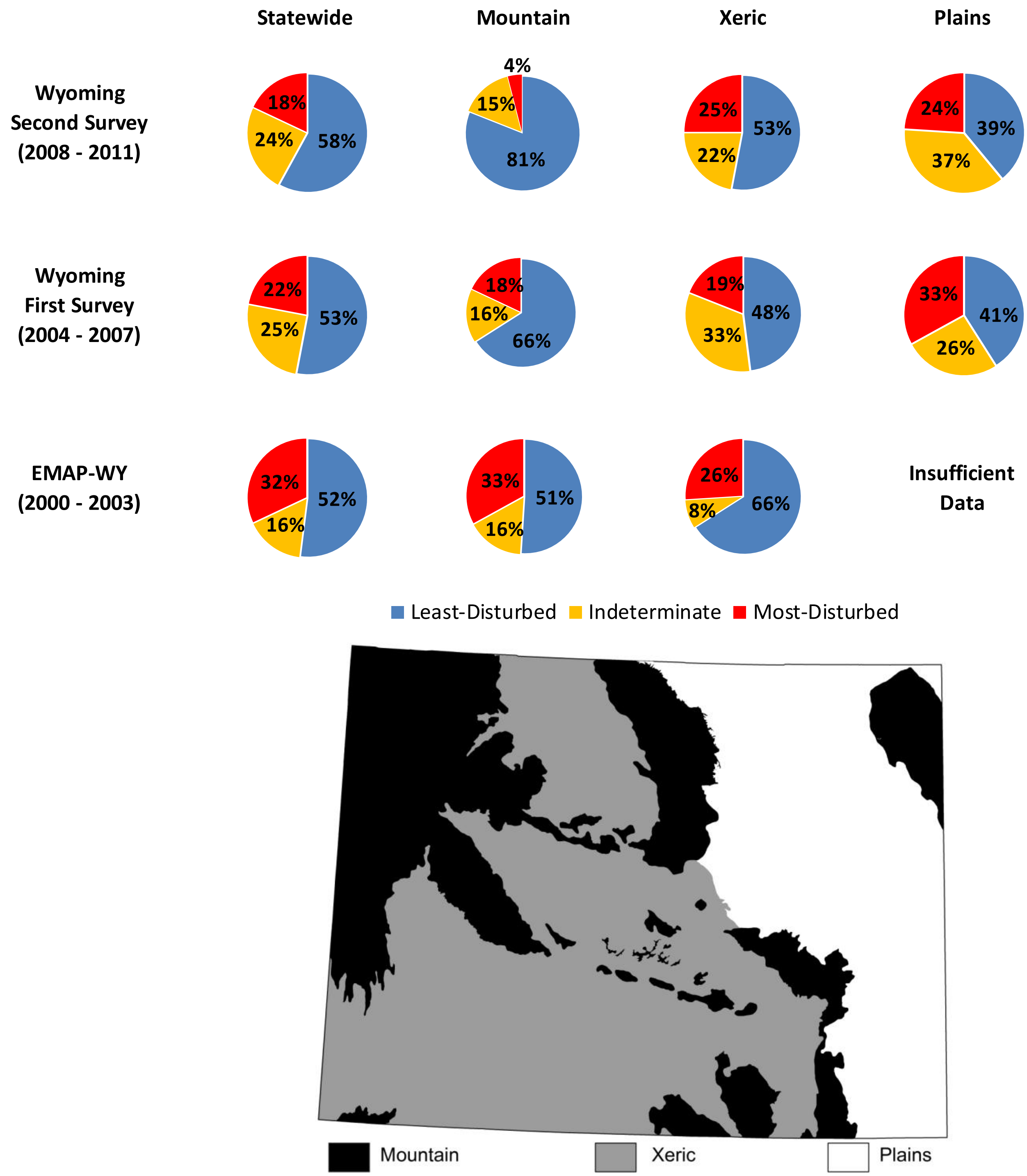
Of equal importance with the current status of water quality in Wyoming's perennial streams and rivers is determining the change in the resource over time. Trend information is informative to track responses of the resource to not only natural processes (e.g. drought) but also detecting changes associated with broad-scale management of the landscape. Comparison of WDEQ/WQD's two statewide surveys with EMAP-WY provides informative trends in the biological condition of Wyoming's perennial streams and rivers from 2000 to 2011. The proportion of perennial streams in the least-disturbed condition statewide has been on a slight non-significant upward trend (6%) since 2000 with virtually all of this change occurring between the first and second statewide surveys (Figure 8). During the past decade, the percentage of perennial streams and rivers in the most-disturbed condition has decreased (-14%) significantly (Figure 8). Biological condition temporal trends are more variable at the climatic region scale. The slight temporal improvement in the percentage of least-disturbed condition statewide is attributed in large part to improving conditions in the mountains. The mountains saw a steady and significant 30% improvement in the percentage of perennial streams assigned a least-disturbed biological condition over the past decade (with a concomitant -29% reduction in most-disturbed condition) (Figure 8). Perennial streams and rivers in the xeric region did not fair as well with a significant -18% reduction in least-disturbed condition from EMAP-WY to the first statewide survey followed by a negligible 5% increase in the second survey. The result is that the least-disturbed biological condition in the xeric has remained similar over the past 10+ years (Figure 8). Xeric perennial streams in the most-disturbed condition have also remained unchanged at around 25% from EMAP-WY to the second statewide survey. What has changed significantly in the xeric over the last decade has been a 14% increase in the indeterminate biological condition. Insufficient data was collected in the plains during EMAP-WY to make conclusions on biological condition trends within this region during the last decade. Even so, the percentage of least-disturbed and most-disturbed streams remained virtually unchanged between the two statewide surveys (Figure 8).

WDEQ/WQD's first and second statewide surveys were designed to assess water quality condition on non-1st order perennial streams and rivers located outside of national parks, federal wilderness and the Wind River Reservation. This stratification was purposefully integrated into the designs to focus on areas of the State where the potential for anthropogenic influences are high and where the WDEQ/WQD has jurisdiction (i.e. outside the Wind River Reservation). The EMAP-WY design evaluated all perennial waters in Wyoming. It could be countered that the results among all three surveys are not comparable to one another due to the differences in designs and sample sizes. Most of these systematic differences (e.g. sample sizes, sample frame resolution) that conceivably could contribute to variability in the temporal differences among the three surveys have been largely addressed implicitly within each survey design. These potential systematic sources of variability were addressed through methods such as weighting and distribution of sites proportional to the representation of perennial streams and rivers within the sample frames. The second statewide survey used the NHD+ sample frame that was a vast improvement over the RF3 used with the first statewide survey and EMAP-WY. The improvement in NHD+ was attributed to increased accuracy (location, connectively, stream type) and resolution primarily with respect to 1st order streams and in desert regions of the west (Wiseman et al. 1993). The greater prevalence of 1st order streams in NHD+ probably was not influential in temporal differences among the three surveys since 1st order streams were not well represented in EMAP-WY and those present in both statewide survey sample frames were removed from consideration. Other systematic sources of variability that include unequal sample sizes and extrapolated stream miles are largely accounted for within the statistical analyses used in this report. What cannot be remedied through design considerations or statistics is the difference in the geographic extent of perennial streams evaluated. Because EMAP-WY evaluated all perennial streams (including national parks and wilderness), one could assume that, when compared to the statewide surveys, EMAP-WY is biased toward higher quality streams with least-impacted biological conditions. Approximately 30% of the 57 sites used in EMAP-WY were located in national parks, wilderness and the Wind River Reservation – all in the mountain climatic region. It is likely this bias contributes variability to the temporal differences in biological condition between EMAP-WY and the statewide surveys, however, the variability is primarily confined to the mountains and to a lesser extent statewide. The bias notwithstanding, the biological condition of non-excluded mountain and statewide perennial streams evaluated during the first and second statewide surveys improved beyond EMAP-WY estimates. This suggests that many mountain perennial streams outside of national parks, wilderness and the Wind River Reservation were at least of similar biological condition to those within these boundaries. Relative to EMAP-WY, results of the two statewide surveys could be considered conservative estimates of biological condition for all perennial streams in the mountains and to a lesser extent statewide. In short, the systematic differences between the three surveys do not appear to preclude their use in determining reasonably accurate temporal trends in biological condition.

The 10+ year drought that affected much of the inter-mountain west including Wyoming was represented by all three surveys, though was most severe during the first statewide survey (2004-2007), particularly within the xeric and plains climatic regions. There is compelling evidence that the influence and regional variation of this drought was a key factor to the overall trends among the three surveys with respect to biological condition.

Severe droughts can have devastating effects on the aquatic life of perennial streams and rivers. Depending on the frequency, magnitude and duration, drought can result in varying impacts to aquatic life including delayed emergence, reduction in aquatic habitat, elevated levels of physicochemical constituents, altered feeding dynamics and delayed or inhibited reproduction all through decreased or complete cessation of surface flow. Statewide, annual stream flows during EMAP-WY and the first statewide survey were -33% and -27% below the average for the periods of record, respectively, which correlated to no improvement in the least-disturbed biological condition. The general improvement in drought conditions coupled with two years (2010-2011) of above normal flows resulted in an overall 25% increase in annual flows above the average and likely contributed to the slight 5% increase in least-disturbed biological condition during the second statewide survey. The effects of the multi-year drought were less pronounced in the mountain climatic region. Normal flows began to resume in mountain perennial streams during the first and

Figure 8 - Biological condition of perennial streams and rivers (by percentage of respective stream length) in Wyoming and its three climatic regions during the first and second statewide surveys in addition to EMAP-WY (Peterson et al. 2007).



second statewide surveys which was a key factor in the marked improvement in biological condition for this region from 2000 to 2011. Conversely, biological condition in the xeric continued to degrade from 2000 to 2007. This reduction in biological condition was coincident with the continued reduction in annual flows in this region from their average (Table 3). A similar reduction in annual flows occurred in the plains from 2000 to 2007. Though insufficient data were available in the plains during EMAP-WY, presumably biological condition in this region also declined during the first seven years of the last decade.

Flow conditions in the xeric and plains during 2008-2011 improved at a rate similar to that observed in the mountains (Table 3). However, there was negligible change in the least-disturbed biological condition for both regions with the current status of this condition in the xeric remaining similar to EMAP-WY levels. Perhaps this pattern was due in part to persistent localized drought conditions in some portions of these regions. Indeed, information from the U.S. Drought Portal indicates localized areas of Wyoming within the plains and xeric regions, remained in drought conditions during the later portion of the 2000 to 2011 period. Another possible explanation for this scenario is that for some streams and rivers, the multi-year drought may have exacerbated already stressed conditions (anthropogenic or other disturbances) where recovery could take longer than the seven years that spanned the first and second statewide surveys.

Assessment of the biological condition of Wyoming's perennial streams and rivers is important to evaluate the overall quality of the resource. Though when a proportion of the resource is in a most-disturbed biological condition, it is just as important for natural resource managers and the public to understand the underlying potential causes of biological degradation. Knowledge of the causes can assist in better focusing resources to address the problem. Results from both statewide surveys provide reasonable estimates of the relative importance of potential stressors that may influence the biological condition of streams and rivers in Wyoming. What can be concluded from these surveys is the relative extent of potential stressors (i.e. how common are they?). However, what cannot be concluded from these relative extent estimates is whether one stressor has more or less influence on the most-disturbed biological condition compared to other stressors (i.e. the stressor's effect).

Channel instability and total suspended solids (TSS) were consistently the most widespread stressors for both the first and second statewide surveys affecting over one-third of perennial stream and river miles in Wyoming. Channel instability and riparian disturbance are currently the most common potential stressors in the mountain climatic region affecting about 20% of the region's perennial streams. The relative extent of these stressors for the mountain region has remained similar since EMAP-WY. Channel instability and TSS were dominant stressors in the plains, potentially affecting greater than 50% of perennial streams in that region. The relative extent of channel instability in the plains has remained largely consistent since EMAP-WY. Finally, riparian disturbance and channel instability were common stressors affecting approximately one-half of perennial stream miles in the xeric region. The current relative extent of riparian disturbance was far less than the 90% documented by EMAP-WY. However, channel instability in the xeric region was greater than the ~30% identified by EMAP-WY. Stressors indicative of nutrient enrichment (nitrate+nitrite-N and total phosphorus) were the least common at the statewide and climatic region scales.

The percentage of Wyoming perennial stream miles affected by channel instability during all three surveys was likely attributable in part to the multi-year drought mentioned previously, particularly during the first survey. Channel instability is a composite physical stressor that includes excess sedimentation, accelerated stream bank erosion and channel incision. Excess sedimentation was by far the dominant of the three sub-stressors statewide and in all three climatic region stream miles documented for channel instability during the first survey. During periods of drought with sustained low or no flow, the ability of streams to transport their existing sediment loads can be limited, resulting in excess sedimentation. The lingering drought that affected some areas of the xeric and plains regions into at least the first-half of the second survey period may partially explain the similar percentages of stream miles affected by excess sediment relative to the first survey.

During the latter part of the second statewide survey, Wyoming streams and rivers were subject to record-breaking peak flows. For many streams these peak flows resulted in accelerated channel geomorphic responses. The large increases in rates of accelerated bank erosion and channel incision noted between the two statewide surveys, often results in contributions of excess sediment and greatly influences overall channel stability. Accelerated bank erosion occurs in a stream when energy dissipation during high flows is achieved by cutting horizontally across the floodplain at an accelerated rate until sinuosity or other boundary conditions are restored. Active incision lowers the base elevation of the channel through scouring with associated degradation of the stream banks contributing excess sediment to a stream. Accelerated bank erosion tends to greatly increase the risk for accelerated lateral channel migration. This migration can in turn increase the risk for channel avulsions (abandonment of part or all of a channel) that can trigger channel incision. For this reason, the relative increase in channel incision may be partially linked to the rise in accelerated bank erosion. Contributions of sediment from accelerated bank erosion may have increased with the record peak flows. This may explain the overall increase in excess sediment and channel instability between the two statewide surveys.

The increase in rates of geomorphic processes between the first and second statewide surveys, most notably in the xeric region, may be linked to past anthropogenic disturbances. These disturbances were likely exacerbated by the record flows near the end of the second survey period causing accelerated rates of bank erosion, channel incision and lateral channel migration to occur. This inference is supported by evidence indicating that several xeric streams with channel instability were deeply incised with minimal active floodplains and had accelerated erosion of steep banks with minimal surface protection and high bank-height ratios though riparian disturbance was minimal to absent. Together these observations suggest instability associated with historical impacts (e.g. channel relocation, meander cutoffs, riparian vegetation removal). In addition, the likelihood that the documented channel instability in some perennial xeric streams can also be attributed to current anthropogenic impacts to the riparian area is high. Especially when considering that current riparian disturbance was documented as a potential stressor for 55% of perennial stream miles in the xeric region (the highest among the three regions) in the second survey – a significant increase of 29% from the first survey. Flow alterations, particularly withdrawals, can also facilitate excess sedimentation via a reduction in sediment competency of the channel. Flow alterations affect almost 60% of perennial stream and river miles in Wyoming. However, while the negative effect of these flow manipulations is likely, the magnitude of the problem remains largely speculative. Together, channel adjustment processes due either to anthropogenic disturbances (past and present), drought and/or record high flows were likely the most important factors driving the widespread excess sediment and channel instability stressors that influence biological condition of Wyoming streams and rivers.

Probability surveys are powerful tools for determining the relative importance and trends of specific stressors that are most likely to influence biological condition. The percentage of stream miles influenced by elevated nitrate+nitrite-N decreased significantly (-13%) statewide from the first to second statewide surveys, which may be attributable to drought recovery. Drought conditions can create lentic (pooled water) conditions in otherwise flowing streams resulting in a deterioration of water quality. When these environments contain large amounts of organic matter, decomposition can create elevated nutrient concentrations (Lake 2011). Chloride and sulfate are toxic to aquatic life at elevated concentrations. Each exceeded their most-disturbed thresholds in only 8% and 9% of statewide stream miles, respectively, during the first survey; no exceedences were observed in the second survey. Chloride and sulfate are both contributors to salinity, and drought-induced effects to salinity during the first survey are likely.

The statewide extent of the most-disturbed *E. coli* condition (an indicator of recreational condition) was low in both statewide surveys with 11% in the first and 3% in the second. The percentage of statewide stream miles in the least-disturbed recreational condition increased significantly from 62% in the first survey to 80% in the second. The most severe phase of the multi-year drought likely contributed to the least-disturbed percentage in during the first survey. Overall, the current survey implies that there is a high recreational condition in Wyoming.

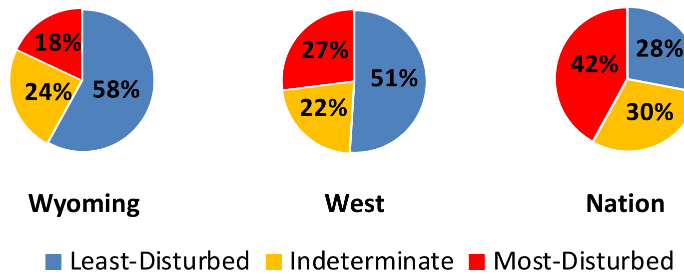
To place these results into perspective, Wyoming was compared to all twelve western states and nationally with respect to biological condition and associated stressors. Comparisons of Wyoming's two statewide surveys to the most recent EMAP-West can be made relatively easily due to similarities in design and evaluation. In addition, conservative comparisons were made to the most current national biological condition status for the lower 48 contiguous. These comparisons were justified since many of the same fundamental principles were applied to the evaluation of biological condition regardless of scale or location. Only stressors common to the Wyoming, EMAP-West and national surveys were compared.

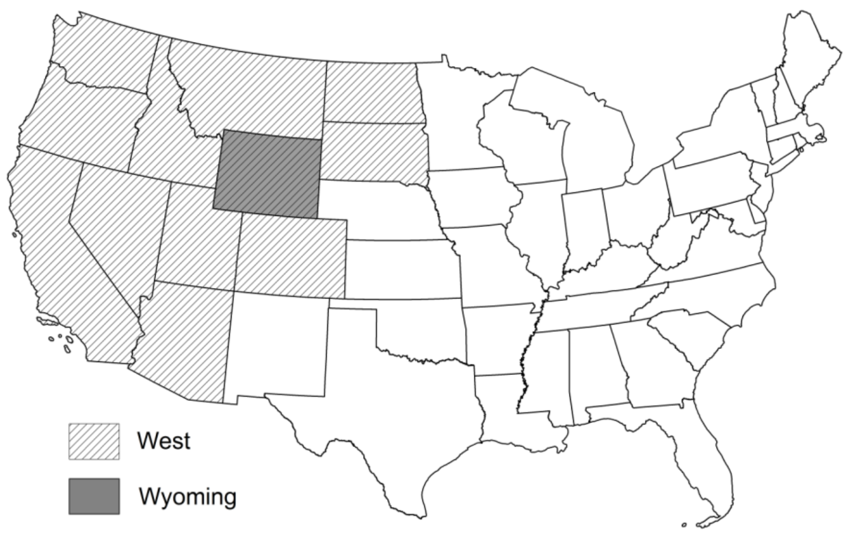
Based on the most recent statewide survey, Wyoming fairs better than the western United States with regard to least-disturbed (58% vs. 51% West-wide) and most-disturbed (18% vs. 27% West-wide) biological conditions (Stoddard et al. 2005) (Figure 9). Channel instability was a common stressor throughout the west and Wyoming affecting 26% and 41% of stream miles, respectively (Figure 9). Interestingly, riparian disturbance was the most common stressor west-wide (47% of stream miles) whereas this stressor ranked third most common (36%) in Wyoming.

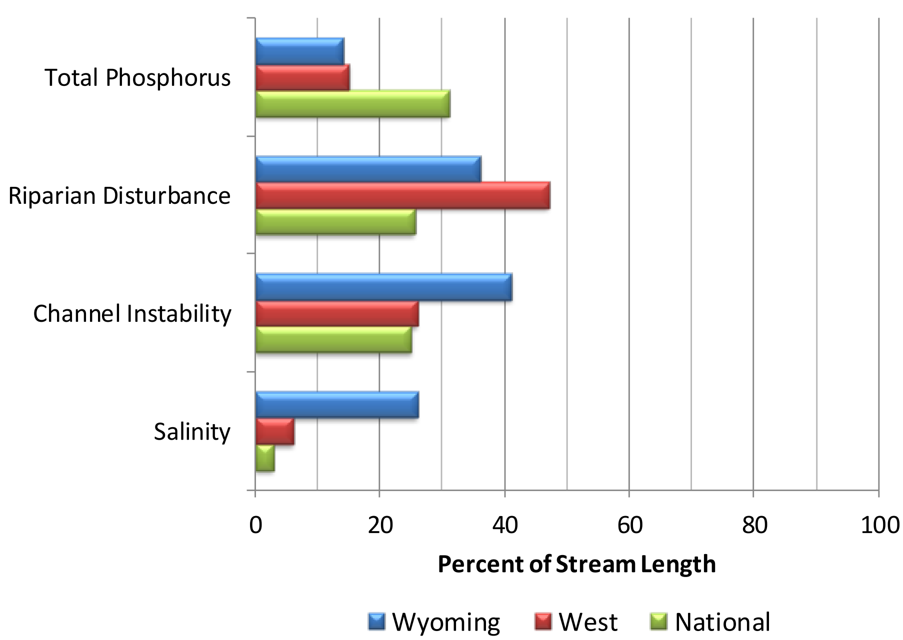
Nationally (lower 48 contiguous states), the percentage of stream miles in the least-disturbed biological condition is much less relative to Wyoming at only 28% (Paulsen et al. 2008, USEPA 2009) (Figure 9). Likewise, the percentage of national stream miles in the most-disturbed biological condition is 42% - much greater than Wyoming's most current estimate. Whereas total phosphorus was the most common (31% of stream miles) stressor nationally, it was considered a potential stressor in only 14% of Wyoming stream miles (Figure 9). Riparian disturbance and excess sediment (26% and 25% of stream miles, respectively) were the second and third most common stressors nationally whereas estimates for these parameters were greater in Wyoming.

While the results from both statewide surveys are informative of biological condition and potential stressors across a broad landscape, the results are not intended to reflect conditions at the watershed or local scales. Smaller scale probabilistic surveys would prove more informative of watershed and local conditions and may be more appropriate for establishing

Figure 9 - Biological condition (top) of perennial streams and rivers (by percentage of respective stream length) and relative extents (bottom) of potential stressors common to the Wyoming (second statewide survey), West-wide (Stoddard et al. 2005) and national (Paulsen et al. 2008, USEPA 2009) probabilistic surveys.







watershed-based monitoring and management priorities. For this reason, the WDEQ has phased out statewide probabilistic surveys and instead initiated a rotating basin probabilistic design in 2010 as part of the State's ten year (2010-2019) monitoring strategy (WDEQ/WQD 2010). Wyoming's probabilistic rotating basin approach establishes an order of rotation and sampling years among five 'superbasins' within the State based on six-digit HUCs. The five superbasins and the associated HUC 6 basins are the: Bighorn/Yellowstone [Bighorn and Yellowstone Basins], Northeast [Belle Fourche, Cheyenne, Little Missouri, Powder and Tongue Basins], Platte [Niobrara, North Platte and South Platte Basins], Green [Great Divide, Green and Little Snake Basins] and the Bear/Snake [Bear and Snake Basins]. Together, information from each of the five superbasin probabilistic surveys will be used to evaluate and report on the water quality condition of Wyoming streams and rivers in the future.

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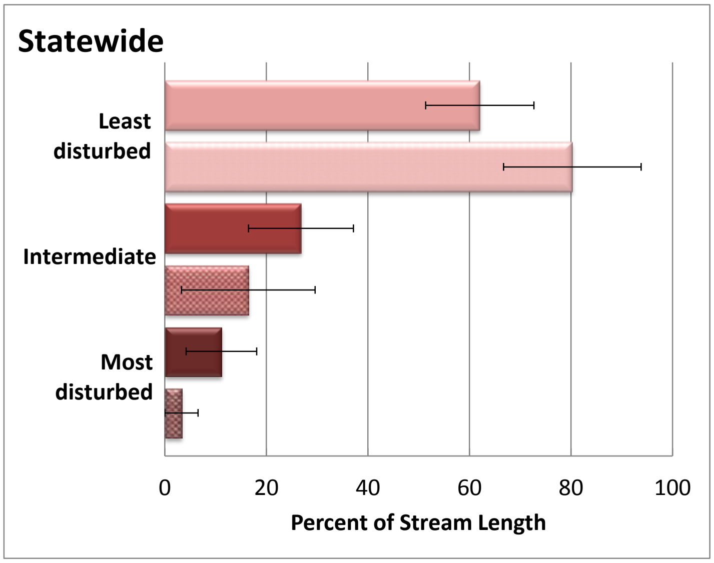
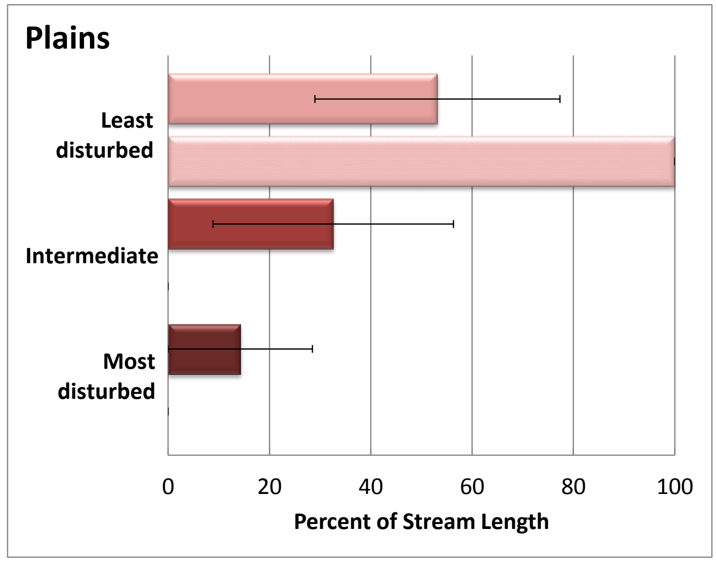
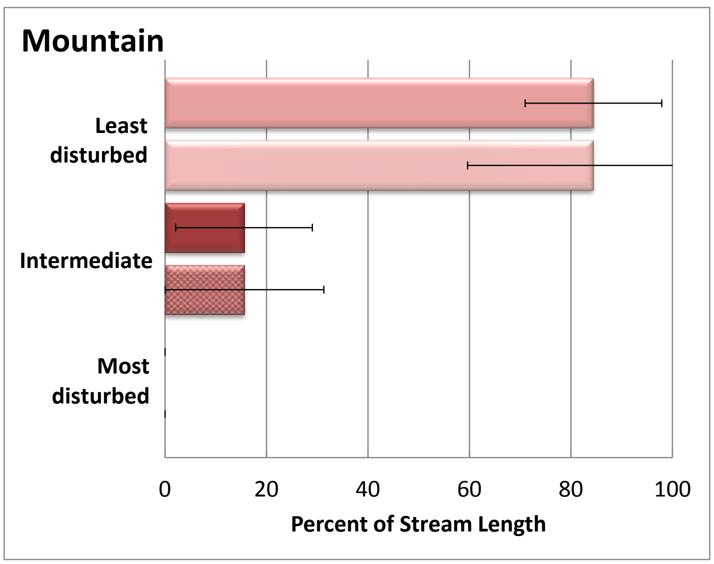
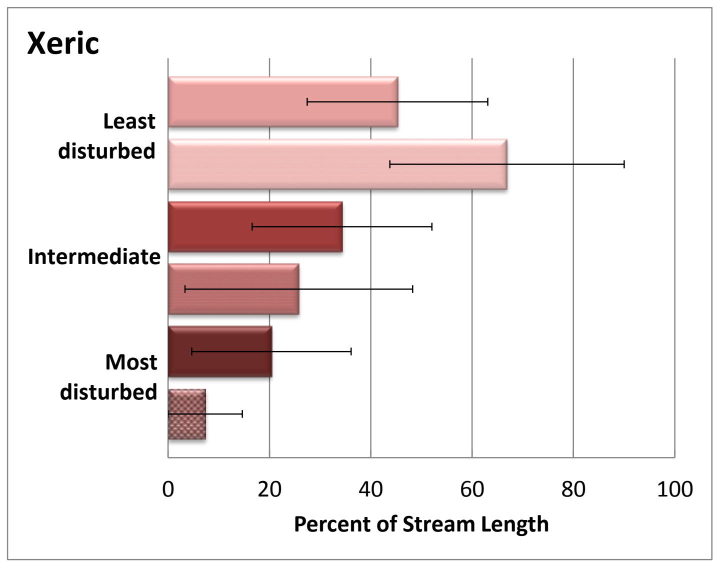
Appendix 1 - Summary of results for *Escherichia coli* at the statewide and climatic region scales. Solid (top) bars represent the first survey (2004-2007) whereas patterned (bottom) bars represent the second survey (2008-2011). Error bars represent the 95% confidence intervals.

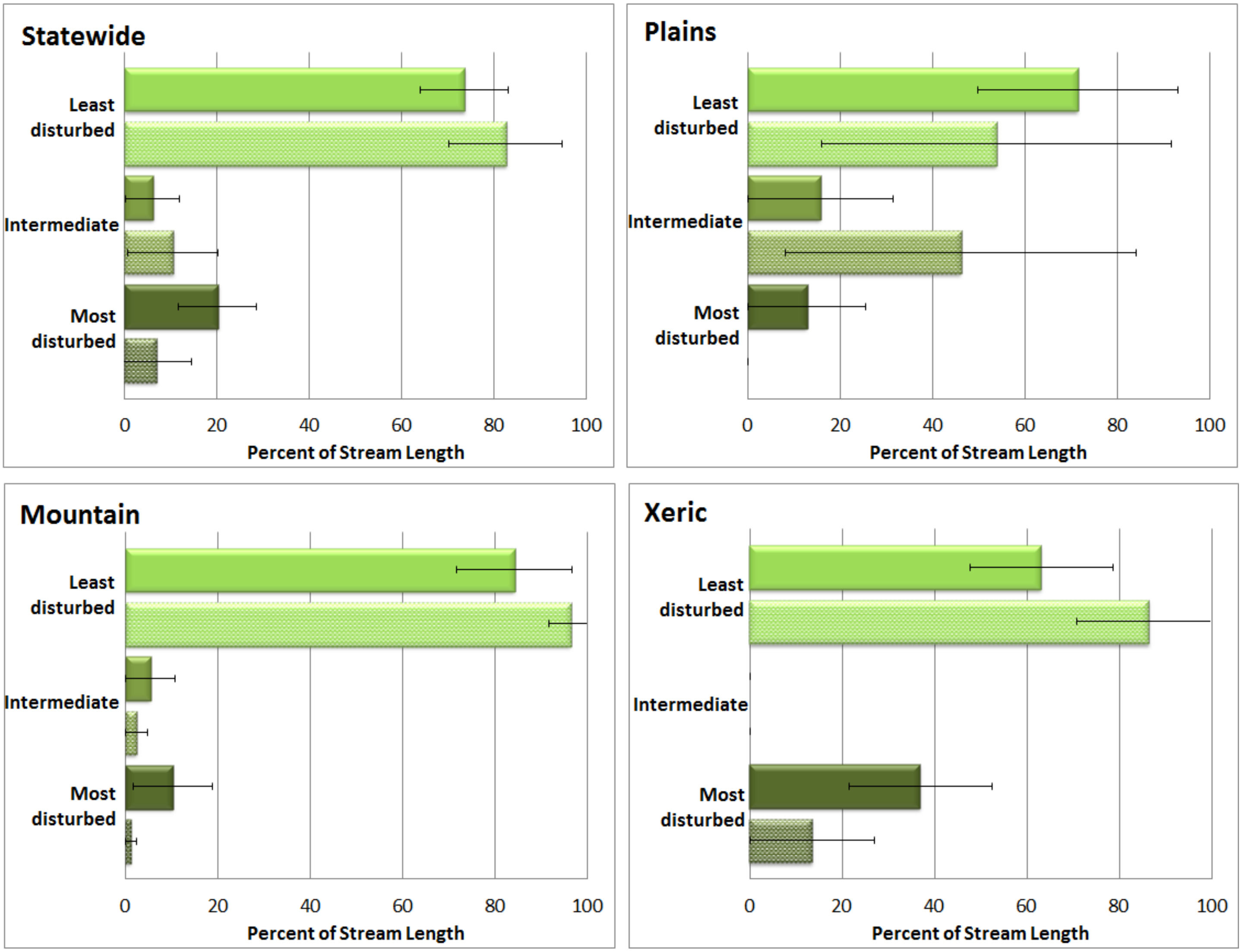




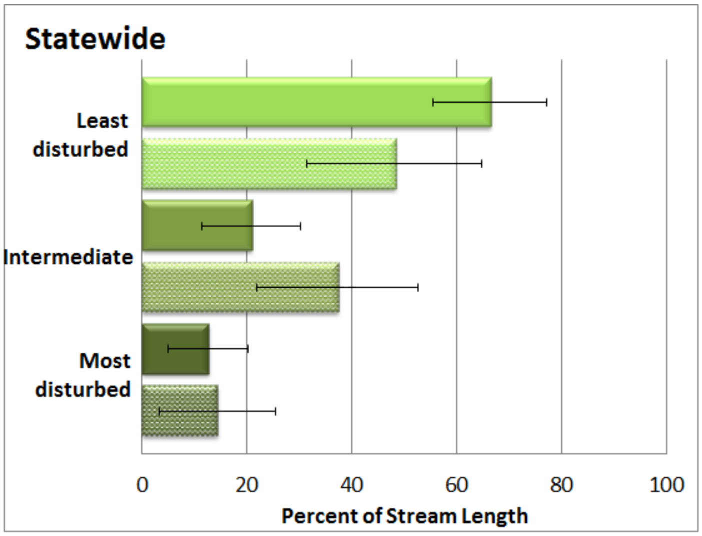


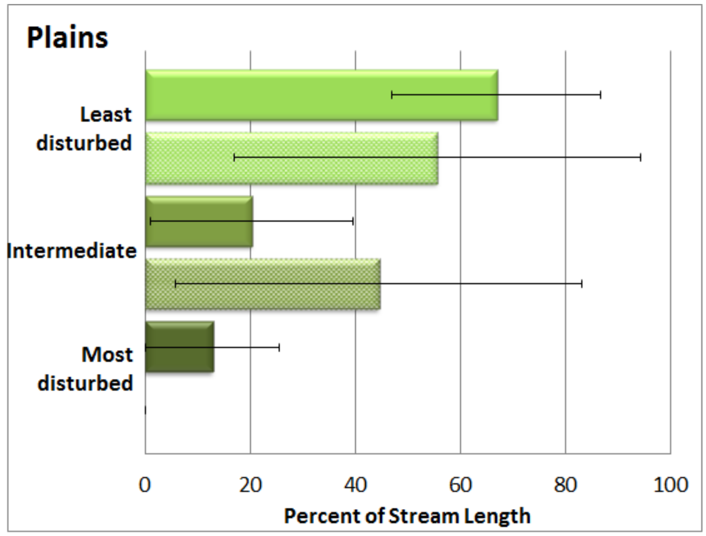


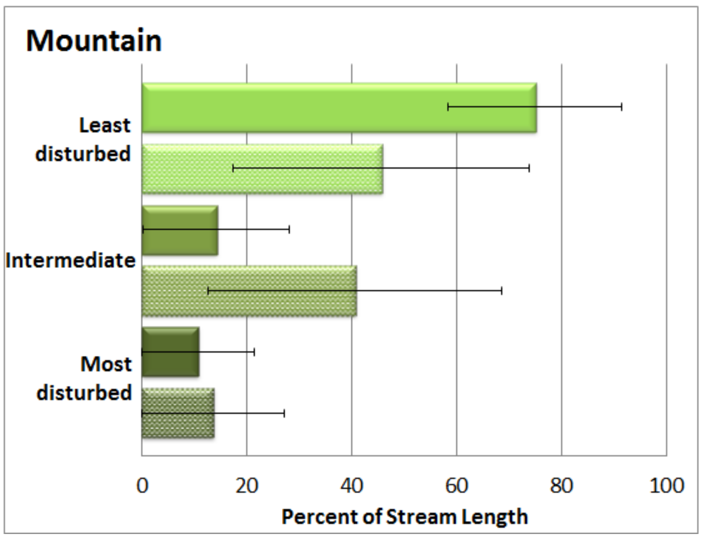
Appendix 2 – Summary of results for nitrate+nitrite-N at the statewide and climatic region scales. Solid (top) bars represent the first survey (2004-2007) whereas patterned (bottom) bars represent the second survey (2008-2011). Error bars represent the 95% confidence intervals.

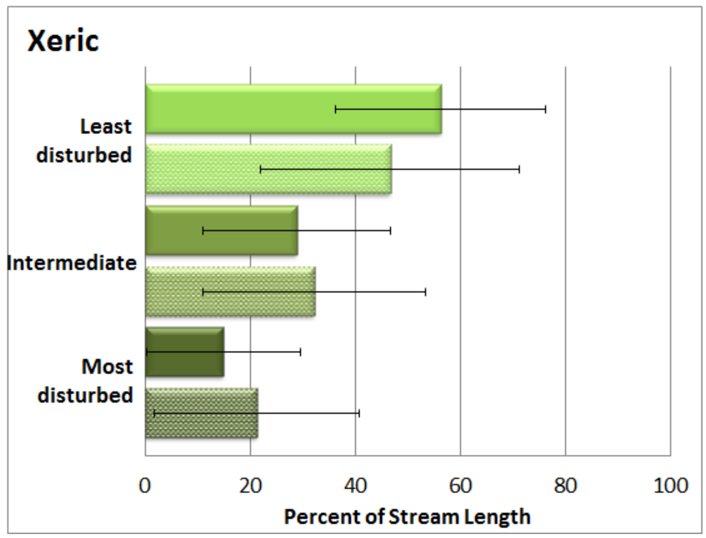


Appendix 3 - Summary of results for total phosphorus at the statewide and climatic region scales. Solid (top) bars represent the first survey (2004-2007) whereas patterned (bottom) bars represent the second survey (2008-2011). Error bars represent the 95% confidence intervals.

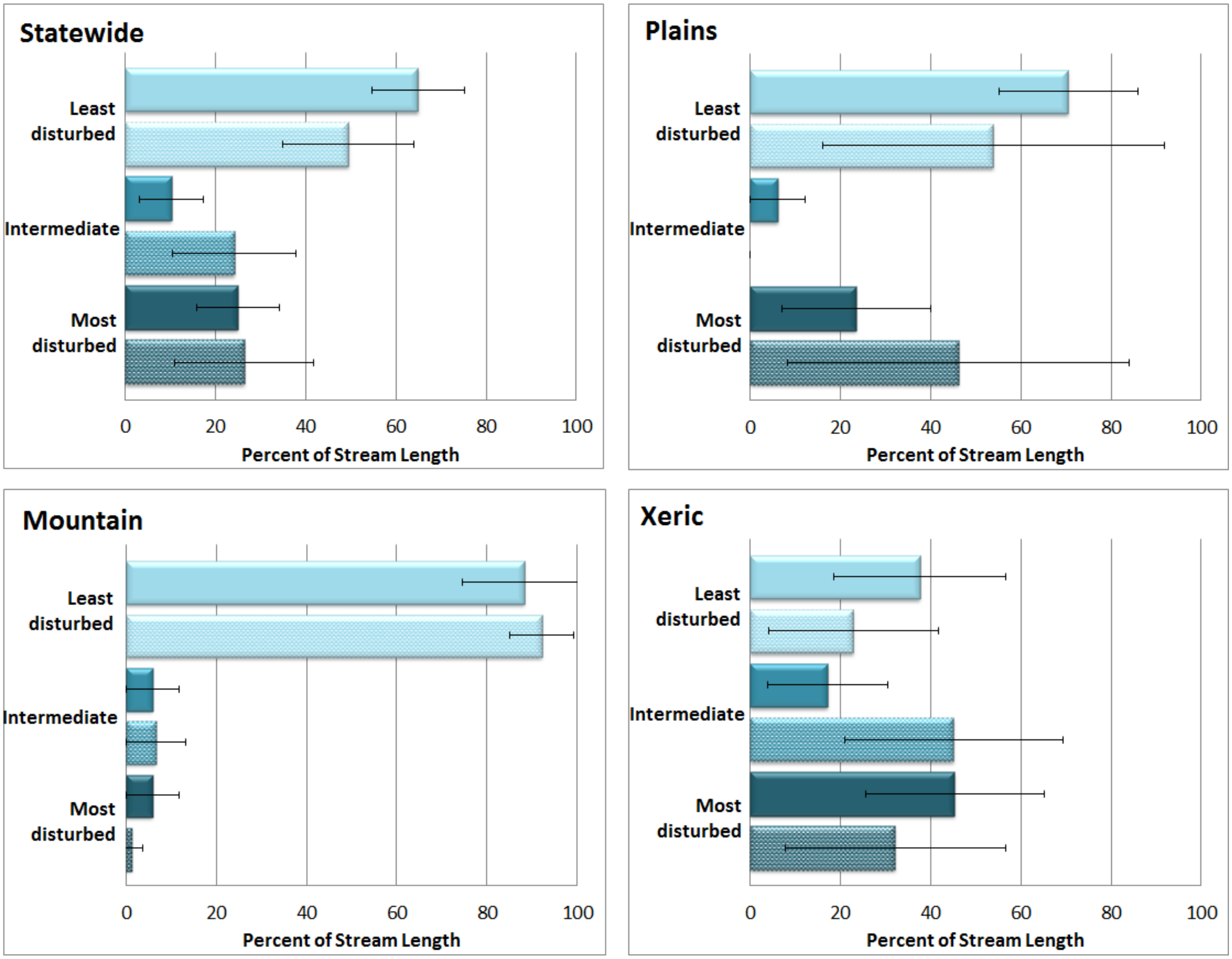




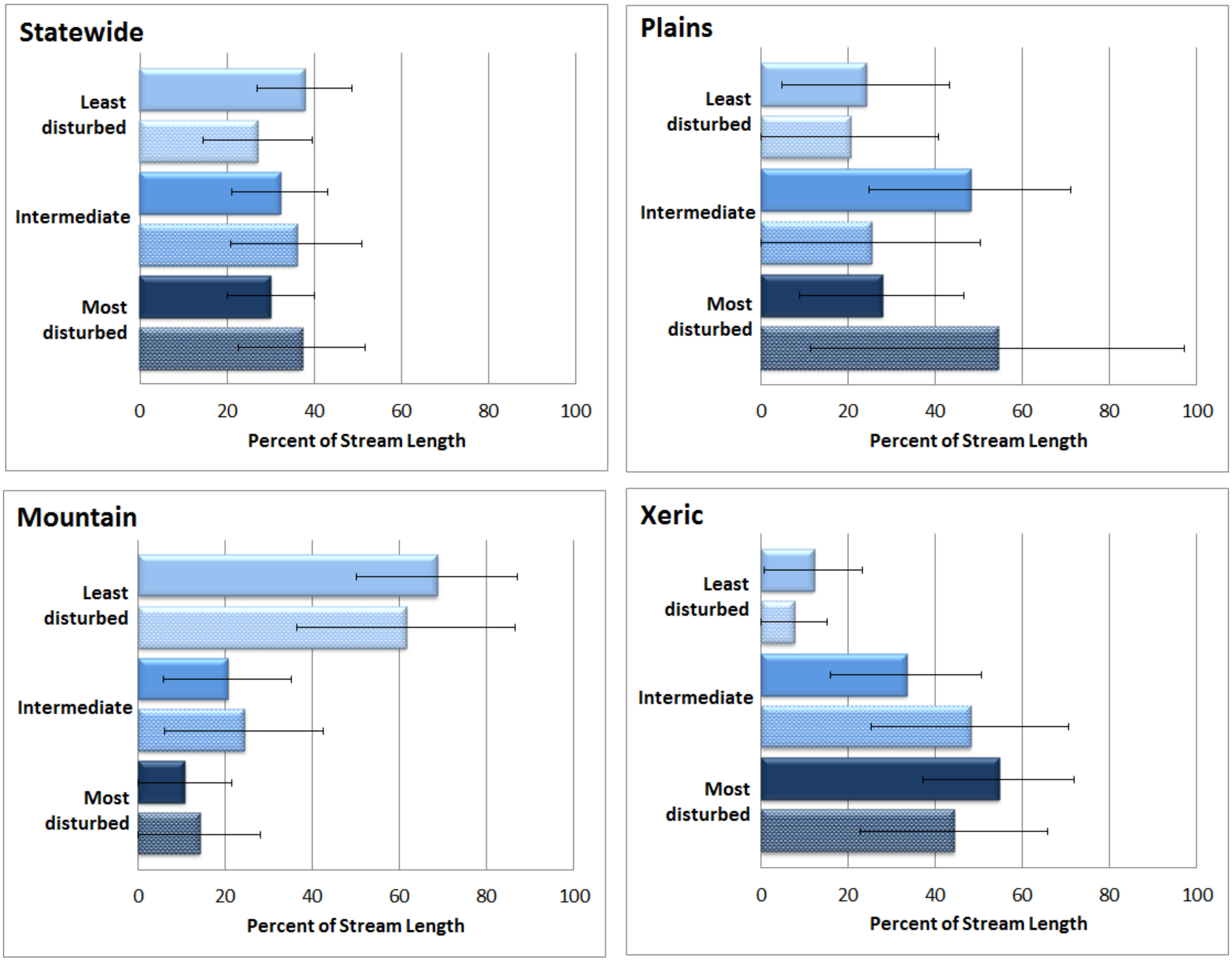




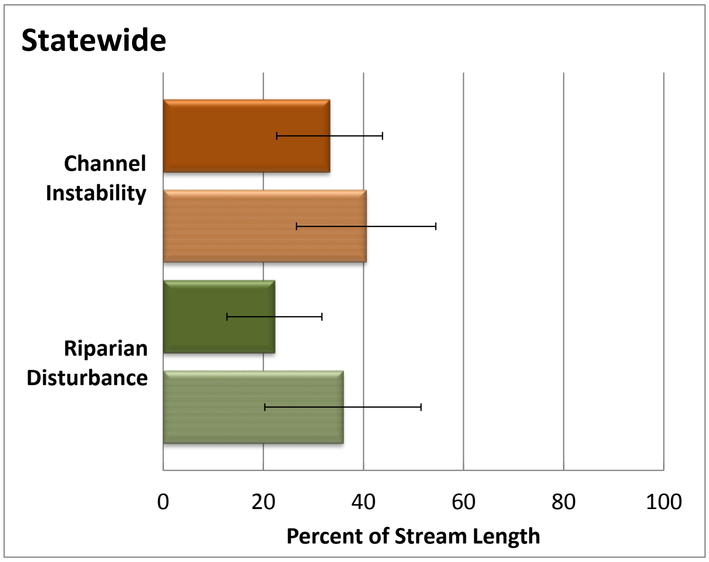
Appendix 4 - Summary of results for salinity at the statewide and climatic region scales. Solid (top) bars represent the first survey (2004-2007) whereas patterned (bottom) bars represent the second survey (2008-2011). Error bars represent the 95% confidence intervals.

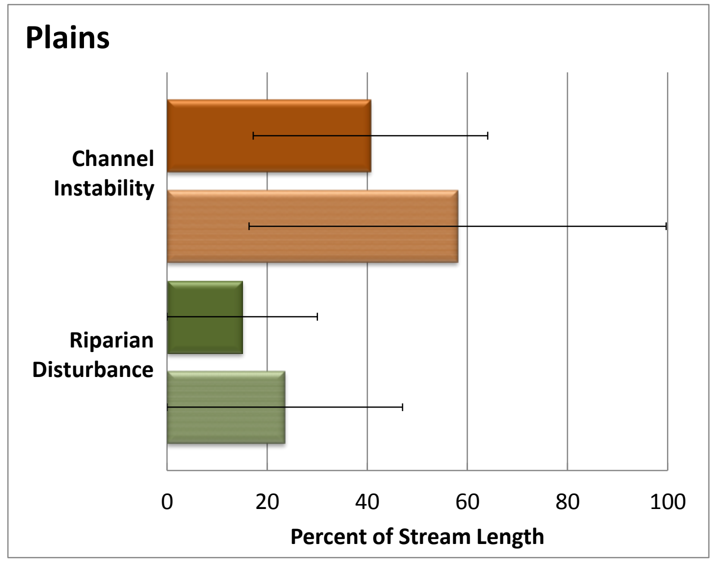


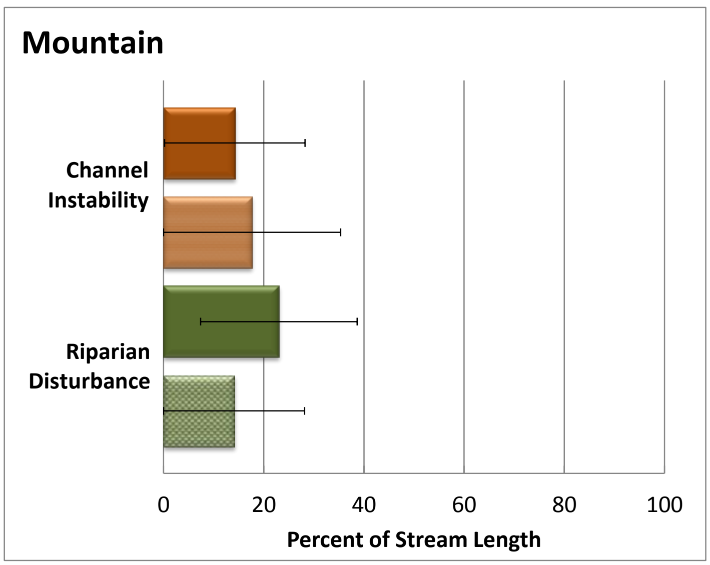
Appendix 5 - Summary of results for TSS at the statewide and climatic region scales. Solid (top) bars represent the first survey (2004-2007) whereas patterned (bottom) bars represent the second survey (2008-2011). Error bars represent the 95% confidence intervals.

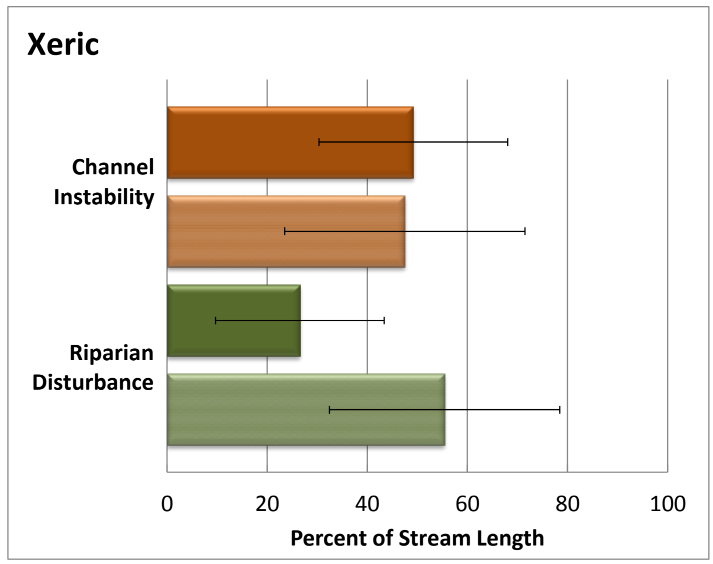


Appendix 6 - Summary of physical stressor results at the statewide and climatic region scales. Solid (top) bars represent the first survey (2004-2007) whereas patterned (bottom) bars represent the second survey (2008-2011). Error bars represent the 95% confidence intervals.









Appendix 7 - Summary of results for the four component sub-stressors that represent channel instability at the statewide and climatic region scales. Solid (top) bars represent the first survey (2004-2007) whereas patterned (bottom) bars represent the second survey (2008-2011). Error bars represent the 95% confidence intervals.