

**ESTABLISHING BASELINE DATA FOR AQUATIC RESOURCES IN NATIONAL
PARKS OF THE NORTHERN GREAT PLAINS NETWORK**

By

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ESTABLISHING BASELINE DATA FOR AQUATIC RESOURCES IN NATIONAL
PARKS OF THE NORTHERN GREAT PLAINS NETWORK

This thesis is approved as a creditable and independent investigation by a candidate for the Master of Science Degree and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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Abstract

Establishing baseline data for aquatic resources in national parks of the Northern Great Plains Network

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Developing a monitoring network requires detailed objectives and expectations. Exploratory studies are often needed to establish baseline characteristics with which to monitor changes whether they're from natural causes, anthropogenic disturbances, or management decisions. Furthermore, an effective aquatic monitoring program not only evaluates chemical and physical parameters of the water, but also provides habitat and invertebrate characteristics. This research effort was conducted to (1) provide baseline descriptions of macroinvertebrate communities within aquatic systems of national parks and (2) select optimal metrics for use in future monitoring efforts by national park staff. Chemical, physical and habitat parameters were taken from small to medium-sized streams, large rivers, springs, and bison watering holes during the summers of 2004 and 2005. Invertebrate samples were also collected from rivers, streams and watering holes using a D-frame sweepnet. Spring invertebrate samples were taken using a hand-net. Metrics were chosen based on their high discriminatory power using Kruskal-Wallis F statistics and correlations to chemical, physical and habitat data using Pearson correlations. Ten metrics were chosen for each system from each community structure category (composition, richness, tolerance, functional feeding guilds, and habit guilds).

Familial diversity (79 families) was highest in small and medium streams. Rivers contained 61 families, springs had 31, and bison watering holes contained 25. Of all invertebrate taxa found, 87% were of class Insecta. Diptera and Coleoptera were the most prevalent insect orders. Collector-gatherers were the most abundant feeding guild in all systems. Springs contained the highest percentage of shredders (mean=19%), while rivers and streams had the highest percentage of collector-filterers (mean=17% and 18%, respectively). Stock ponds contained the highest percentage of predators (mean=38%). Habit guilds displayed greater variation between systems than feeding guilds. Clingers were highest in streams and rivers (mean=30% and 33%, respectively). Sprawlers were most abundant in springs (mean=39%), and swimmers were highest in stock ponds (mean=53%).

Stream metrics included percent non-insecta, EPT: EPT+Chironomidae, EPT richness, Shannon-Wiener Diversity, habit guild diversity, percent sprawlers, functional feeding group diversity, predator richness, Chironomidae richness and HBI. River metrics included percent EPT, percent Chironomidae, EPT richness, total richness, non-insecta richness, clinger richness, swimmer richness, collector-gatherer richness, collector-filterer richness, and modified HBI. Stream and river metrics were strongly correlated with physical/chemical and habitat measurements. Spring metrics included percent EPT, percent Chironomidae, EPT richness, Chironomidae richness, percent climbers, percent gliders, percent collector-gatherers, percent shredders, percent predators, and HBI. Stock pond metrics included percent dominant, percent Chironomidae, non-insecta richness, Margalef diversity, Chironomidae richness, habit evenness, clinger richness, functional feeding diversity, shredder richness, and tolerant taxa. Spring and stock pond measurements displayed weaker discriminatory power and fewer significant correlations with physical/chemical and habitat parameters. Several metrics

(EPT metrics, Chironomidae metrics, HBI, Shannon-Wiener diversity, total richness, collector-gatherer richness, collector-filterer richness, predator richness, swimmer richness, clinger richness) were common across systems and are commonly used by other monitoring agencies as monitoring tools.

These data may be applied to future monitoring of chemical, physical, habitat, and invertebrate vital signs in each park. Optimal metric sets recommended from this effort are those likely to detect change in water quality and habitat. However, further exploratory data is probably needed to fully describe the fauna of these systems.

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List of Abbreviations

Metric Abbreviation	Full Name
TotAbnd	Total Abundance
PerEPT	Percent Ephemeroptera, Plecoptera, Trichoptera
PerOlig	Percent Oligochaeta
PerTanytars	Percent Tanytarsini
PerCricop	Percent Cricotopus
PerEphem	Percent Ephemeroptera
PerTric	Percent Trichoptera
PerPlec	Percent Plecoptera
PerMollus	Percent Mollusca
PerNonInsc	Percent Non-Insecta
PerInsc	Percent Insecta
PerDipt	Percent Diptera
PerChirn	Percent Chironomidae
PerDomn	Percent Dominant
Shannon	Shannon-Wiener Diversity
Even	Evenness
Simpson	Simpson Diversity
BaetEphem	Baetidae: Ephemeroptera
HydTri	Hydropsychidae: Trichoptera
Margal	Margalef Diversity
Pct3Dom	Percent 3 Dominant Taxon
Pct5Dom	Percent 5 Dominant Taxon
Pct10Dom	Percent 10 Dominant Taxon
TotRich	Total Richness
PerEPTTx	Percent EPT Richness
EPTTx	EPT Richness
TricTx	Trichoptera Richness
PerTricTx	Percent Trichoptera Richness
DiptTx	Diptera Richness
PerDiptTx	Percent Diptera Richness
ChirTx	Chironomidae Richness
PerChirTx	Percent Chironomidae Richness
ColTx	Coleoptera Richness
PerColTx	Percent Coleoptera Richness
OdonTx	Odonata Richness
PerOdonTx	Percent Odonata Richness
EPTtoEPTC	Ephemeroptera, Plecoptera, Trichoptera: EPT + Chironomidae
HiruTx	Hirudinea Richness
PerHirTx	Percent Hirudinea Richness
Etx	Ephemeroptera Richness
PerETx	Percent Ephemeroptera Richness

PlecTx	Plecoptera Richness
PerPlecTx	Percent Plecoptera Richness
NonInscTx	Non-Insecta Richness
PerNInTx	Percent Non-Insecta Richness
InscTx	Insecta Richness
PerInscTx	Percent Insecta Richness
PerCF	Percent Collector-Filterers
PerCG	Percent Collector-Gatherers
PerScr	Percent Scrapers
PerShr	Percent Shredders
PerPred	Percent Predators
CFtoCG	Collector-gatherers:Collector-filterers
ShrtoC	Shredders: Collectors
ScrtoC	Scrapers: Collectors
ShrtoTP	Shredders: Total minus Predators
CFTx	Collector-filterer Richness
CGTx	Collector-gatherer Richness
ScrTx	Scraper Richness
ShrTx	Shredder Richness
PredTx	Predator Richness
PerCFTx	Percent Collector-filterer Richness
PerCGTx	Percent Collector-gatherer richness
PerScrTx	Percent Scraper Richness
PerShrTx	Percent Shredder Richness
PerPredTx	Percent Predator Richness
FFGShan	Functional Feeding Guild Diversity
FFGEven	Functional Feeding Guild Evenness
PerSwm	Percent Swimmer
PerClg	Percent Clingers
PerClb	Percent Climbers
PerBur	Percent Burrowers
PerSka	Percent Skaters
PerGL	Percent Gliders
PerSpr	Percent Sprawlers
SwmTx	Swimmer Richness
ClgTx	Clinger Richness
ClbTx	Climber Richness
BurTx	Burrower Richness
SkaTx	Skater Richness
GLTx	Glider Richness
SprTx	Sprawler Richness
PerSwmTx	Percent Swimmer Richness
PerClgTx	Percent Clinger Richness
PerClbTx	Percent Climber Richness
PerBurTx	Percent Burrower Richness

PerSkaTx	Percent Skater Richness
PerGLTx	Percent Glider Richness
PerSprTx	Percent Sprawler Richness
HabitShan	Habit Guild Diversity
HabitEven	Habit Guild Evenness
PerInt	Percent Intolerant
PerTol	Percent Tolerant
HBI	Hilsenhoff Biotic Index
IntTx	Intolerant Taxa
TolTx	Tolerant Taxa
PerIntTx	Percent Intolerant Taxa
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Introduction

The National Park Service (NPS) is known for its conservation efforts toward maintaining and managing minimally impacted ecological systems (NPS 2006). Many parks are subjected to negative human impacts such as urban encroachment, air and water pollution, and excessive visitation. These impacts can threaten the quality or existence of many natural resources and ecosystems in the parks. To help prevent the loss or impairment of natural resources, Congress appropriated funds for the National Park Service to establish the Natural Resource Inventory and Monitoring (I&M) Program (NPS 1996). The NPS I&M program was established in 1992 to acquire information on natural resources needed to maintain ecological integrity (NPS 1996). The NPS I&M Program has five main goals (NPS 2006): 1) to develop baseline inventories of park resources and ecosystems to determine the resource's status, 2) to monitor resources and systems to better understand their conditions and to determine if those resources change over time, 3) establish inventory and monitoring programs throughout the NPS system, 4) integrate inventory and monitoring into park management and decision making, and 5) share information with partnering natural resource agencies for attaining similar goals. Meeting these goals will give the NPS an understanding of the systems within the park and facilitate decision making, communicating with the public, and working with other agencies.

One important component of the inventory phase of the program is to develop 'vital signs' for each network. Park vital signs are selected physical, chemical, and biological elements and processes of park ecosystems that represent the overall condition of the park's natural resources, change predictably to stressors, and are important to humans (NPS 2006). Vital signs serve as measurable signals that indicate changes that may impair the long-term health of

natural resources or ecosystems. Early detection of these changes allows park managers to take steps to restore ecological health of park resources before serious damage occurs (NPS 2006).

Aquatic systems are an integral part of the overall ecology of parks and understanding the issues of park water resources can be used as a basis for making management decisions, working with other entities, and communicating with the public. Baseline aquatic inventories are an important first step for evaluating and monitoring the health of park aquatic ecosystems. Inventories supply baseline information that park managers need to efficiently manage and protect these resources. Continued monitoring can provide feedback concerning the resource conditions and management objectives. Monitoring feedback can in-turn prompt management actions or allow managers to evaluate management effectiveness.

Water Quality Importance

Water resources have major environmental, social, and economic impact. Freshwater is limited and in high demand. Nonetheless, it is being exploited and degraded at disturbing rates by humankind. In 1850, 43,000 cubic meters of water were available per year to each person, but the average per capita amount of water available today has fallen to 9000 cubic meters per year, simply because of the increase in global population (Gleick 2000). One billion people have no safe water, while nearly 3 billion people live without access to adequate sanitation systems necessary to keep what water they have clean and free from water borne diseases (Gleick 2000). Pollution of rivers and lakes reduces the supply of high quality water. The South Dakota Department of Environment and Natural Resources reported in 2004 that 44% of all stream miles did not support their designated uses. These uses include fishing, swimming, drinking water, and agriculture. Twenty percent of stream miles with immersion uses were not swimmable.

Man has forced changes on aquatic systems, many leading to higher organic material loading and eutrophic conditions (Wetzel, 2001). With the realization that impaired water systems inhibit drinking, fishing and recreational uses, and waste assimilation, legislation was enacted to protect water resources. The protection of human health and human use was the main driving force behind this action.

The Clean Water Act (1972) was created to restore and maintain the physical, chemical, and biological integrity of the nation's water. This statute employs regulatory mandates for national and state agencies to reduce pollutant discharges. States, territories, and designated tribes create standards for their surface waters based on designated uses and water quality criteria (US EPA 2003). Water quality criteria are descriptions of the conditions in a waterbody necessary to support defined designated uses. Section 303(d) requests a listing of every state's impaired waters and lists any body of water not meeting water quality standards. The United States Environmental Protection Agency (US EPA) is required by the Clean Water Act (Sec 304a) to provide standards for water quality that use the latest scientific information. State agencies are also guided by Section 304(a) to employ water quality criteria that protect human health and aquatic life.

US EPA determines allowable levels at which specific chemicals or pollutants are not likely to negatively affect human health, aquatic life, or wildlife. Humans are exposed to these chemicals in a number of ways, including drinking untreated surface water and eating fish or shellfish. States can use published allowable levels as "human health criteria" and include them in their water quality criteria. By doing this, state and national agencies work together to improve water quality. Aquatic life includes fish, invertebrates, and plants. Aquatic life criteria are focused on protecting whole communities of aquatic organisms, including a wide array of

animals and various plants and microorganisms (US EPA 2003). Criteria for wildlife deal with the effects of pollutants with high bioaccumulation factors and effects upon the food chain.

Identifying Impaired Waters

The Clean Water Act of 1972 called for a list of each state's impaired waters through Section 303(d) (USEPA 2002b). This list drives the completion of Total Maximum Daily Load (TMDL). TMDLs must be established for each water body and pollutant causing impairment. A TMDL is the total allowable load of a single pollutant from all contributing point and non-point sources that will still allow a water body to comply with standards. This calculation is used by the state to ensure safe use of its water bodies. In 1998, over 20,000 water bodies nationwide were impaired, requiring 40,000 TMDLs (US EPA 2002b). Water quality assessment is necessary for the calculation of TMDLs, but it must be closely linked to best management practices. State and federal agencies, such as the Department of Environment and Natural Resources and Natural Resources Conservation Service, work with landowners to implement best management practices. Implementation plans provide a means for collaborative efforts between government agencies and private landowners to improve water quality.

Biological Monitoring

Measuring Biological Integrity

Aquatic resources with high biological integrity have a well adapted, balanced community, high species diversity, and good functional organization for the region in which they are located (Karr et al. 1986; Karr 1981; Karr and Dudley 1981). Biological monitoring aims to detect change in the biological integrity of aquatic systems, specifically, change

caused by humans (Karr 1981). To detect the effects of human activities on biological systems, biological monitoring must be able to differentiate between changes caused by human disturbance and natural variability.

Biological integrity retains three primary elements: physical, chemical, and biological. These three parameters are clearly stated in the Clean Water Act. Federal and state governments require their waters to maintain biological integrity. Biological communities react to all elements in their environment and bioassessment can offer a more complete and valuable monitoring approach than simple chemical and physical monitoring. In an attempt to help protect ecological integrity, the US EPA set a goal to: “. . . fully integrate biocriteria, nutrient criteria for the protection of human health and the maintenance and improvement of the chemical, physical and biological integrity of the Nation’s waters” (US EPA 2002a).

Monitoring biota provides a means to evaluate a multitude of stressors. Earlier monitoring programs in the U.S. focused on chemical contamination of waters (Karr and Chu 1999), but biomonitoring provides a mechanism to evaluate cumulative impacts of multiple stressors such as excess nutrients, temperature change, excess sediment load, and habitat degradation (Barbour and Yoder 2000).

An index is defined as something that reveals or indicates (American Heritage Dictionary 2000). Therefore, biological indices for aquatic systems reveal or indicate changes or problems within the systems. The ability of a system to sustain a balanced biotic community is one of the best indicators of integrity for that system. Karr (1981) originally developed an assessment of biotic integrity using fish communities. His original measurements fell under broad categories (species composition, trophic composition, abundance and composition) that measured biotic integrity of streams. These indicators or metrics were weighted according to

stream order. The fish index of biotic integrity initiated the multimetric approach for assessment of streams. Karr et al. (1986) further explained the biological responses to certain ecological factors or human induced impacts. These factors included energy source, water quality, habitat quality, flow regime and biotic interactions (competition, predation, disease). The IBI incorporates entire community characteristics and facilitates monitoring efforts through comparisons with minimally disturbed reference sites. Biological indices such as Karr's IBI are widely used in aquatic ecosystem management and monitoring today (Barbour et al 2001; Barbour and Yoder 2000; Barbour et al 1999; Bramblett et al 2003, 2005; Braskamp 2002; Cairns and Pratt 1993; DeShon 1994; Fausch et al. 1994; Gronke 2004; Larson and Troelstrup 2001; Lewis et al 2001; Lorenzen 2006; Lyons et al 1995; Maxted et al 2000). Indices help managers make objective decisions about the health of water resources.

When expected biota are absent or lacking, different management must be applied to address problems from disturbance affecting the system. According to Karr and Chu (1999), the best indices are not only at the community level, but integrate responses at the individual, population, ecosystem, and landscape levels. Effort should be made to maximize the effectiveness of detecting degradation, but also to communicate meaningful ecological information (Barbour et al. 2000).

Reference Condition

Reference sites have been used extensively in biomonitoring and bioassessment protocols (Hayford and Ferrington 2005; Gronke 2004; Braskamp 2002; Larson and Troelstrup 2001; Reynoldson et al 1997). Reference sites should be representative of test sites and should demonstrate conditions and biotic communities similar to what is expected in undisturbed communities within a region. Reference sites should be minimally impaired or

represent the best attainable conditions for the region. It is important to note that the reference condition does not necessarily imply a pristine area or one not impacted by human disturbance. In reality, an area such as this may no longer exist. The reference condition is simply the best ‘target’ useful for establishing interim management goals.

Reynoldson et al. (1997) provided one definition for reference and compared two methods of establishing reference conditions. They define a reference condition as “the condition that is representative of a group of minimally disturbed sites organized by selected physical, chemical, and biological characteristics.” Reference sites should be classified into groups where habitat and invertebrate communities would be expected to be similar (Reynoldson et al. 1997). This allows biologists to make comparisons between reference sites and test sites without the confounding effects of habitat and land-use variability. The concept of ecoregions delineates geomorphic characteristics and land-use attributes and places sites into distinct groups. Many studies have taken advantage of using ecoregions to assemble groups of sites (Gronke 2004, Braskamp 2002, Sandin et al. 2000, Rabeni and Doisy 2000, Plafkin et al. 1989).

Ecoregions

Aquatic habitats and biota vary naturally among landscapes on large scales. Many methods used to analyze and assess water quality need an effective geological framework to organize results and limit spatial variability (Omernik and Griffith 1991). Using a spatial framework to organize information from ecological measurements allows indicators to be meaningful on a site-specific basis, allows cooperative development of monitoring methods used by many units, and allows multi-state use of reference sites or reference databases (USGS 2003).

Application of ecoregions to study areas can be a useful way to organize environmental information. Ecoregions can help distinguish differences in land and water interactions, regional variations in water quality, and biogeographical patterns. Landscape level characteristics reflect the uniqueness of each ecoregion (Omernik 1987). Differences in ecoregions are based on patterns in soils, landforms, land use, and potential natural vegetation (Omernik 1987). Ecoregions allow for logical classification of sites for the establishment of region-wide reference conditions. Biological monitoring can be improved when regionalization is utilized as part of the biological assessment of an aquatic system (Barbour et al. 1999).

Using Benthic Macroinvertebrates for Biological Monitoring

Researchers and managers have used many different biological organisms and their response to environmental conditions to determine changes in aquatic ecosystems (Karr 1981; Troelstrup and Perry 1989; Patrick 1995; Kerans and Karr 1994; 1998; Zimmer et. al 2000; Gronke 2004). Biological assessments of aquatic systems have indicated deficiency when no physical or chemical factors indicated a violation (Ohio EPA 1987). Biological assessments focus on the living biota of an aquatic system, not on chemical criteria. Exclusive reliance on chemical criteria will only detect impairment from chemical disturbance. Physical habitat loss, fragmentation, invasion by exotic species, water withdrawals for irrigation, or over-harvest of fish are all disturbances that harm aquatic systems as much or more than chemical disturbance (Karr and Chu 1999). Biological monitoring can assess a broad spectrum of environmental stressors such as acidity, wastes, metals, agricultural runoff and sedimentation. The response of organisms to chemicals is important because organisms cycle those chemicals and wastes into nutrients (Patrick 1995).

Benthic macroinvertebrates have been widely utilized for biomonitoring in recent years (e.g. Kerans and Karr 1994; Death and Winterbourne 1995; Merritt et. al 1999; Pinel-Alloul et. al 1996; Larson and Troelstrup 2001; Roy et al. 2003; Lauridsen and Friberg 2005). Their ubiquity and sedentary lifestyle accounts for their importance in determining site-specific impacts. Cairns and Pratt (1993) explain that using macroinvertebrates is popular because they are diverse, long-lived and sedentary organisms. Invertebrates are an important part of aquatic ecosystems. Pollutant bioaccumulation, genetic composition, population numbers, community structure and system stability have all been used as invertebrate endpoints for monitoring environmental disturbance (Rosenberg and Resh 1993). Macroinvertebrates often predictably react to human disturbance in aquatic systems. Roy et al. (2003) suggested that increased urbanization in stream catchments resulted in lower diversity and higher populations of tolerant stream macroinvertebrates. Urbanization led to increased sediment transport, reduced substrate and sediment size, and increased organic loading. Death and Winterbourn (1995) found a strong linear relationship between substrate stability and species number for New Zealand streams. As substrate stability decreased, species richness also decreased. Foley (1997) observed correlations between landscape disturbance and macroinvertebrate assemblages in the littoral zone of Oak Lake. Sites prone to disturbance displayed greater abundances of tolerant organisms compared to sites that were not prone to disturbance.

Developing Metrics

Metrics are defined by Karr (1981) as measurements describing community structure (i.e. number of species, number of individuals, trophic structure, and tolerance value) that change in a predictable way with increased human disturbance. Metric usefulness as an

indicator of disturbance depends in part on ecological relevance to the biological assemblage being evaluated, sensitivity to stressors and ability to provide a response that is distinguishable from natural variability (Barbour and Yoder 2000; Karr and Chu 1999). The multimetric approach compiles data from several metrics into an easily interpreted index value (Barbour and Yoder 2000).

There are several basic steps for metric development (Barbour et al, 1995; Barbour et al., 1999; Barbour and Yoder, 2000). First, unimpaired or least impaired sites (i.e. reference sites) are identified to account for natural variability. Second, one needs to identify candidate metrics using baseline regional inventory and assessment data. Metrics are chosen to characterize composition, richness, functional groups, and pollution tolerance (Karr 1981; Barbour et al. 1999). Metric selection should also allow discrimination between reference sites and impaired sites. In other words, metrics should detect impairment well and discriminate between natural and human influence (Karr and Chu 1999). Metrics should increase or decrease in response to disturbance. Larson and Troelstrup (2001) calculated discriminatory power by subtracting average test site values from average reference site values and dividing by the standard deviation of the reference site values. When the resulting values are greater than one, the metrics are better able to discriminate between natural variation and anthropogenic disturbances. Bramblett et al. (2003) selected metrics based on several criteria. First, any metrics with ranges of less than four units were discarded. Additionally, metrics with >90% zero values were also considered inadequate. Secondly, metrics were chosen based upon their ability to respond to stressors. Spearman Rank correlations were used to determine correlations to human disturbance. Thirdly, a metric's precision was established. Metrics needed to discriminate well between sites (low within site variability relative to between site

variance). Bramblett et al. (2005) calculated discriminatory power by a “signal-to-noise” ratio calculated from a random-effects analysis of variance (ANOVA). Signal was the mean square error in raw metric values among their 10 reaches, and noise was the residual mean square error of raw metric values from repeat visits to the same reach. They chose metrics with a signal-to-noise ratio of at least 3. Finally, metrics were eliminated based on redundancy. When two or more metrics were significantly correlated, the metric with the lowest discriminatory power was discarded.

After developing a core set of metrics, thresholds must be defined to help managers decide what sites are impaired and which are unimpaired. Each core metric is scored relative to reference conditions. Low scores indicate large deviation from the reference conditions while high scores indicate similarity with the reference condition. The sum of all metric scores provides an index of biotic integrity for a particular site.

Macroinvertebrate Metrics

Indicators of disturbance includes species, organisms, or groups or organisms with specific environmental requirements. Degradation and elimination of habitat, competitive displacement, and/or local extirpation of relatively intolerant taxa may all influence macroinvertebrate metrics (Larson 2001; Griffith et al. 2001; Yoder and Rankin 1995; Rosenberg and Resh 1993). Reduced richness is natural in some aquatic systems because of natural regional conditions. Larson (2001) examined responses of several invertebrate metrics to disturbances on an eastern South Dakota stream. He determined that certain invertebrate metrics were highly correlated to chemical and physical attributes in the stream, several of which were attributed to disturbances in the upper portions of the stream. Griffith et al. (2001) used redundancy analysis and canonical correspondence analysis to assess

relationships between chemical and physical characteristics and macroinvertebrate communities in several stream sites in the Southern Rockies of Colorado. They determined that total richness, taxa abundances, taxa dominance, and number of Chironomidae larvae were sensitive to the effects of mining, riparian disturbance, and stream size. Biological response signatures have also been used to detect specific impairment types. Response patterns of invertebrates may be used to determine the type and degree of impairment (Yoder and Rankin 1995). These response patterns were termed “Biological Response Signatures” (Yoder and Rankin 1995). For example, Yoder and Rankin (1995) found that EPT taxa, percent tolerant, percent Dipteran and noninsects and percent *Cricotopus* all consistently indicated impacts from industrial point source pollution. Percent *Glyptodentipes* spp. also showed higher values from impacts of wastewater treatment plants.

Intolerant taxa are those first eliminated by disturbance. Therefore, a decrease in intolerant taxa can indicate a stress or disturbance on the entire system. Often, taxa intolerant to pollution are specialists and a disturbance that destroys specialized habitat or water quality requirements will eliminate intolerant taxa. Taxa tolerant to disturbances are sometimes generalists and not as affected by particular disturbance. As a disturbance increases, tolerant individuals tend to predominate in the community. Intolerant individuals become less abundant as disturbance increases, leading to greater dominance by tolerant, opportunistic taxa.

Hilsenhoff Biotic Index scores provide a measure of average pollution tolerance of invertebrates within a community (Hilsenhoff 1987). Scores are assigned to each taxa based on its tolerance to organic pollution and range from 0-10, increasing as invertebrates tolerance increases (0=very intolerant, 10=very tolerant). Stone et al. (2005) observed that HBI scores

were significantly correlated with in-stream habitat scores, riparian cover, and orthophosphate concentrations in agriculture-impacted streams of Southern Illinois. Total richness of generally intolerant insect orders may also indicate aquatic condition, since these taxa tend to disappear with increases of disturbance. Maxted et al. (2000) established metrics for low-gradient streams in six Atlantic coastal states. They determined that the HBI and the intolerant orders Ephemeroptera, Trichoptera and Plecoptera were best at discriminating impairment.

The richness of the community is the total number of families, genera, and/or species and serves as a measure of diversity. Richness is often utilized as an invertebrate community metric (Foley 1997; Larson 2001; Maxted et al. 2000; Braskamp 2002; Gronke 2004; Lorenzen 2006) and usually decreases as a stream ecosystem is degraded (Rosenberg and Resh 1993, Death and Winterbourne 1995, Biggs and Smith 2002). EPT richness is also a common and powerful metric used for its discriminatory power for biotic integrity research (Plafkin et al. 1989; Hannaford and Resh 1995; Maxted et al. 2000; Zweig and Rabeni 2001). For example, Maxted et al. (2000) analyzed 106 streams in 6 states and selected several biological metrics that best discriminated reference sites from impaired sites. They identified EPT taxa as an important group in evaluating streams because it consistently discriminated well between impaired and non-impaired sites.

The Diptera is a relatively diverse order of insects that are variable in their tolerance to disturbance. Many Diptera taxa, particularly Chironomidae, have broad-based distributions and may occur even in highly polluted systems (King and Richardson 2002; Lenat and Resh 2001; Hudson et al. 1990). However, a high diversity of Diptera is usually an indicator of good water quality (Lenat 1983). The tribe Tanytarsini (Chironomidae) represents a relatively intolerant group of midges (Johnson et al. 1993). The degree to which they represent the total number of

midges indicates the general sensitivity of the midge assemblage (Johnson et al. 1993). A high percentage of Tanytarsini among the midges may indicate lower levels of anthropogenic stress. Gronke (2004) found that Tanytarsini abundance was nearly seven times greater in reference lake littoral zones than impaired lake littoral zones. Foley (1997) also observed a higher proportion of Tanytarsini from lake littoral sites less prone to disturbance.

An invertebrate's means of dispersal or method of finding refuge is influenced by disturbance. Aquatic invertebrates may seek protection from a disturbance by moving to a refuge, using morphological adaptations that render them more tolerant to disturbance or a resistant stage in their life cycle (Mackay 1984). Other survival strategies may include variable growth rates and sensitive dispersal mechanisms (Mackay 1984).

Trophic measures are also used to evaluate biological integrity. The trophic structure of the community provides information on changes in water quality through how the organisms attain their food (Karr et al. 1986). Species are assigned to a trophic group based on their food acquisition adaptations. Guilds include collectors-gatherers, collector-filterers, scrapers, shredders, and predators (Merritt and Cummins 1996). Trophic structure can change in response to land-use surrounding a water body. Larson and Troelstrup (2001) found that filterer-collectors, shredders, and piercers decreased in streams with high erodability, while collector-gatherers, predators, and scrapers all increased in the same impaired stream. Gronke (2004) found that collector-gatherers were negatively correlated with pH while burrowers were negatively correlated with shoreline vegetation. Kerans and Karr (1994) also found lower numbers of grazers and predators from streams with human disturbance while filterers were more abundant.

Managing Aquatic Resources

Managing and monitoring any natural resource requires detailed planning and preparedness. Most importantly, specific objectives must be addressed to get the most benefit out of the monitoring program. Davis (1997) developed a basic ecological monitoring program for Channel Islands National Park. The park's goals for the monitoring plan included 1) determining present and future ecological health, 2) establishing empirically normal limits of resource variation, 3) providing early warning of system changes, and 4) identifying the agents of those changes. Three main steps are needed to address the park's concerns (Table 1). These steps include: 1). developing a conceptual ecosystem model, 2) conducting design studies to develop vital signs and 3) monitoring system health (Davis et al. 1993; Davis 1997). These steps have also been applied to achieve the overall goal of the NPS I&M program (NPS 2006).

Designing a monitoring program requires adequate resources of time, money, and expertise. The National Research Council (NRC) (1990) developed a generic monitoring design similar to Davis et al. (1993) that can be used for designing and implementing a monitoring program (Figure 1). Feedback loops are a critical part of using the NRC's monitoring design. Feedback systems can be used as scientific knowledge and understanding increase to transfer resources toward unknown issues and away from problems that have already been suitably addressed. The NRC also addresses the importance of defining questions and objectives thoroughly according to management priorities and concerns. Their flowchart and development of feedback loops let managers refine their objectives to limit problems to specific questions. Feedback mechanisms are very important to answer refined questions and these are refined using the best available information.

Table 1. Steps in developing an effective monitoring program for Channel Islands National Park (Davis et al 1993; Davis 1997)

<u>STEP 1</u>	Develop a conceptual ecosystem model
	- Set limits on systems to monitor - Inventory natural resource using literature or field surveys for inadequately known taxa - Make an exhaustive list of mutually exclusive components of the system - Identify relationships among system components (e.g. biogeographic units, taxonomic divisions)
<u>STEP 2</u>	Conduct studies to develop monitoring protocols for ecosystem vital signs
	- Select critical components to serve as vital signs - Set component priorities (partnering value, feasibility, scientific worth) - Design monitoring protocols
<u>STEP 3</u>	Monitor system health
	- Obtain funding - Obtain personnel - Implement monitoring protocols - Use information from monitoring and apply to management issues

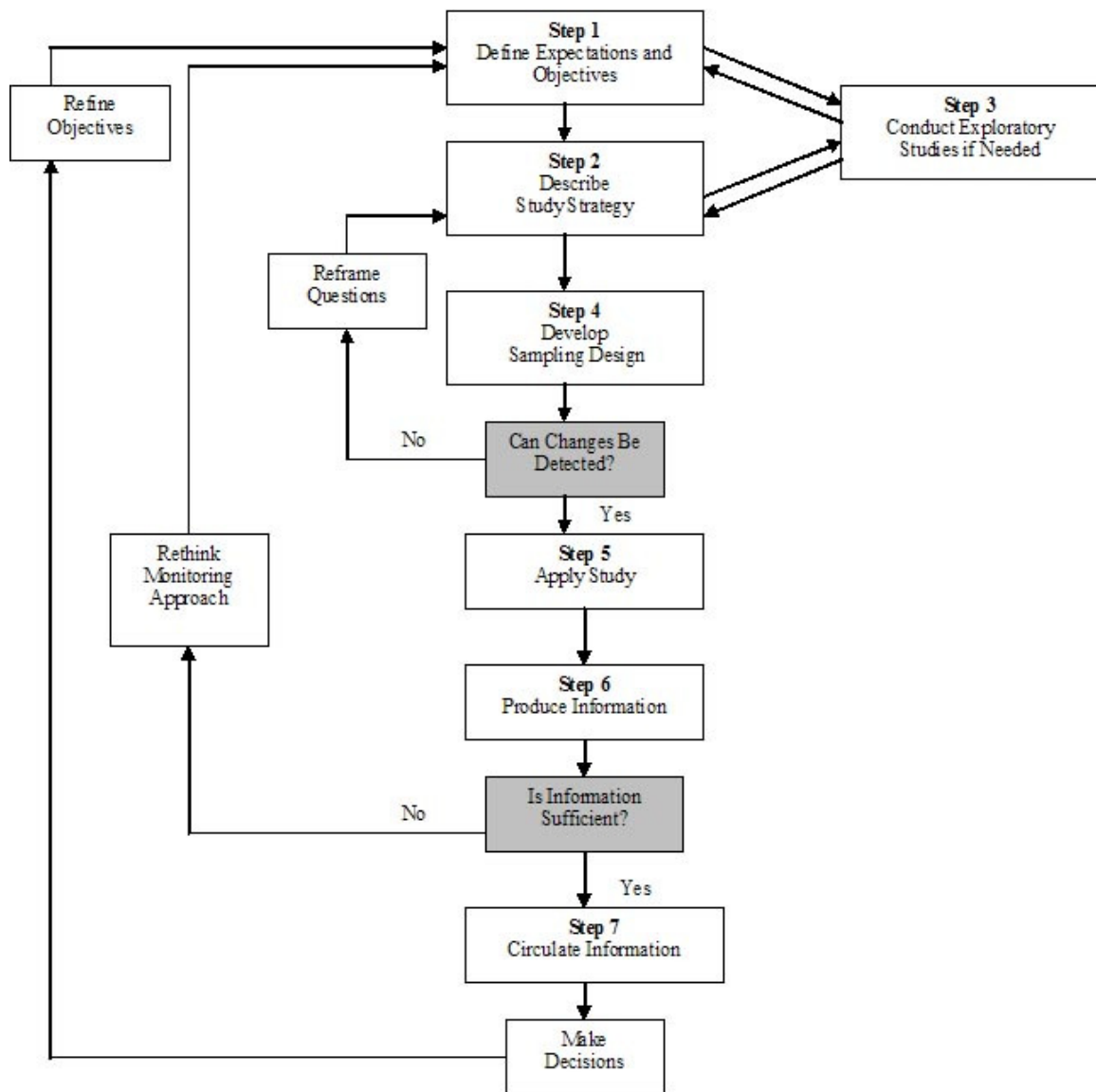


Figure 1. Flowchart for designing and implementing a water quality monitoring program, modified from National Research Council (1990).

Using Biological Indicators as a Management Tool

Ecological integrity involves consideration of structure and function. Concerns may arise when using ecological indicators as a resource management tool. First, monitoring programs that depend on just a few indicators may oversimplify the system and fail to consider all critical components of the ecosystem (David and Beyeler 2001). This can lead to poorly

informed management decisions. Managers need a group of measures to fully evaluate ecological complexity. Second, programs with vague long-term monitoring goals may impede selection of ecological indicators. Specific objectives should be determined early in the process to concentrate monitoring on defined management issues (Goldsmith 1991). These objectives should relate to both short-term and long-term goals. Finally, failure to use accepted and standardized protocols may lead to management programs that lack scientific rigor. Standard protocols need to be established for correct interpretation of indicators (David and Beyeler 2001; Goldsmith 1991). Correct development of ecological indicators will allow manager to monitor for ecological integrity.

Biological indicators need to possess several attributes to be utilized for measuring biological integrity of a system. Biological indicators need to be able to indicate adjustments in entire communities rather than particular species. They must be sensitive to anthropogenic changes with the system and be able to respond quickly to stressors. Biological indicators also must be easy to measure, cost-effective, and scientifically defensible (Barbour et al. 2000). Indicators should signal an impending change, predict changes that may be stopped by management actions, and have a low variability in response (David and Beyeler 2001).

Recognition of Impairment

Recognition of impairment or anthropogenic disturbance is influenced by variability of data, sample size, magnitude of disturbance, and statistical assumptions. When dealing with populations or communities of organisms, especially invertebrates, subsampling and taxonomic resolution may strongly influence detection of differences among sites and time periods. King and Richardson (2002) examined differences in taxonomic resolution and subsampling approaches for detecting impairment in a Florida wetland. They compared fixed

count subsampling (100, 200, 300), fixed area (10%, 25%), combination (100+10%), and a large rare (LR) search (100+LR, 10%+LR). Comparisons indicated that the 100, 10%, 100+10% had low accuracy in detecting impairments. Both 200 and 300 invertebrate counts did well at detecting impairments, but they recommend a 200 count to efficiently subsample. A 300 count didn't do much better at detecting impairments than 200 counts, but absorbed significantly more time, and hence, more money. They also demonstrated how a search for large and rare specimens was important to show diversity in a sample and to detect impairments in an aquatic system. Key species, however uncommon they were in a sample, are important in terms of biomass and diversity. Taxonomic resolution is also important in detecting impairment. Identifying specimens only to family significantly reduces the ability to detect impairment in the system. They recommend keying at least to genus and, wherever possible, to species. Their results demonstrated that keying only Chironomidae to species while everything else was only to family was nearly as good as keying everything to genus or species. This indicates the importance of using Chironomidae for detection of impairment, although they are difficult and time consuming to identify to species.

Taxonomic resolution also is needed to identify certain types of impairment using biological response signatures (Yoder and Rankin 1995). Discernable patterns in biological communities can be used to indicate certain types of impairments. Yoder and Rankin (1995) demonstrated that *Cricotopus spp.* best differentiated "Complex Toxic" impacts (impact from a combination of municipal waste water treatment plants and industrial point sources and where at least one other major disturbance happened such as fish kills or severe sediment contamination). *Glyptotendipes spp.* was also higher in areas with a higher degree of organic enrichment.

National Parks and Monitoring

Establishing a long-term monitoring program allows managers and biologists to create a solid foundation for future management decisions. The National Park Service's goals are to 1) leave parks unimpaired, 2) conserve native species, and 3) conserve the natural processes and conditions of the ecosystem (NPS 2006). This means park staff must meet the Clean Water Act's standards and manage streams for pristine conditions.

Inventory and monitoring goals include setting up a program for the national parks that stem from their main objectives and concerns. This involves scoping work and developing indicators of disturbance that can be used efficiently for long term monitoring . Scoping work includes informational meetings with the National Parks to address issues and concerns with park resources and to get accustomed to natural resources that are contained within each park.

Each network has determined Vital Signs for its parks. Vital signs are a set of physical, chemical, and biological factors and processes of the park's ecosystems that represent the overall health or condition of park resources (NPS 2006). Vital signs can be used to characterize the current status and determine trends in the condition of the park's aquatic resources. These trends are important assessment tools for the effectiveness of management activities and provide early warning of threats to the systems. Park staff and other natural resource partners have identified macroinvertebrates and other water resource characteristics as important vital signs for ecological health within parks. Scoping meetings held in the Northern Great Plains Network (NGPN) helped to reveal potential stressors and important aquatic resources of the National Parks (Table 2). Meetings with park staff, state and federal monitoring agencies, and academia highlighted the importance of water quality to the park's monitoring program. Macroinvertebrates were also rated high at these meetings as an essential

way to monitor both water quality and the biological integrity of the aquatic systems (personal communication).

Project Goal and Objectives

The Great Plains Network of the NPS is in the planning phase of a long-term program to monitor the health of park ecosystems. Over the next few years the network will develop a monitoring plan for aquatic ecosystems. This plan will provide background information on park aquatic resources, stressors to those resources, current monitoring efforts, a list of potential indicators and the reasons for choosing such indicators, the protocols to be used in monitoring, threshold or trigger levels, and potential management responses. Data are needed to establish baseline conditions within water bodies of the network parks and to help develop a list of potential indicators to be used in monitoring. This data will be used by park staff to facilitate long-term monitoring. Baseline macroinvertebrate data from the parks can also be used by state and federal agencies to facilitate the establishment of reference conditions.

Project Goals

1. Provide descriptions of macroinvertebrate communities within aquatic habitats of the NGPN.
2. Select invertebrate metrics with high discriminatory power and low within site variability for future monitoring by park staff.

Table 2. Concerns and priorities of park staff in the NGPN. (Dan Licht pers. comm.)

National Park	Concerns of Park Staff
Agate Fossil Beds	-“the health of the river” -“Irrigation upstream of river is depleting flows, could effect potential fishery.” - “Does Niobrara water quality and quantity meet goal of healthy ecosystem?”
Badlands National Park	-concerns about state protected fish -overall “Water Quality.”
Devil’s Tower National Monument	-“ Health of riparian corridor, specifically cottonwoods and willows, perhaps due to altered hydrographs” -“ Water quality and quantity of Belle Fourche [River]”
Fort Laramie National Historic Site	-“River oxbow [and] species found within the river” - “Dams on Laramie and North Platte, pesticides from fields, irrigation canal” - changing land use surrounding park and effects on canals and streams in park
Fort Union Trading Post National Historic Site	- “Erosion control on the river” - “the dam” - “ changing riparian vegetation” - “pesticide use” and “Invertebrate response to pesticides”
Jewel Cave National Monument	-“Water quality in the springs.” -“Sewage system effects, leaks, potential overflow.”
Knife River Indian Village National Historic Site	-“ altered hydrograph” -“ water quality on Knife River” -“Water quantity will remain an issue because center pivots are still increasing” -“Non-point from cattle will continue especially on NIOB including perhaps more feedlots” -“Sediment loads” -“Monitor aquatic biota (inverts, herps).” -“exotic species and altered hydrograph”
Niobrara Scenic and Missouri Recreational Rivers	-integrity of Grizzly Creek -impacts of new effluent system -impacts of developed area of Mount Rushmore on surrounding streams (Grizzly and Battle Creek) -“Water quality and quantity from canal as seeps through soil and impacts to plants.”
Mount Rushmore National Memorial	-“Declines in water quality (pesticide runoff from agriculture and golf course near South Unit)” - “Changes in water quantity (water rights for park not established; golf course near South Unit will use a lot of Little Missouri River water) and flow regimes”
Scott’s Bluff National Memorial	-“water quality as it affects the cave and surface water” -“water quality depletion” -“macroinvertebrates in springs, streams, and caves”
Theodore Roosevelt National Park	
Wind Cave National Park	

Study Area

National Parks

All sampling sites were located within the NGPN of the NPS (Table 3, Figure 2). The parks are located in South Dakota, North Dakota, Wyoming, and Nebraska. Scoping work (informational meetings) was completed for all thirteen parks to determine priority issues within aquatic systems of each park.

Sites not only belong to different states and parks, but to different ecoregions and land uses adjacent to the parks. Landscape and land-use is repeatedly shown to affect aquatic communities and water quality of systems within their respective area (Schelke et al. 2005, Carr 2005, Niyogi 2004). Parks within the NGPN fell within six different ecoregions (Table 4). Consequently, natural differences in habitat, physical, chemical parameters and invertebrate communities may occur. Each site was divided into different system types (small-to medium-sized streams, large rivers, springs, and bison watering holes) and one to three reaches were sampled from each lotic system (Table 5).

Agate Fossil Beds National Monument

Agate Fossil Beds National Monument was established for its 9.2 million year old Miocene epoch mammal fossil deposits and was once part of “Captain” James H. Cook’s Agate Springs Ranch. This area was also a gathering place for Chief Red Cloud and other Oglala Lakota Indians (NPS 2006b). It is located within shortgrass and sandhills prairie along the Niobrara River in northwestern Nebraska at 42° 25’ 9” N and 104° 2’ 41” W and is part of Omernik’s (1987) Western High Plains ecoregion (Table 4). The bluffs in this area are sparsely vegetated and the rest of the prairie consists of mixed-grass prairie with *Bouteloua spp.*,

Hesperostipa connata, *Lupinus pusillus*, and *Argemone polyanthmos* (NPS 2002b). The Arikaree Group aquifer system underlies the park (Harris and Kondratieff 1991). Ranchland is widely scattered in the land surrounding the park.

The Niobrara River travels through approximately 1100 ha of the park's center from west to east. The Niobrara has a shifting sand and sand/mud substrate. Park staff aquatic resource concerns are centered on the Niobrara River and include stream and riparian health concerns (Table 2). Baseline water quality data reports (NPS 1998b) specify five parameters exceeding state water quality criteria. These parameters included: pH, cadmium, copper, lead, and fecal coliform bacteria.

Badlands National Park

Badlands National Park was established in 1929 for its scenic and scientific value. The hills, peaks, and bluffs were formed by wind and water erosion of the volcanic ash and sediment that was deposited there millions of years ago (NPS 2006b). Today, the park is 98,868 hectares and located at 43° 37' 31" N and 102° 52' 31" W and is part of Omernik's (1987) Northern Great Plains ecoregion (NPS 2002b).

Most of the sparse vegetation is composed of mixed-grass prairie consisting of *Pascopyrum smithii*, *Bouteloua gracilis* and *Schizachyrium scoparium* (NPS 2002b). Several ephemeral streams run through the park, but these only run for a very short time after heavy rainfall or snowmelt. Sage Creek runs through the park and usually runs all year. Stock dams have been established for bison. Park staff voiced concern over CCC Spring found within the park and also the quality of habitat and water within the stock dams. Baseline information on Sage Creek was also discussed as an important aspect of park aquatic resources. Baseline water quality data reports (NPS 1998c) specify eight parameters exceeding state water quality criteria

at least once during the screening years. These parameters included: pH, copper, sulfate, nitrite, lead, fecal coliform, total coliform and turbidity.

Table 3. National Parks, alpha codes of parks, total park hectares and stream reaches sampled for each system type within each park in the NGPN (NPS 2003) Each reach was sampled three times throughout the study.

Parks	Alpha code	Hectares	Stream Reaches	River Reaches	Spring Reaches	Watering holes
Agate Fossil Beds National Monument	AGFO	1,236	1	0	0	0
Badlands National Park	BADL	98,868	3	0	1	5
Devils Tower National Monument	DETO	550	0	1	3	0
Fort Laramie National Historic Site	FOLA	336	1	3	0	0
Fort Union Trading Post National Historic Site	FOUS	182	0	1	0	0
Jewel Cave National Monument	JECA	548	0	0	3	0
Knife River Indian Villages National Historic Site	KNRI	711	0	3	0	0
Missouri National Recreation River	MNRR	13,695	0	3	0	0
Mount Rushmore National Memorial	MORU	501	5	0	0	0
Niobrara National Scenic River	NIOB	8,513	5	3	0	0
Scott's Bluff National Memorial	SCBL	1,215	0	5	1	0
Theodore Roosevelt National Park	THRO	28,509	0	3	0	0
Wind Cave National Park	WICA	11,451	8	0	0	0

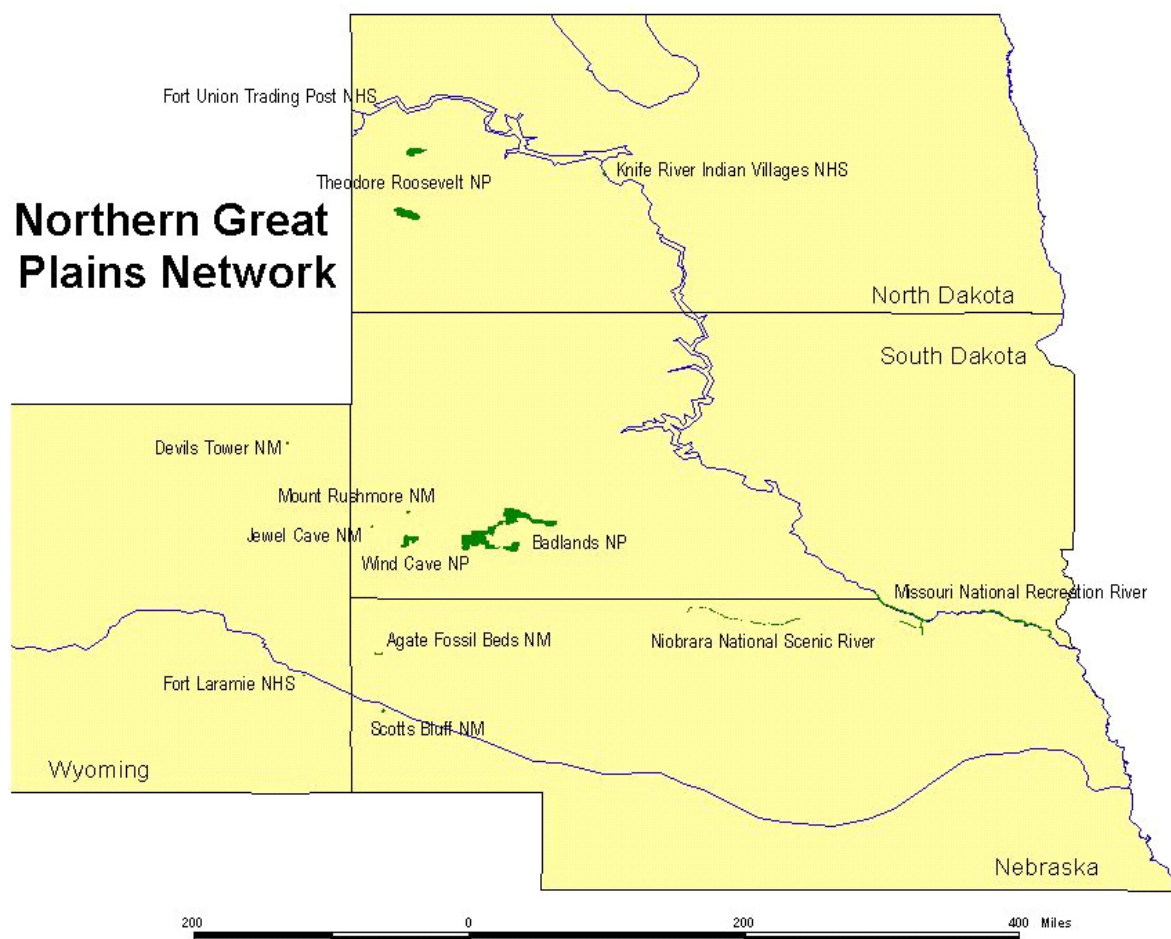


Figure 2. Map depicting the NGPN of the National Park Service and the respective parks (NPS 2003).

Table 4. Ecoregions and their descriptions that encompass parks within the NGPN (Bryce et al. 1998).

Ecoregion	Descriptions	Summer mean Temperature (min/max, oC)	Annual Average Rainfall (cm)	Parks Within Region
Northwestern Great Plains	Semi-arid area of rolling plains and fields, with shale, siltstone, and sandstone. Limited agriculture	13/29	38	BADL, FOUS, KNRI, THRO
Northwestern Glaciated Plains	Transition between drier Northwestern Great Plains and moister Northern Glaciated Plains. Encompasses southwestern part of glaciation and contains prairie potholes	16/32	53.3	MNRR, NIOB
Middle Rockies	Composed of steep mountains covered by coniferous forests. Soils primarily Alfisols. Cattle grazing, lumbering, and recreation are common land-uses.	13/28	43.2	DETO, JECA, MORU, WICA
Northern Glaciated Plains	Flat to rolling topography composed of glaciated soil. Many temporary and season wetlands. Also is a transition for tall and short grass prairie. Agriculture is common	16/31	48.3	MNRR, NIOB
Nebraska Sand Hills	Large areas of grass stabilized by sand dunes. Mostly treeless and lacking cropland agriculture	14/33	41.9	NIOB
Western High Plains	Primarily smooth prairie grasslands. Agriculture primarily cattle grazing with some sorghum fields	14/33	41.9	AGFO, FOLA, NIOB, SCBL
Western Corn Belt Plains	Primarily used for agriculture although once all tallgrass prairie. Nearly level plains with 63-89 cm of rainfall yearly. Many surface and groundwater concerns from fertilizer and pesticide runoff and livestock concentrations	17/31	61.0	MNRR

Table 5. Sites sampled within each park and classification of each site into stream river, spring or stock pond.

Park	Sites	Site Classification
Agate Fossil Beds National Monument	Niobrara River	Stream
Badlands National Park	Sage Creek	Stream
	CCC Spring	Spring
	Watering holes B,U,F,A,L	Bison Watering Hole
Devils Tower National Monument	Belle Fourche River	River
	Springs S,P,R	Springs
Fort Laramie National Historic Site	North Platte River	River
	Laramie River	River
	Deer Creek	Stream
Fort Union Trading Post National Historic Site	Missouri River	River
Jewel Cave National Monument	Chokecherry Spring, Jewel Cave Spring, Prairie Dog Spring	Springs
Knife River Indian Villages National Historic Site	Missouri River	River
	Knife River	River
Missouri National Recreation River	Missouri	River
Mount Rushmore National Memorial	Beaver Dam Creek (Starling Creek)	Stream
	Lafferty Gulch	Stream
	Grizzly Creek	Stream
Niobrara National Scenic River	Niobrara River	River
	Berry Falls	Stream
	Fort Falls	Stream
	Smith Falls	Stream
Scott's Bluff National Memorial	North Platte River	River
	Central Canal	River
	Gering Canal	River
	Scotts Spring	Spring
Theodore Roosevelt National Park	Little Missouri River	River
Wind Cave National Park	Beaver Creek	Stream
	Cold Spring Creek	Stream
	Highland Creek	Stream

Devil's Tower National Monument

Devil's Tower National Monument is 550 total hectares and was the first to be established as a national monument in 1906. The formation itself was fashioned by igneous rock and exposed after the softer sedimentary rock had been eroded. The tower consists of many symmetrical joint columns (NPS 2006b). Devil's Tower is located at 44° 35' 27" N and 104° 42' 54" W and lies in the Middle Rockies ecoregion (Omernik 1987). This park consists of mostly ponderosa pine but also has some prairie landscape (NPS 2002b).

Devils Tower has two main types of aquatics within the park. Three springs are located within the park and the Belle Fourche River flows through the park and along the park's boundary (personal communication). Baseline water quality data reports (NPS 1998d) specify four parameters exceeding state water quality criteria at least once during the screening years. These parameters included: sulfate, cadmium, fecal coliform bacteria, and turbidity.

Fort Laramie National Historic Site

Fort Laramie National Historic Site was established for cultural and historic purposes. In 1938, the 336 hectares became part of the National Park Service. It is located at 42° 12' 5" N and 104° 33' 30" W in the Western High Plains ecoregion (Omernik 1987).

FOLA has several main aquatic resources within the park. These include the North Platte River, Laramie River, Deer Creek and the county irrigation canal.

Visits with park staff revealed concerns about the North Platte and Laramie River (Table 2). Deer Creek is directly impacted by livestock that are able to graze the stream bank and enter the stream. Baseline water quality data reports (NPS 1998e) specify eight parameters exceeding state water quality criteria at least once during the screening years. These parameters included: pH, cadmium, copper, silver, nickel, lead, fecal coliform, and turbidity.

Fort Union Trading Post National Historic Site

Fort Union Trading Post National Historic Site was also established for cultural purposes. It was originally established by the American Fur Company in 1828 and was later bought by the U.S. Army in 1867. In 1966, the 182 hectares of northwest North Dakota became a national park (NPS 2006b). The park is located at 24° 0' 1' N and 104° 2' 41'' W of the Northern Great Plains ecoregion (Omernik 1987). Most of the park consists of restored prairie and some riparian forests. Vegetation consists of trees and shrubs and mixed-grass prairie (NPS 2002b).

The Missouri River flows along the park boundary, with the confluence of the Yellowstone River occurring downstream from the park. Concern for the river from park staff was only mentioned in respect to the preservation of the pallid sturgeon. Much of the water quality data for the park is at least one decade old (NPS 1999), revealing a need for an up-to-date assessment and monitoring program for the park. Baseline water quality data reports (NPS 1999a) specify only fecal coliform bacteria exceeded state water quality criteria. The park's main focus is the cultural history of the fort. Therefore, natural aquatic ecosystems have not been well studied.

Jewel Cave National Monument

Jewel Cave has been an attraction since its discovery by the Michaud brothers in 1900 (Conn 1977), but was not established as a national park until 1933. The park was established for the cave and the unique speleothems (e.g. boxwork and hydromagnesite balloons) found within the cave. The 548 hectare park is located in the southwest Black Hills. Jewel Cave National Monument is located at 43° 44' 18'' N and 103° 51' 26'' W and is part of the Middle Rockies ecoregion. Vegetation consists of mostly Ponderosa Pine (*Pinus ponderosa*) and some

western snowberry (*Symphycarpus occidentalis*) shrublands (NPS 2002b). However, much of this (80-90%) was burned in the Jasper fire of 2000.

Springs are the only water resources within the park. There are no perennial streams within the park, but any drainage that may find its way into the cave is a concern (especially from road and parking lot runoff). Concerns with springs within the park and just adjacent to the park arose at scoping meetings (Table 2). The NPS Water Resources Division (2000a) reviewed past data on the park, but no springs that are found within the park were included in the data. Other water data collected within and adjacent to the park yielded eleven parameters that exceeded state water quality criteria (NPS 2000a). These included: pH, chloride, cadmium, chromium, copper, lead, silver, zinc, fluoride, Bis (2-ethylhexyl) phthalate, and pentachlorophenol.

Knife River Indian Villages National Historic Site

Knife River Indian Village National Historic Site was established for its cultural resources in 1974. The park is located in central North Dakota and encompasses both sides of the Knife River as it joins with the Missouri River (47° 21' 15" N and 101° 23' 7" W, NPS 2002b).

The park's vegetation consists of cottonwood riparian forests, native mixed-grass and restored prairie. Riparian woodlands mostly cover the floodplain (NPS 2002b). The Knife River and Missouri river both flow through the park. Not much data exists on the water within the park boundaries.

The Knife River is the main concern to park staff. This river is widely used by visitors and local people for fishing and canoeing. No specific stressors were mentioned at scoping meetings, but an overall interest in aquatic communities within the river and water quality

within the river (Table 2). A short part of the Missouri River flows by the northeastern border of the park and also a section flows by the southeastern border. During high flows the southern part of the Missouri will flow back into the Knife River, giving the illusion that the Knife River is flowing backwards (South to North instead of North to South, personal communication). One past measurement of pH exceeded the states criteria to protect aquatic life (NPS 1997a).

Missouri National Recreation River

Missouri National Recreational River (MNRR) is a linear park with limited land on each bank. The purpose of the park is to conserve the riverine system and provide recreational opportunities for visitors. The MNRR includes two reaches along the Nebraska-South Dakota border and encompasses 13,695 hectares. They are protected as parts of the nation's Wild and Scenic River System and were designated to preserve the free-flowing nature of the river in this area. The river exhibits islands, bars, and chutes and represents the natural landscape of the Missouri River during pre-settlement days (NPS 2003). The MNRR lies in the Northwestern Great Plains and the Western Corn Belt Plains ecoregions (Table 4). Park staffs main concerns are centered on introduction of exotic species and the altered hydrograph (Table 2). Baseline water quality data reports (NPS 1998f) specify 20 parameters exceeding state water quality criteria at least once during the screening years. These parameters included: dissolved oxygen, antimony, pH, copper, sulfate, nitrite, nitrate, mercury, selenium, thallium, cadmium, chlorine, lead, zinc, carbon chloroform, lead, heptachlor epoxide, fecal coliform, total coliform, and turbidity.

Mount Rushmore National Memorial

Mount Rushmore National Monument was established in 1933 for the granite carvings or “faces.” The park consists of 501 hectares in the central Black Hills of South Dakota and has rugged terrain (NPS 2006b). Mount Rushmore National Memorial is located at 43° 52’ 44” N and 103° 24’ 10” W (NPS 2002b). This park is located in the Middle Rockies ecoregion (Table 4).

This park’s vegetation consists of Ponderosa Pine, including some old growth forest along with some birch and bur oak (NPS 2002b). Lafferty Gulch, Grizzly Bear Creek, and Beaver Dam Creek are the perennial streams within the park. Park staff expressed concerns with the overall water quality of these streams (Table 2). Baseline water quality data reports (NPS 2000b) specify five parameters exceeding state water quality criteria at least once during the screening years. These parameters included: dissolved oxygen, pH, antimony, fecal coliform, and turbidity.

Niobrara National Scenic Riverway

The Niobrara National Scenic Riverway is also a linear park with limited land on each bank.. The park is located along a main stretch of the Niobrara in north central Nebraska (NPS 2006). The park lies at 42° 35’ 27” N and 98° 6’ 36” W (NPS 2002b). Many spring-fed tributaries flow into the Niobrara. The 8,513 hectare park has old boreal forests (NPS 2002b). This section of river was established as a park in 1991 and was created to preserve the natural river.

Park staff concerns mainly focused on the impact of visitor use, especially around popular waterfalls. Riparian and stream habitat have been denuded from visitors walking up the stream or making social trails through the riparian zone. The city of Valentine has sewage

effluent that runs into Minnechaduza Creek, a tributary of the Niobrara. The park currently receives water quality data on a five year rotational scale from the Nebraska Department of Environmental Quality. Park staff also want to begin monitoring aquatic biota, but as of now, no macroinvertebrate data has been collected for the park. Baseline water quality data reports (NPS 1995) specify eight parameters exceeding state water quality criteria at least once during the screening years. These parameters included: copper, pH, fluoride, beryllium, fecal coliform, *E. coli*, turbidity and lead.

Scott's Bluff National Monument

Scott's Bluff National Monument was established in 1919 for geological and cultural purposes (NPS 2006). The park's 1,215 hectares contain badlands and prairie topography with some riparian forests. The park lies at 41° 50' 13" N and 103° 42' 20" W in the Western High Plains ecoregion (Table 4). Most of the park is mixed grass prairie but there are some riparian woodlands along the North Platte River as it flows along the boundary (NPS 2002b). Some Ponderosa Pine and Rocky Mountain Juniper dot the landscape (NPS 2002b).

The largest aquatic resource in the park is the North Platte River. The North Platte has an altered hydrograph, exotic plant species, irrigation withdrawals, and pollution from adjacent agricultural and municipal runoff (NPS 1999b). Park staff have voiced concerns primarily over Scott's Spring and the irrigation canals. Baseline water quality data reports (NPS 1999b) specify three parameters exceeding state water quality criteria at least once during the screening years. These parameters included: nitrate plus nitrite, sulfate, and fecal coliform. Sampling for this project included Scotts Spring and two irrigation canals within the park. The North Platte River was also sampled for basic water quality data and macroinvertebrates.

Theodore Roosevelt National Park

In 1947, Theodore Roosevelt National Park was established in memory of President Theodore Roosevelt and for the scenic and natural resources found within the park. The 28,509 hectare park consists of 3 sections, the North Unit, the South Unit, and a small unit in the middle called the Elkhorn Unit (NPS 2006). All three units are located in the Northern Great Plains ecoregion (Table 4). The general area of Theodore Roosevelt National Park is at 47° 35' 59" N and 103° 15' 49" W (NPS 200b).

The Little Missouri River flows between the North and South Unit, and adjacent to the Elkhorn Unit. Some pesticides are also used inside the park to control exotic species such as leafy spurge (Berkley et al. 1998). Future oil and gas development in the area will likely raise new concerns for water quality (NPS 2003). Sampling took place on the Little Missouri as this was the main aquatic resource mentioned by park staff and seemed to have the most potential for problems. Baseline water quality data reports (NPS 1997b) specify 18 parameters exceeding state water quality criteria at least once during the screening years. These parameters included: pH, arsenic, cadmium, copper, lead, mercury, zinc, fluoride, sulfate, barium, beryllium, chromium, nickel, uranium, total coliform, fecal coliform, and turbidity.

Wind Cave National Park

Wind cave was established in 1903 to protect the cave and its resources. The park area around Wind Cave was established later in 1912. Today, the park is 11,451 hectares and is a mix of woodland, shrubland, and mixed-grass prairie. The park lies at 43° 34' 52" N and 103° 24' 52" W and is also located within the Middle Rockies ecoregion.

Park staff are especially concerned about Beaver Creek. A lumber processing industry just upstream of the park may influence water quality. Increased levels of sediment and

chemicals such as arsenic may result from runoff from this industry. Baseline water quality data reports (NPS 1998g) specify nine parameters exceeding state water quality criteria at least once during the screening years. These parameters included: dissolved oxygen, pH, cadmium, copper, lead, zinc, sulfate, nickel, and fecal coliform. Recently, USGS has collected invertebrate data from Wind Cave National Park, but those data are not yet available. Other sampling sites included Cold Spring Creek and Highland Creek.

Methods

Methods for this effort were adapted from EPA's Environmental Monitoring and Assessment Program (EMAP). Modifications were made to several sampling procedures as constraints in money and time prevented us from fully adapting the methodology. Furthermore, EMAP protocols are primarily used for sampling in streams and rivers. Consequently, some methodology was changed and adapted for sampling in springs and bison watering holes.

Habitat and biological assessments were conducted at all reach lengths within each study site. Reach lengths were 40 times the wetted width of the channel (Lazorchak 1998) with 10 transects in each reach. A hand held Global Positioning System (GPS) was used to determine latitude and longitude at all transects of the sampling reach (Appendix A).

Physiochemical Methods

Physiochemical assessments of aquatic systems within the NGPN were conducted using field and laboratory analysis. Chemical parameters were collected, preserved and analyzed according to procedures suggested by EMAP protocols (Lazorchak et al. 1998) and the South Dakota Department of Health. The South Dakota Department of Health Lab

follows procedures outlined in standard methods (Eaton et al. 1998). Specific conductance ($\mu\text{S}/\text{cm}$), pH in standard units, water temperature ($^{\circ}\text{C}$), and dissolved oxygen (mg/L) were measured at each transect using a Yellow Springs Instrument 556 multiprobe unit. This meter was calibrated per manufacturers procedures prior to each sampling (See Figure 3 for transect layout of Bison Watering Holes). Turbidity, alkalinity and suspended and dissolved solids were also measured once within each reach from grab samples collected from the lowest transect. Turbidity was measured at time of field sampling using a Hach Model 2100P turbidimeter (EPA 180.1) and the meter was calibrated prior to field sampling as per manufacturers instructions. Turbidity is measured in Nephelometric turbidity units (NTUs) and provides a measure of light scattering by particles within a water sample. In lakes and streams these particles come from three major sources: algae, detritus, and silt (Michaud 1991). Alkalinity was measured titrimetrically using a Hach digital titrator (EPA 310.1). Alkalinity reagents were tested against established standards prior to each sampling date. Suspended and dissolved solids were measured gravimetrically following Eaton et al. (1998) (SM 2540 C; SM 2540 D)..

Fecal coliform(SM 9222 B EC), total phosphorus, total Kjeldahl nitrogen (TKN), nitrates, and ammonia samples were processed at the South Dakota Department of Health and followed the department's protocols, many of which were taken from Eaton et al. (1998). Total phosphorus was determined using the ascorbic acid method (EPA 365.2, Eaton et al. 1998). TKN was evaluated using the Block Digestor Method (Eaton et al. 1998, EPA 351.2). Nitrates were analyzed using the automated cadmium reduction method (Eaton et al. 1998, SM 4500 NO_3) and ammonia was determined using the Flow Injection Analysis Method (Eaton et al. 1998, SM 4500 NH_3 H). Ten percent of the samples analyzed were sample duplicates and distilled water blanks collected at random during the sampling period.

Weather

Weather measurements noted from each site included cloud cover, air temperature, wind speed, and wind direction. These measurements were taken with a Kestrel 3000 weather instrument. Major storm events that occurred prior to sampling were noted in the field book.

Physical Habitat Methods

Physical habitat includes the structural attributes that influence or sustain organisms within the aquatic system (Lazorchak et al. 1998). Understanding the habitat of a system allows better assessments of anthropogenic disturbances and ecosystem condition. Habitat measurements differed between system types (Table 6). Stream and spring bank habitat characteristics were assessed at each (left and right) bank along the reach. Large river bank habitat characteristics were measured at one bank, alternating between left and right banks. Stock pond habitat characteristics were assessed from randomly selected transects and shoreline points (Figure 3). One point on each length of transect was randomly selected for chemical sampling.

Substrate size can influence the hydraulic roughness and consequently the water velocity and dissolved oxygen available to invertebrates. Substrate size can also influence the interstitial habitat that is essential for cover and spawning (MacDonald et al 1991). Embeddedness may indicate changes in the rates of upland erosion and sediment supply (Dietrich et al. 1989) and fill in the interstices, reducing habitat for benthic fish and invertebrates (Platts et al. 1983, Rinne 1988).

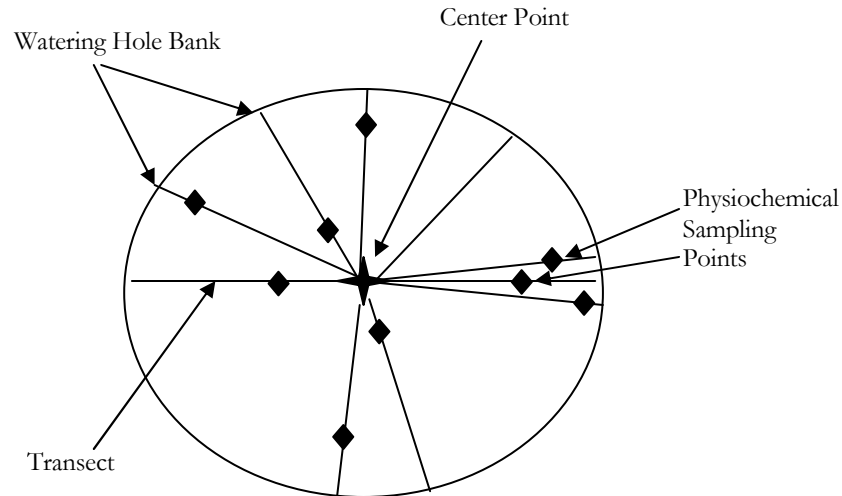


Figure 3. Bison watering hole habitat and chemical assessment layout. Ten angles from the center point were randomly selected as transects and habitat measures were assessed at the watering hole banks at each of those transects. A random location on each transect length was also selected for chemical sampling.

Table 6. Habitat measurements taken at each aquatic system type within the Northern Great Plains Network.

Streams	Rivers	Springs	Watering Holes
Bottom Substrate	Cross-Channel Substrate	Bottom Substrate	Bottom Substrate
Bank Embeddedness	Shoreline Dominant Substrate	Bank Embeddedness	Bank Embeddedness
Erosion	Shoreline Subdominant Substrate	Erosion	Erosion
Flow/Current Velocity	Maximum Current Velocity	Flow/Current Velocity	
Bank Slope	Bank Slope	Bank Slope	Bank Slope
Width/Depth	Woody Snags	Width/Depth	
Canopy Cover	Canopy Cover	Canopy Cover	Canopy Cover
Bank Vegetation	Bank Vegetation	Bank Vegetation	Bank Vegetation

Substrate size and embeddedness were visually evaluated based on a template of substrate sizes at each of the 10 transects and using procedures adapted from those described by Plafkin et al. (1989) and EMAP protocols (Lazorchak et al. 1998). The basis of the

procedure was an organized selection of 6 substrate particles (Table 7). Substrate size was measured using a gravelometer to facilitate separation of particle sizes in the field. Wood substrate was simply recorded as ‘wood’. Substrate was recorded five times across each transect. Embeddedness was recorded as the fraction of a particle that was surrounded by (embedded in) fine sediments on the stream bottom. Embeddedness was visually estimated during substrate measurements and was recorded five times across each stream transect (Lazorchak et al. 1998).

In large rivers, estimating bottom substrate and embeddedness is difficult. As an alternative, shoreline substrate was recorded. Dominant substrate was recorded as comprising the highest percentage of shoreline substrate, while sub-dominant substrate was estimated as the second highest shoreline substrate. Cross-channel substrate was assessed by touching a pole at five random locations across the channel and determining substrate by sound and touch.

Table 7. Substrate types and sizes for aquatic system within the Northern Great Plains Network (Lazorchak et al .1998).

Substrate	Size
Bedrock	>4000 mm
Boulders	250 to 4000 mm
Cobbles	64 to 250 mm
Gravel	2 to 64 mm
Sand	0.06 to 2 mm
Wood	Any size wood substrate

Canopy cover was measured using a convex spherical densitometer (Lazorchak et al. 1998). Bank ground cover vegetation was measured using a density board (Larson and Troelstrup 2001). This technique calls for a person to stand 5 meters from the board and

visually tally unobscured numbers on a board 2m long and 10 cm wide, divided into six (30 cm) alternatively black and white sections. Each section is labeled one through six (6 being at the top, and 1 at the bottom). The resulting score ranges from 0 (board totally obscured) to 21 (board totally visible) and provides a measure of understory vegetation density on the bank.

Bank erosion was visually estimated from a 10 meter length of bank centered on each transect point. Erosion was assessed by estimating the linear percentage of bank with signs of erosion within the 10 m section.

Bank slope may also indicate the stability of the bank (Thompson and Green 1994). Bank slope was measured at each transect using a clinometer along a sighting line 5 m up-gradient from the water line at each transect.

Flow from springs and small-medium streams was measured following the 0.6x depth method with a Marsh-McBirney Model 2000 velocity meter (Carter and Davidian, 1969). Channel width, depth and stream velocity were later used to calculate discharge. In wadeable streams 1m or deeper, measurements were taken at 0.2 and 0.8x depth and the average of the two measurements was used for flow. Taking flow measurements in streams also provided depth and width of the channel. In large rivers, maximum current velocity was recorded once along the channel thalweg. Spring flows too low to use the Marsh-McBirney, were estimated by measuring the time required to fill a graduated cylinder to a specific volume.

Large, woody snags provide habitat for invertebrates and fish in large rivers and often contribute to the diversity of these organisms within the system (Benke et al. 1984). Woody snags within view from each large river transect bank location were tallied to estimate woody snag habitat.

Biological Methods

Invertebrate samples were taken from five randomly chosen transects and pooled to create one composite sample for each reach on each sampling date. A D-frame net (350 μ m mesh) was used for invertebrate sampling at stream, river and stock pond sites. The base of the net was positioned against the substrate and the stream bottom was sufficiently disturbed to dislodge stream organisms for three minutes. In flowing systems the organisms are carried by the current into the net. In non-flowing systems, the net was swept through the water to collect all dislodged organisms. Five sweepnets were combined to generate one composite sample. The sample was placed into a labeled container and preserved with 70% ethanol. Springs were sampled using a hand-net (350 μ m mesh). Springs with very little flow were sampled by visually searching and picking for three minutes.

Macroinvertebrate Sorting and Identification

Invertebrate samples were subsampled and sorted in the laboratory (Barbour et al. 1999). Samples were rinsed thoroughly in a 250 μ m mesh sieve to remove ethanol and fine sediment. Large organic material (i.e. leaves, twigs, macrophytic mats) were visually inspected for invertebrates and discarded. After washing, the sample was spread evenly in a gridded pan and resuspended in water (Barbour et al. 1999). Four random grid cells were selected. The four grid cells were extracted from the whole sample and placed in another gridded pan. If more than 300 organisms ($\pm$ 20%) were found within this sample, then subsampling was complete. If the invertebrate density of the four rings had many more than 300 organisms, randomly selected rings were extracted from that subsample and placed in another gridded pan for sorting until 300 ($\pm$ 20%) organisms were found. If, in the original gridded pan, 300 organisms ($\pm$ 20%) could not be found within the four rings, another ring was chosen until

300 organisms (+/- 20%) are found or the entire pan was sorted. After invertebrate sorting, the tray was scanned for large, rare, and voucher specimens. Ten percent of the samples were re-checked for quality control during the first year of invertebrate sorting.

Major taxa were separated into separate vials to be identified to the lowest possible level (genus, species) using regional identification keys (Appendix B). Identification to the generic and species level provided the most accurate information on ecological health of the stream site or the level of impairment (King and Richardson 2002). Invertebrate identifications were randomly checked by capable staff for quality control. Voucher specimens of each taxa were also kept for future reference.

Statistical Analysis

Summary statistics were calculated for physical, chemical and biological parameters by system, habitat type, park, and site. Metrics were generated by category (composition, richness, functional feeding guilds, habit guilds and tolerance to organic pollution) and optimal sets defined for each of the major habitat types (bison watering holes, springs, streams, and rivers).

Several invertebrate metrics were optimized for each system (Appendix F). Since no reference sites were available to determine optimal metrics, Kruskal-Wallis (KW) ANOVA F-statistics were utilized to determine differences among sites ($p\text{-value} \leq 0.05$). The F-statistic served as a measure of between site discriminatory power. The F-value was calculated by dividing the Between Sites Mean Square by the Error Mean Square. A significant F-value suggests that variance among sites was significantly greater than what could be expected due to chance. High values for the KW F statistic represented sites with high discriminatory power (Table 8). Redundant metrics (e.g. %EPT and %E) and metrics with undefined values or zero values for over 25% of the total values were eliminated from the selection process.

Spearman rank correlations were then calculated to determine relationships among metrics and environmental conditions. This analysis provided a means to examine each metric's relationship to measures of anthropogenic disturbance. Those metrics with high discriminatory power and significant correlations with indicators of anthropogenic disturbance comprised the optimal set for each system type. The five groups of metrics (Composition, Richness, Habitat, Functional Feeding Group (FFG), and Tolerance) were included in the final metric set for each system (Karr and Chu 1999, Barbour et al. 1995).

Table 8. KW ANOVA summary table for determining F-Statistic. Between site variability represents the ability of the metric to discriminate between sites. Within site variability represents the error the metric possesses. A greater F-Statistic results from larger discriminatory power and smaller error. k = the independent variables (sites); n =sample size (site visits).

Source	DF	SS	MS	F-Statistic
Between Sites (B)	$k-1$	SSB	MSB	MSB/MSError
Within Sites (Error)	$k(n-1)$	SSError	MSError	
Total (T)	$kn-1$	SST	-	

Results

Fifty-eight sites were assessed in the NGPN (Table 5). A total of 300 different genera and species were found from all system types (Appendix D, Appendix M). Familial diversity was highest in small and medium streams with 79 families, while rivers contained 61 families, springs contained 31 families, and bison watering holes harbored 25 families. Of all invertebrate taxa found, 87% were of class Insecta. Diptera and Coleoptera were the most prevalent Insecta orders (Table 9).

Table 9. Numbers of family and genera for orders of Class Insecta found in the NGPN.

Insecta	Families	Genera
Diptera	15	103
Coleoptera	12	44
Trichoptera	10	25
Ephemeroptera	9	25
Hemiptera	9	22
Odonata	6	16
Plecoptera	6	12
Collembola	2	2
Lepidoptera	1	2
Megaloptera	1	1

Small- and medium-sized streams

Physical and Chemical Parameters

Most stream chemistries met water quality standards set by the state in which the system was found (Table 10, Appendix G). Fecal coliform were wide-ranging (<10/100ml to 8900/100ml). Total suspended solids (TSS) and total dissolved solids (TDS) were both highly variable among sites, but Sage Creek at BADL had the top measurements for both TSS and TDS (1418 mg/L and 7631mg/L). Lafferty Gulch (MORU) had consistently higher measurements for total phosphorus (1.97 mg/L), while other sites in the area averaged about (0.47 mg/L). No site exceeded ammonia standards set by its state. Conductivity was most variable at Sage Creek (BADL, Figure 4). Water temperature was also variable at nearly all sites (Figure 5), with reach 2 of Highland Creek (WICA) being the most variable (range=9.9 °C to 24.6 °C). Ninety-three percent of the values for pH were between 7.0 and 9.0, but Beaver Dam Creek (MORU) reached 5.55 and 84% of Beaver Dam Creek's pH measurements were below 7.0 (Figure 6). Dissolved oxygen was below state water quality standards for one site (Beaver Dam Creek (MORU)).

Table 10. Average physical and chemical parameters for small and medium-sized streams of the NGPN. Parameters in bold indicate at least one measurement did not meet state water quality standards.

Parameter	N	Mean	Min.	25%	Median	75%	Max
Dissolved Oxygen (mg/L)	657	8.7	0.2	7.8	9.1	10.2	18.4
Conductivity ($\mu\text{S}/\text{cm}$)	657	504	62	165	426	565	5158
pH (median)	657	8.2	5.6	7.9	8.2	8.5	9.7
Water Temperature ($^{\circ}\text{C}$)	657	16.7	9.5	13.9	16.4	19.4	26.7
Alkalinity (mg/L)	56	147	8	62	155	203	420
Turbidity (NTU)	54	88	0	3	4	11	3280
TSS (mg/L)	56	68	1	5	9	26	1418
TDS (mg/L)	55	454	5	135	276	393	7631
Total Phosphorus (mg/L)	55	0.72	0.01	0.03	0.06	0.17	18.80
TKN (mg/L)	55	0.66	<0.23	<0.23	0.25	0.48	10.6
NH ₃ (mg/L)	55	0.02	<0.02	<0.02	<0.02	<0.02	0.26
NO ₃ (mg/L)	55	0.49	<0.10	<0.10	<0.10	1.00	2.40
Fecal Coliform (org/100 mL)	43	644	<10	<10	40	250	8900

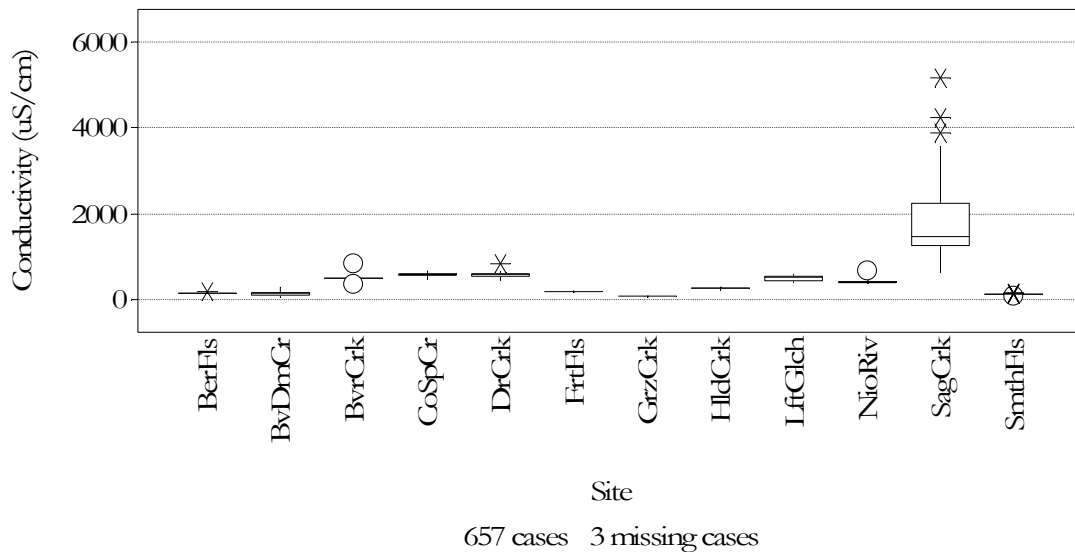


Figure 4. Box and whisker plot for conductivity at each stream within the NGPN. Site abbreviations: BerFls=Berry Falls, BvDmCr=Beaver Dam Creek, CoSpCr=Cold Spring Creek, DrCrk=Deer Creek, FrtFls=Fort Falls, GrzCrk=Grizzly Creek, HldCrk=Highland Creek, LftGlch=Lafferty Gulch, NioRiv=Niobrara River, SagCrk=Sage Creek, SmthFls=Smith Falls.

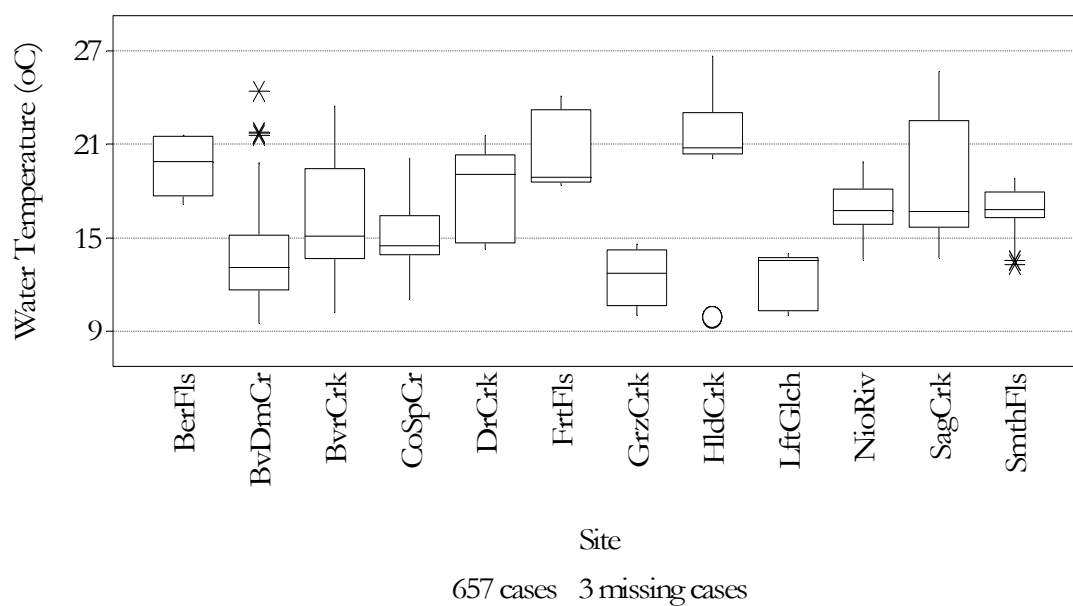


Figure 5. Box and whisker plot for water temperatures at stream sites of the NGPN. Site abbreviations: BerFls=Berry Falls, BvDmCr=Beaver Dam Creek, CoSpCr=Cold Spring Creek, DrCrk=Deer Creek, FrtFls=Fort Falls, GrzCrk=Grizzly Creek, HldCrk=Highland Creek, LftGlch=Lafferty Gulch, NioRiv=Niobrara River, SagCrk=Sage Creek, SmthFls=Smith Falls.



Figure 6. Box and whisker plot for pH in streams of the NPGN. Site abbreviations: BerFls=Berry Falls, BvDmCr=Beaver Dam Creek, CoSpCr=Cold Spring Creek, DrCrk=Deer Creek, FrtFls=Fort Falls, GrzCrk=Grizzly Creek, HldCrk=Highland Creek, LftGlch=Lafferty Gulch, NioRiv=Niobrara River, SagCrk=Sage Creek, SmthFls=Smith Falls.

Habitat

Landscapes in the NGPN included plains areas, in Wyoming, Nebraska and North Dakota, Black Hills of South Dakota and Wyoming, and badlands areas in South Dakota and North Dakota. Landscapes and land uses changed from each area to the next. Bank slope varied from 0% to 100% (Table 11, Appendix H) and highest sloping areas were found in the waterfalls of Berry Falls, Smith Falls, and Fort Falls (NIOB, Figure 7). Although not consistently, stream discharge was highest at Berry Falls (max=0.299 m³/s). Stream discharge was always high at the Niobrara River (AGFO), averaging 0.210 m³/s. Embeddedness was lowest at MORU and NIOB sites, except Beaver Dam Creek (MORU) displayed higher levels

of embeddedness (mean=83%). Highest levels of embeddedness were found at Niobrara River (AGFO) (mean=99%, Figure 8).

Table 11. Small and medium-sized stream habitat characteristics within the NGPN.

Parameter	N	Mean	Min.	25%	Median	75%	Max
Bank Slope (%)	650	39	0	20	31	57	100
Discharge (m ³ /s)	65	0.035	0.000	1.190E-03	0.012	0.044	0.299
Bank Vegetation	660	10	0	5	10	17	21
Canopy Cover (%)	660	45	0	0	33	100	100
Bank erosion (%)	660	16	0	0	0	29	100
Embeddedness (%)	657	56	0	16	56	100	100
Substrate:							
<i>Bedrock (%)</i>	657	11	0	0	0	0	100
<i>Boulder (%)</i>	657	9	0	0	0	0	100
<i>Cobble (%)</i>	657	9	0	0	0	20	100
<i>Gravel (%)</i>	657	29	0	0	20	60	100
<i>Sand (%)</i>	657	28	0	0	0	40	100
<i>Fine (%)</i>	657	10	0	0	0	0	100

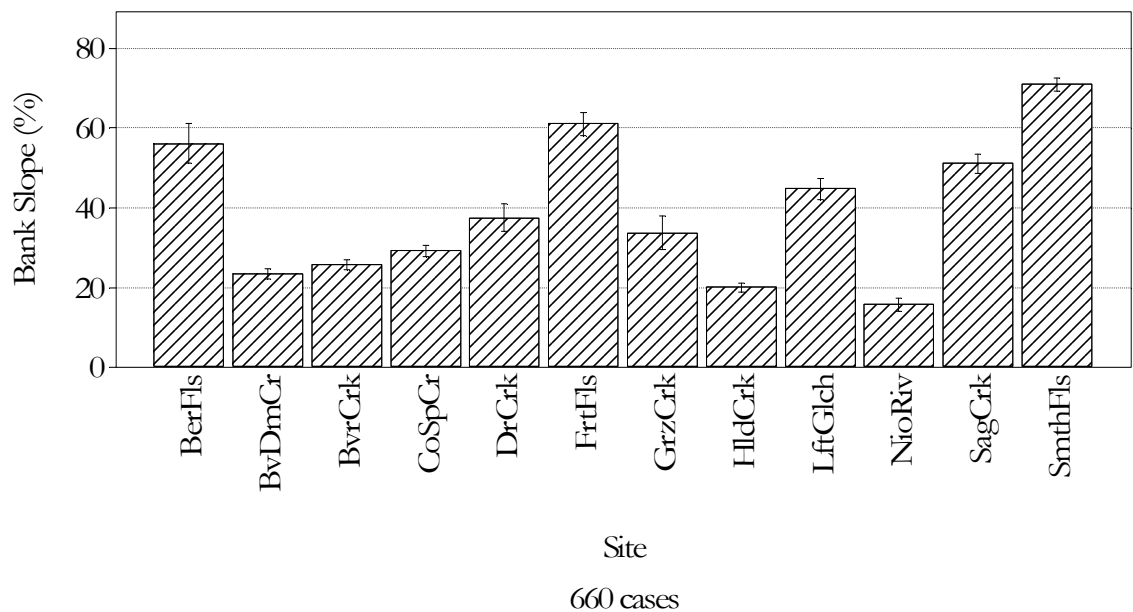


Figure 7. Mean (+/- 1 se) percent bank slope for streams of the NGPN. Site abbreviations: BerFls=Berry Falls, BvDmCr=Beaver Dam Creek, CoSpCr=Cold Spring Creek, DrCrk=Deer Creek, FrtFls=Fort Falls, GrzCrk=Grizzly Creek, HldCrk=Highland Creek, LftGlch=Lafferty Gulch, NioRiv=Niobrara River, SagCrk=Sage Creek, SmthFls=Smith Falls.

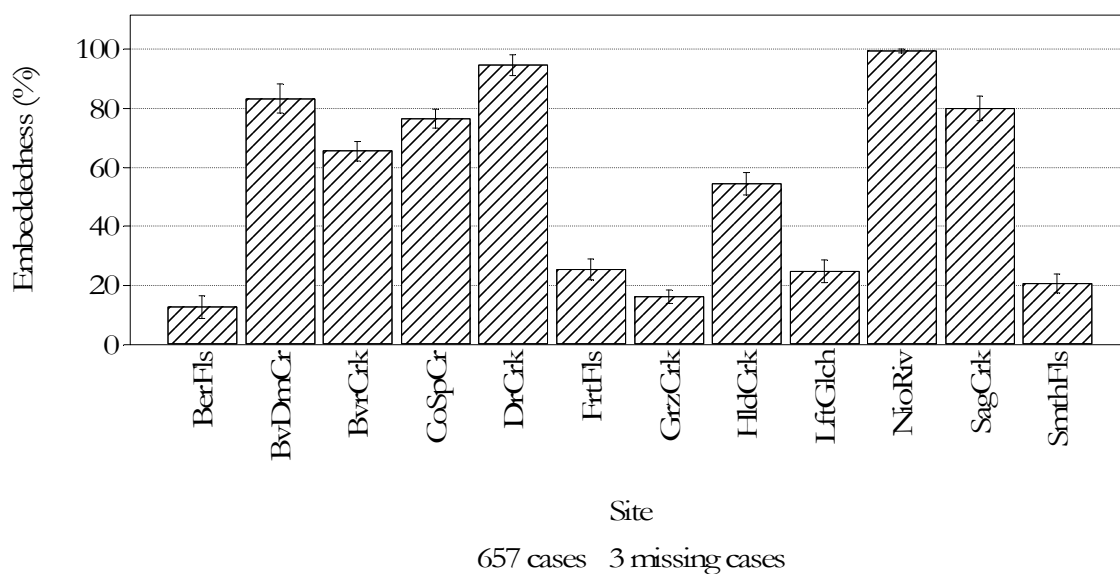


Figure 8. Mean (+/- 1 se) substrate embeddedness at each stream site within the NGPN. Site abbreviations: BerFls=Berry Falls, BvDmCr=Beaver Dam Creek, CoSpCr=Cold Spring Creek, DrCrk=Deer Creek, FrtFls=Fort Falls, GrzCrk=Grizzly Creek, HldCrk=Highland Creek, LftGlch=Lafferty Gulch, NioRiv=Niobrara River, SagCrk=Sage Creek, SmthFls=Smith Falls.

Stream substrate types varied from clay/silt and sand (e.g. Deer Creek (FOLA), Niobrara River (AGFO)), gravel and cobble (e.g. Highland and Beaver Creeks (WICA)) to boulder and bedrock (e.g. Grizzly Creek (MORU)), Fort Falls, Berry Falls, and Smith Falls (NIOB, Figure 9). Beaver Creek and Fort Falls contained all substrate types and had the highest substrate diversity for streams. However, Beaver Creek (WICA) displayed the most even mix of substrate types.

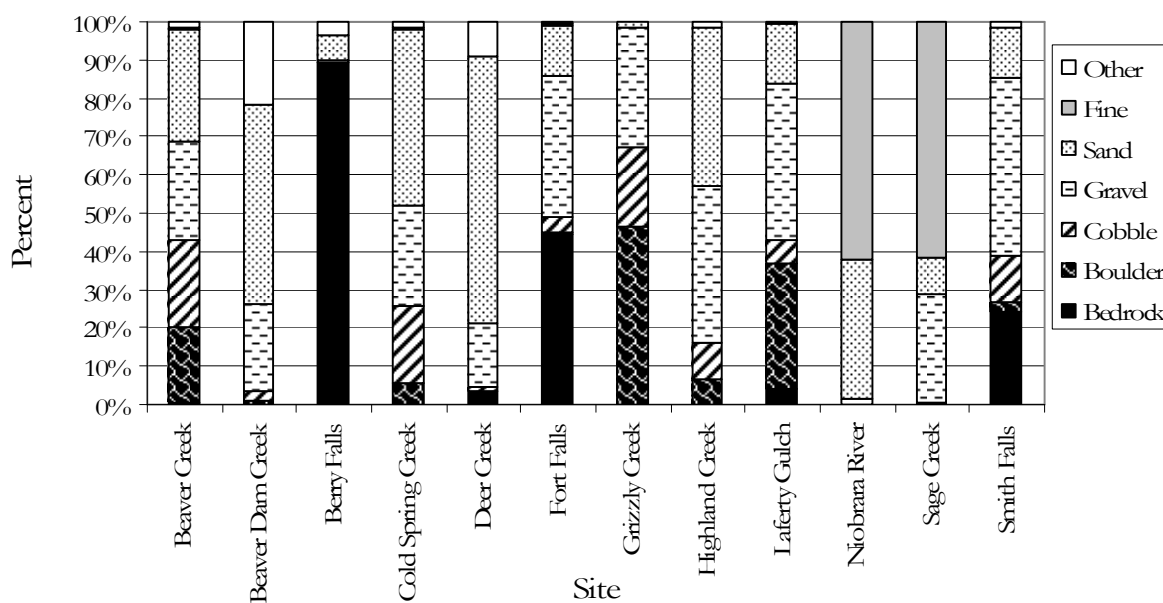


Figure 9. Average percent of each substrate type for streams in the NGPN.

Invertebrate Composition and Abundance

Insects composed 86% of the 219 invertebrate taxa collected from small and medium-sized streams (Appendix E). Overall, familial and generic diversity was high with 77 families and 188 genera. Diptera and Coleoptera contributed the greatest numbers of families and genera for streams (Table 12). Fifty different taxa were unique to stream habitats within the NGPN (Appendix C). Most of the unique taxa were insects. Diptera and Trichoptera were the most common orders (Diptera=14 genera and species, Trichoptera=8 genera and species).

Table 12. Class Insecta familial and generic diversity for streams in the NGPN.

Order	Families	Genera
Diptera	12	68
Coleoptera	13	33
Trichoptera	9	16
Ephemeroptera	6	10
Hemiptera	8	15
Odonata	6	12
Plecoptera	5	8
Collembola	1	1
Lepidoptera	0	0
Megaloptera	1	1

Feeding guilds consisted primarily of collector-gatherers (58%), collector-filterers (17%), and predators (14%). Clingers (30%) and swimmers (29%) were the most common invertebrate habit guild. Sprawlers (17%) and burrowers (14%) also contributed a significant number (Figure 10).

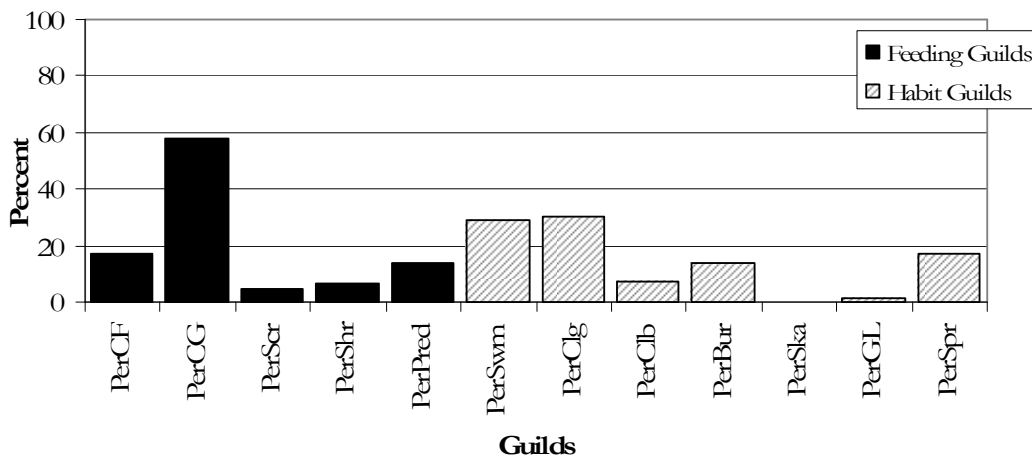


Figure 10. Functional feeding guilds and habit guilds of streams in the NGPN.

Stream Invertebrate Metrics

Ninety-eight metrics were screened for small and medium streams (Appendix I) and ten were selected for future monitoring. Many evaluated metrics displayed high discriminatory

power (KW F-value), and several were significantly correlated with either physical, chemical or habitat parameters (Table 13). Composition, richness, feeding guild, habit guild, and tolerance metrics are represented in the final set (Table 14).

Table 13. Kruskal-Wallis (KW) F-values and their associated p-values for each of the stream metrics for the NGPN.

Metric	KW F-value	P-Value
% Non-Insecta	3.54	<0.001
EPT:EPT+Chironomidae	5.31	<0.001
EPT Richness	2.89	0.002
Chironomidae Richness	3.06	0.001
Shannon Diversity Index (H')	3.15	0.001
Habit Guild H'	2.34	0.009
% Sprawler	3.10	0.001
FFG H'	2.08	0.021
Predator Richness	4.38	<0.001
Modified HBI	5.45	<0.001

Table 14. Optimal invertebrate metrics for streams within the NPGN.

Metric	N	Mean	Min.	25%	Median	75%	Max.
% Non-Insecta	65	17.0	0.0	1.3	7.6	29.2	66.5
EPT:EPT+Chironomidae	65	0.46	0.00	0.41	0.81	0.97	1.00
EPT Richness	65	3	0	2	3	5	11
Chironomidae Richness	65	4	0	2	3	5	14
Shannon Diversity Index (H')	65	1.73	0.00	1.40	1.85	2.28	2.80
Habit Guild H'	65	1.06	0.00	0.89	1.14	1.32	1.54
% Sprawler	65	17.0	0.0	3.3	12.5	24.6	66.1
FFG H'	65	0.78	0.00	0.47	0.90	1.04	1.29
Predator Richness	65	4	0	2	4	7	14
Modified HBI	65	5.3	3.1	4.6	5.0	6.3	9.6

Stream systems within the Black Hills and the Niobrara basin all exhibited similar invertebrate metric characteristics. Systems within the Nebraska panhandle and eastern Wyoming (i.e. FOLA's Deer Creek) displayed higher HBI values. Wind Cave streams also had higher HBI values (Figure 11). Those areas with less intolerant organisms were generally more accessible to livestock or bison (i.e. BADL, WICA, FOLA).

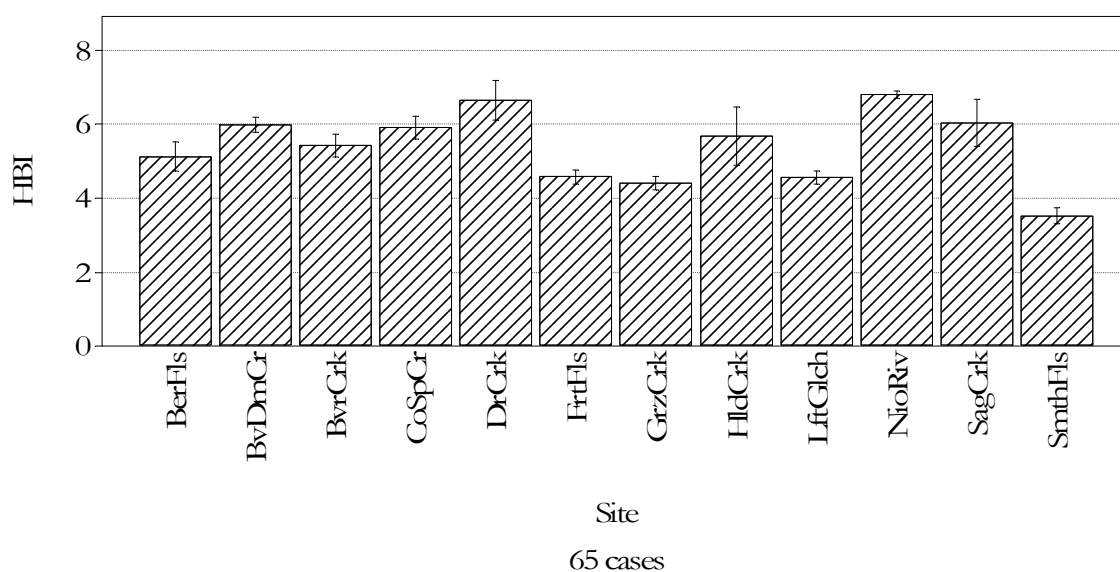


Figure 11. Mean (+/- 1 se) intolerant taxa richness for small and medium streams for the NGPN. Site abbreviations: BerFls=Berry Falls, BvDmCr=Beaver Dam Creek, CoSpCr=Cold Spring Creek, DrCrk=Deer Creek, FrtFls=Fort Falls, GrzCrk=Grizzly Creek, HldCrk=Highland Creek, LftGlch=Lafferty Gulch, NioRiv=Niobrara River, SagCrk=Sage Creek, SmthFls=Smith Falls.

Black Hills and Niobrara sites had the highest Shannon-Wiener Diversity (H') of all NGPN. Streams at NIOB had similar diversity. Not surprisingly, Sage Creek (BADL) displayed the lowest H' for all sites (Figure 12). Percent non-insect abundance was lowest at Grizzly Creek, Fort Falls, Highland Creek, and Sage Creek (range=0%-66.5%). Highest percentages of non-insecta abundances were found from the Niobrara River (AGFO, Figure 13). The EPT: EPT + Chironomidae ratio averaged about 1.00 in Berry Falls, Highland Creek,

and Smith Falls. Percent EPT richness also reached over 40% at Fort Falls, Smith Falls, Berry Falls, and Grizzly Creek.

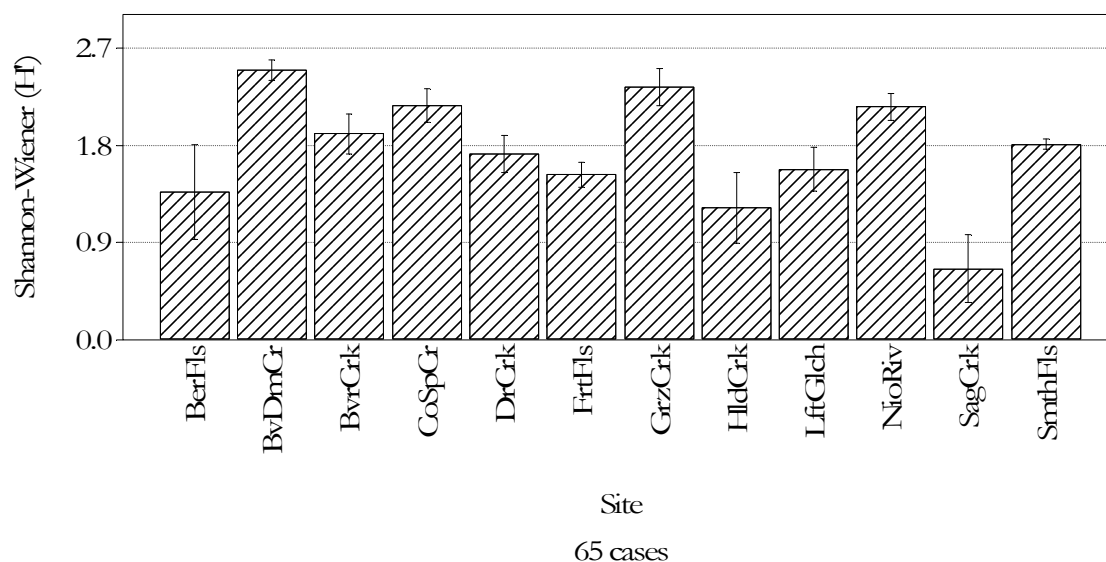


Figure 12. Mean (+/- 1 se) Shannon Diversity (H') for all small and medium sized streams within the NGPN. Site abbreviations: BerFls=Berry Falls, BvDmCr=Beaver Dam Creek, CoSpCr=Cold Spring Creek, DrCrk=Deer Creek, FrtFls=Fort Falls, GrzCrk=Grizzly Creek, HldCrk=Highland Creek, LftGlch=Lafferty Gulch, NioRiv=Niobrara River, SagCrk=Sage Creek, SmthFls=Smith Falls.

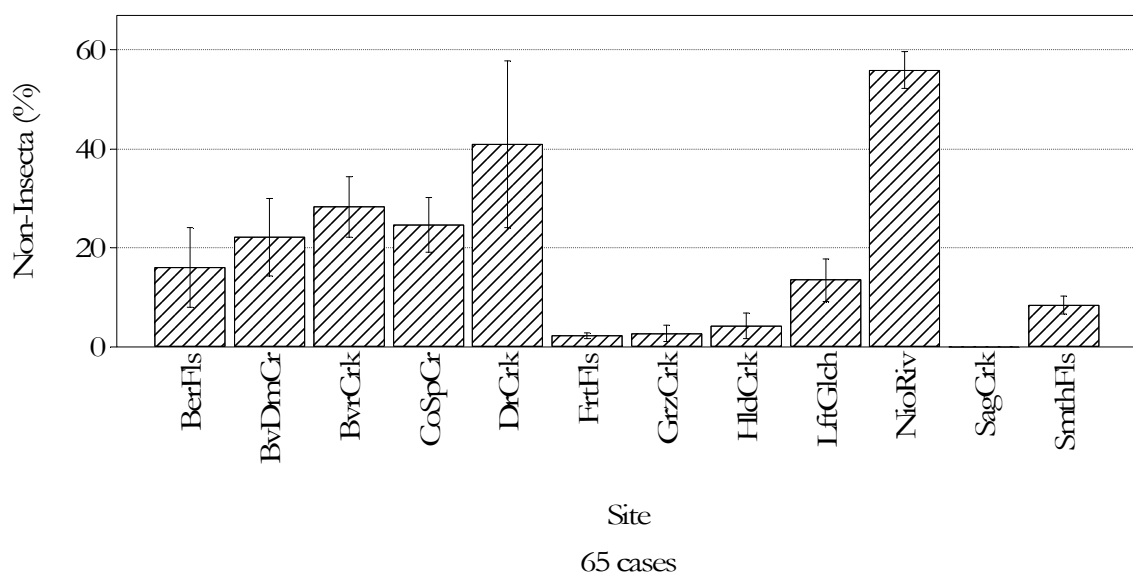


Figure 13. Mean (+/- 1 se) percent of non-Insecta abundance at each stream site of the NGPN. Site abbreviations: BerFls=Berry Falls, BvDmCr=Beaver Dam Creek, CoSpCr=Cold Spring Creek, DrCrk=Deer Creek, FrtFls=Fort Falls, GrzCrk=Grizzly Creek, HldCrk=Highland Creek, LftGlch=Lafferty Gulch, NioRiv=Niobrara River, SagCrk=Sage Creek, SmthFls=Smith Falls.

Embeddedness was significantly correlated to several metrics, especially in streams.

HBI (Figure 14) and Chironomidae taxa (Figure 15), were positively correlated with percent embeddedness in streams ($p\text{-value} \leq 0.05$).

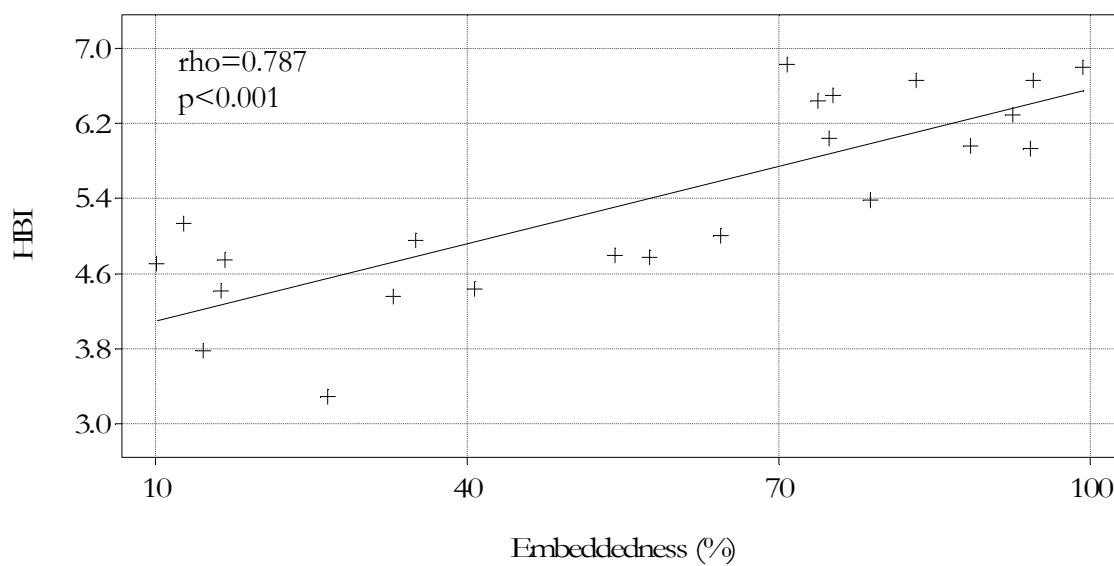


Figure 14. Scatter plot of modified HBI versus percent substrate embeddedness for streams within the NGPN. Greater tolerances to organic pollution are correlated with higher percentages of substrate embeddedness.

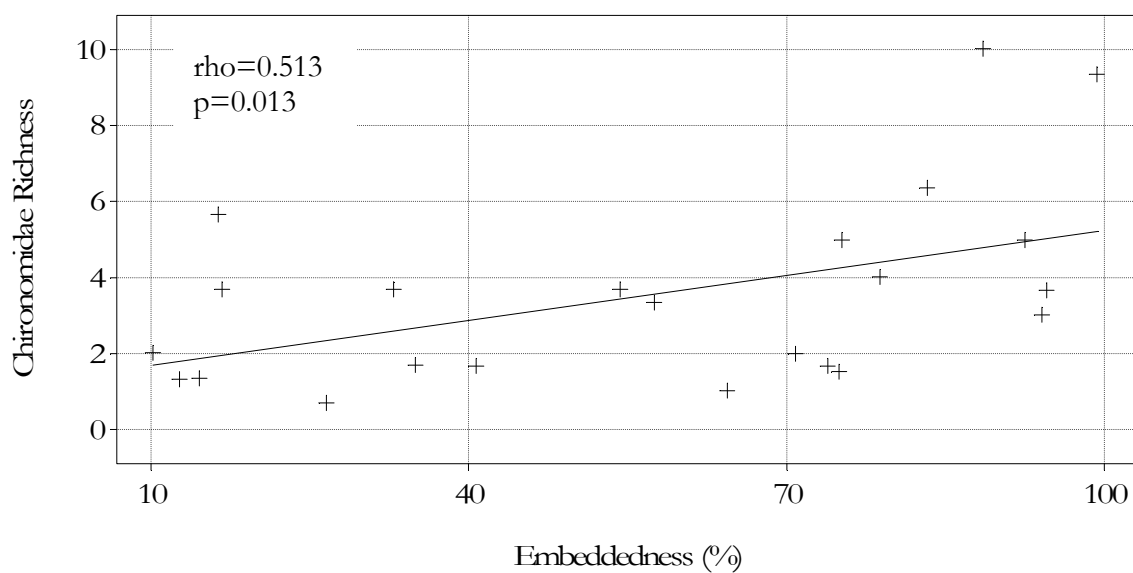


Figure 15. Scatter plot of Chironomidae taxa versus percent substrate embeddedness for streams within the NGPN.

HBI was related to riparian vegetation. HBI was correlated with both canopy cover (Figure 16) and ground cover density (Figure 17). Intolerant organism abundance was also positively correlated with canopy cover ($\rho=0.820$, $p<0.001$) and vegetation density ($\rho=-0.705$, $p<0.001$).

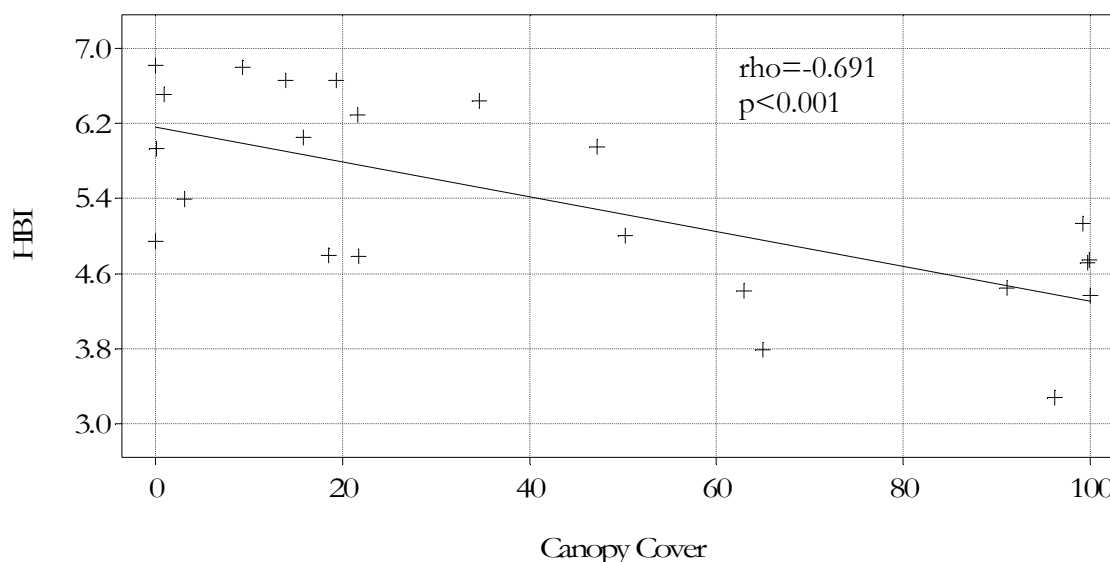


Figure 16. HBI versus percent canopy cover for streams of the NGPN.

Large Rivers

Physical and Chemical Parameters

Most physical and chemical parameters of large rivers met standards for their respective state (Table 15, Appendix G). Measurements outside of state water quality standards included pH, turbidity, and fecal coliform bacteria. pH was only over 9.0 for the Belle Fourche River on one sampling date. Each transect was consistently over 9.0 for pH on that date (Figure 18). Turbidity was over water quality standards only on the Little Missouri River (THRO). High turbidity for this area may be a natural condition of the river in some parts of the year. The badlands nature of the landscape contributes suspended and

dissolved solids to aquatic systems within the area. Median river turbidity was only 10 NTUs for all sites. Fecal coliform bacteria exceeded 200/100ml at the Belle Fourche (DETO).

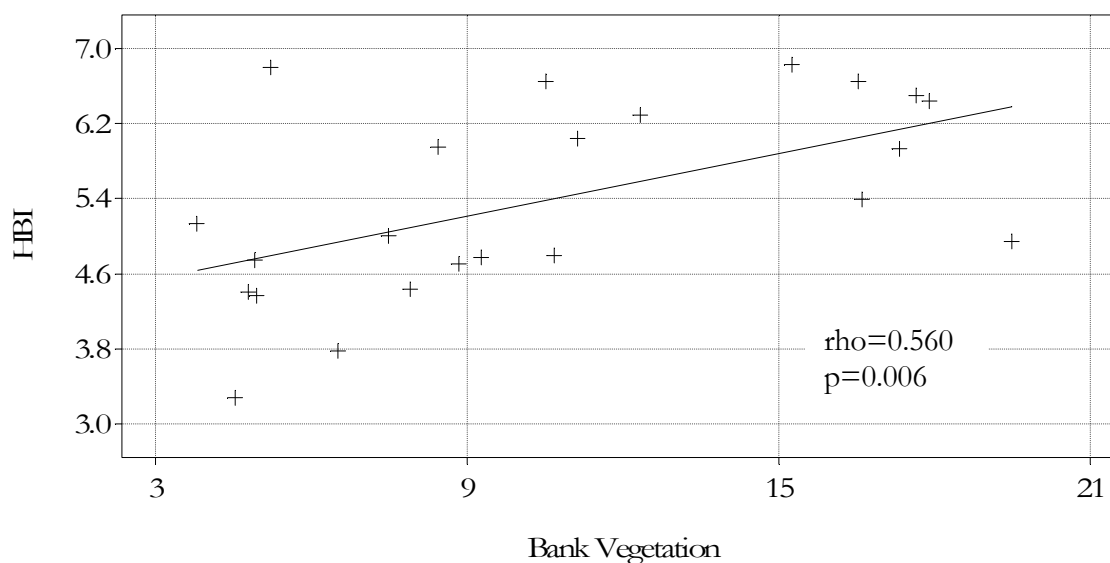


Figure 17. HBI versus bank vegetation for streams within the NGPN.

Table 15. Physical and chemical parameters for large rivers of the NGPN. Parameters in bold indicate at least one measurement did not meet state standards.

Parameter	N	Mean	Min.	25%	Median	75%	Max
Dissolved Oxygen (mg/L)	539	9.3	6.9	8.3	9.1	9.9	14.3
Conductivity ($\mu\text{S}/\text{cm}$)	540	817	167	604	728	1046	1861
pH (median)	539	8.3	7.5	8.1	8.3	8.4	9.4
Water Temperature ($^{\circ}\text{C}$)	540	20.6	11.7	17.3	21.3	23.2	29.2
Alkalinity (mg/L)	55	182	42	143	169	203	620
Turbidity (NTU)	55	2271	1	5	10	47	116000
TSS (mg/L)	55	43	1	10	27	60	181
TDS (mg/L)	55	528	19	372	469	645	1517
Total Phosphorus (mg/L)	55	0.296	0.004	0.030	0.058	0.166	4.64
TKN (mg/L)	55	0.80	0.23	0.23	0.35	0.65	8.90
NH_3 (mg/L)	55	<0.02	<0.02	<0.02	<0.02	<0.02	0.13
NO_3 (mg/L)	55	0.43	<0.1	<0.1	0.1	0.3	3.7
Fecal Coliform (org/100 mL)	36	143	<10	10	25	88	2300

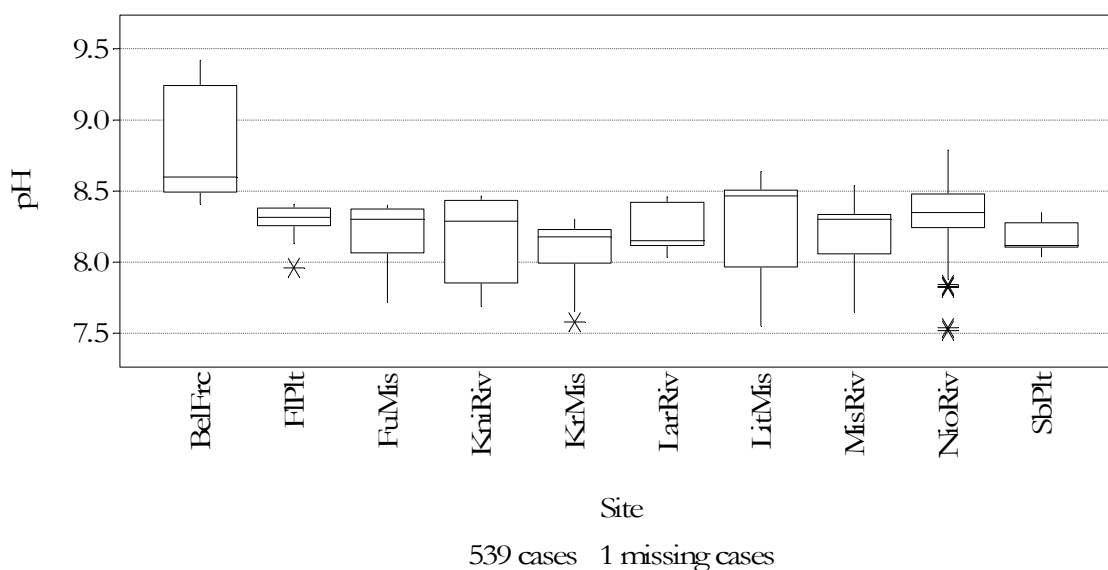


Figure 18. Box and whisker plots for pH at all large river sites within the NGPN Site abbreviations: BelFrc=Belle Fourche River at DETO, FlPlt=North Platte River at FOLA, FuMis=Missouri River at FOUS, KniRiv=Knife River at KNRI, KrMis=Missouri River at KNRI, LarRiv=Laramie River at FOLA, LitMis=Little Missouri River at THRO, MisRiv=Missouri River at MNRR, NioRiv=Niobrara River at NIOB, and SbPlt=North Platte River at SCBL.

Habitat

River bankfull levels ranged from 0m to 30m and velocity ranged from -0.05m/s to 2.6m/s (Table 16, Appendix H). River substrate was primarily sand across the channel, although the Niobrara River (NIOB) had bedrock substrate in reaches 1 and 2. Snags were highest in the Missouri River (MNRR), averaging about 8 per transect. The Niobrara (NIOB) averaged about 6 snags per transect and most were found in the sandy stretch of reach 3 (Figure 19).

Table 16. Habitat parameters for large rivers within the NGPN.

Parameter	N	Mean	Min.	25%	Median	75%	Max
Bank Slope (%)	540	40	0	14	30	58	100
Max Current Velocity (m/s)	540	0.51	-0.05	0.25	0.46	0.74	2.60
Vegetation Density	540	12	0	6	15	18	21
Canopy Cover (%)	540	11	0	0	0	0	100
Bank Full (m)	540	2.8	0.0	0.7	1.5	4.0	30.0
Snags	540	5	0	0	2	6	75
Substrate:	540						
<i>Bedrock (%)</i>	540	6.9	0	0	0	0	100
<i>Boulder (%)</i>	540	0.6	0	0	0	0	100
<i>Cobble (%)</i>	540	17.8	0	0	0	0	100
<i>Gravel (%)</i>	540	6.5	0	0	0	0	100
<i>Sand (%)</i>	540	59.6	0	0	100	100	100
<i>Fine (%)</i>	540	10.9	0	0	0	0	100

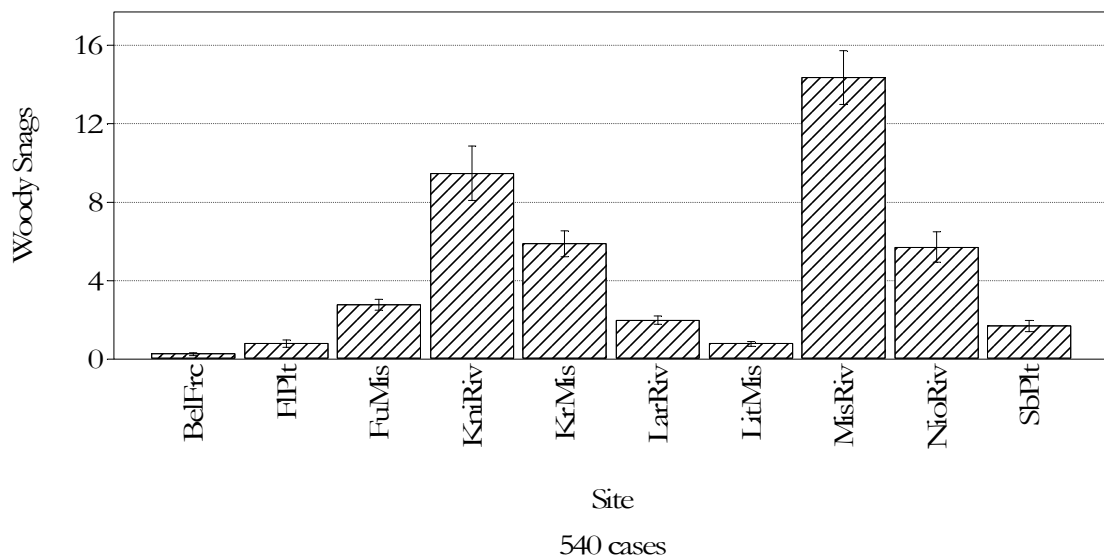


Figure 19. Mean (+/- 1 se) woody snag counts for large river sites within the NGPN. Site abbreviations: BelFrc=Belle Fourche River at DETO, FlPlt=North Platte River at FOLA, FuMis=Missouri River at FOUS, KniRiv=Knife River at KNRI, KrMis=Missouri River at KNRI, LarRiv=Laramie River at FOLA, LitMis=Little Missouri River at THRO, MisRiv=Missouri River at MNRR, NioRiv=Niobrara River at NIOB, and SbPlt=North Platte River at SCBL.

Current velocity was highest from Missouri River and Niobrara sites (MNRR, FOUS) (Figure 20). As expected, Knife River had the lowest current velocity; the lower end

of the river received backflow from the Missouri River causing some negative velocity measurements.

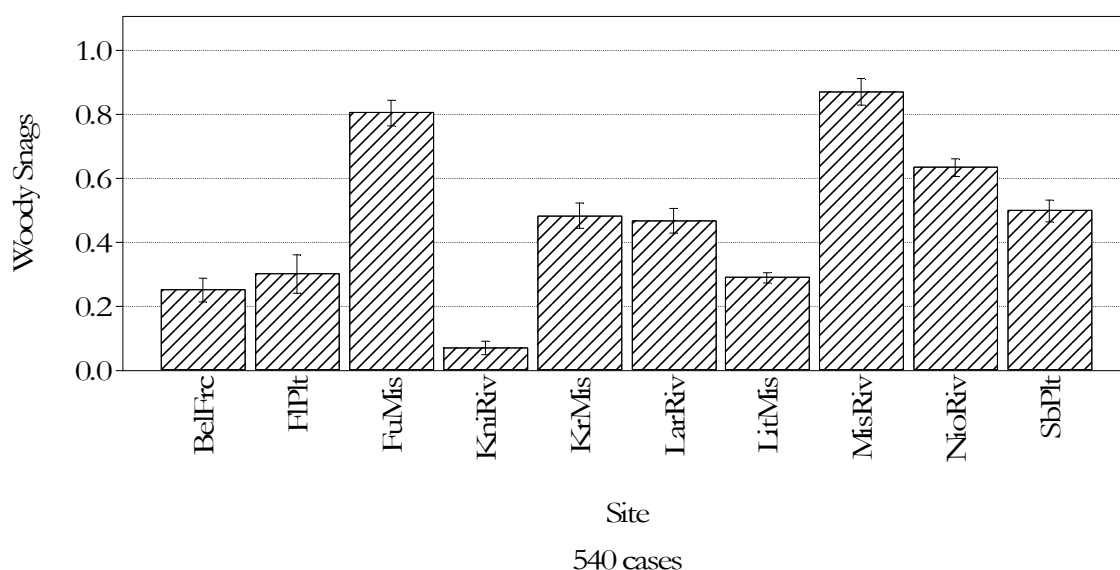


Figure 20. Mean (+/- 1 se) current velocities for large river sites within the NGPN. Site abbreviations: BelFrc=Belle Fourche River at DETO, FlPlt=North Platte River at FOLA, FuMis=Missouri River at FOUS, KniRiv=Knife River at KNRI, KrMis=Missouri River at KNRI, LarRiv=Laramie River at FOLA, LitMis=Little Missouri River at THRO, MisRiv=Missouri River at MNRR, NioRiv=Niobrara River at NIOB, and SbPlt=North Platte River at SCBL.

Invertebrate Composition and Abundance

A total of 179 different invertebrate genera and species were found in large rivers of the NGPN (19 orders, 62 families, and 148 genera, Appendix E). Most of these were insects (85%) Coleoptera contributed the highest familial richness, while Diptera contributed the largest number of genera (Table 17). Thirty-three invertebrate genera collected were only found in large rivers (Appendix C). Ephemeroptera contributed the most to the unique taxa (9 genera), while Diptera contributed 8 genera. Heptegeniidae (Order: Ephemeroptera) and

Chironomidae (Order Diptera) were the most frequently encountered families for the unique taxa.

Table 17. Families and genera for Insecta orders of large rivers in the NGPN.

Order	Families	Genera
Diptera	7	43
Coleoptera	12	29
Trichoptera	5	9
Ephemeroptera	8	20
Hemiptera	5	9
Odonata	3	7
Plecoptera	4	5
Collembola	2	2
Lepidoptera	1	1
Megaloptera	1	1

Feeding guilds primarily consisted of collector-gatherers (45%) (Figure 21).

Collector-filterers and predators were also well represented (18% and 19%). Habit guilds were dominated by clingers (33%) and swimmers (31%), with burrowers and sprawlers contributing moderately (15% and 13%) to guild structure. Overall functional feeding guild (FFG) diversity equaled 0.82 while the Niobrara River (NIOB) and the Laramie River (FOLA) had the highest FFG diversity (both with $H' = 1.02$). The Missouri River (KNRI) had the highest FFG evenness (0.77), while overall FFG evenness equaled 0.66. Habit guild diversity was highest at the Niobrara River ($H' = 1.18$) and overall Habit diversity was 1.02. Habit evenness was highest at the Missouri River (KNRI) (1.00), while overall habit evenness reached 0.73.

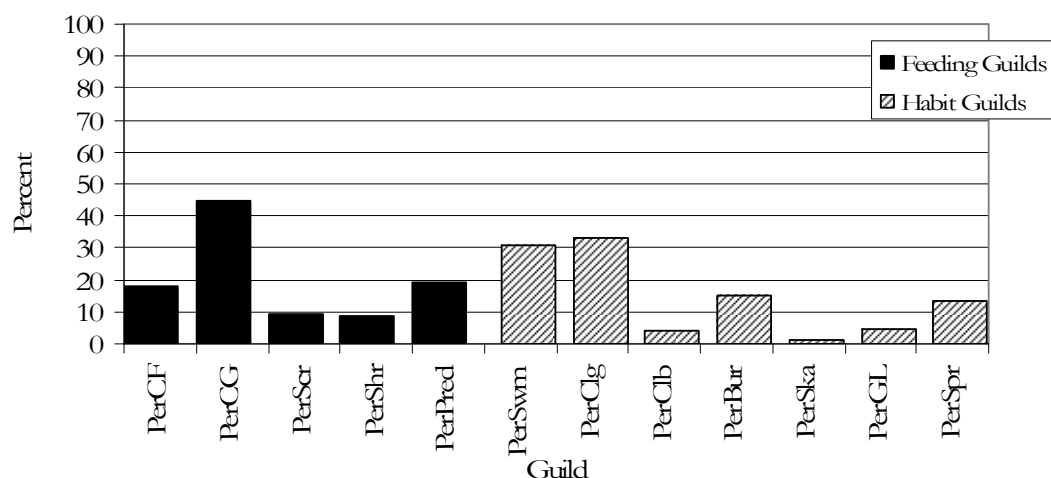


Figure 21. Functional feeding guilds and habit guilds of large rivers in the NGPN.

River Invertebrate Metrics

Ninety-eight metrics were screened for large rivers of the NGPN (Appendix J). Like streams, a majority of the metrics discriminated well among sites (Table 18). Several metrics were also correlated with habitat, chemical and physical parameters. Ten metrics were eventually chosen based on high discriminatory power (KW F statistic) and significant correlations with chemical and physical or habitat parameters (Table 19).

Table 18. Kruskal-Wallis (KW) F-values and their associated p-values for each of the river metrics for the NGPN.

Metric	KW F-value	P-value
% EPT	4.88	<0.001
% Chironomidae	2.73	0.004
Total Richness	3.56	<0.001
EPT Richness	4.88	<0.001
Non-Insecta Richness	2.37	0.011
Clinger Richness	4.82	<0.001
Swimmer Richness	2.47	0.001
Collector-gatherer Richness	3.25	0.001
Collector-filterer Richness	4.76	<0.001
Modified HBI	2.26	0.015

Table 19. Optimal invertebrate metrics for large rivers in the NGPN.

Metric	N	Mean	Min.	25%	Median	75%	Max.
% EPT	53	31.7	0.0	2.0	24.5	55.0	93.5
% Chironomidae	53	22.9	0.0	2.0	9.6	34.0	100.0
Total Richness	53	11	2	5	9	16	26
EPT Richness	53	3	0	1	2	4	10
Non-Insecta Richness	53	2	0	1	2	3	6
Clinger Richness	53	3	0	1	2	4	9
Swimmer Richness	53	2	0	1	2	4	6
Collector-gatherer Richness	53	5	1	2	4	7	13
Collector-filterer Richness	53	1	0	0	1	2	6
Modified HBI	53	5.5	2.9	4.7	5.2	6.2	9.0

Percent EPT varied considerably among river sites (Figure 22). The North Platte (FOLA) had the highest percentage of Chironomidae and total richness was greatest at the Niobrara River (NIOB), followed by the Laramie River (FOLA). Non-Insecta taxa were also most abundant from the Laramie River. HBI averaged approximately 5.0, but HBI values over 6.0 were found from the Knife River and Missouri River (KNRI, Figure 23).

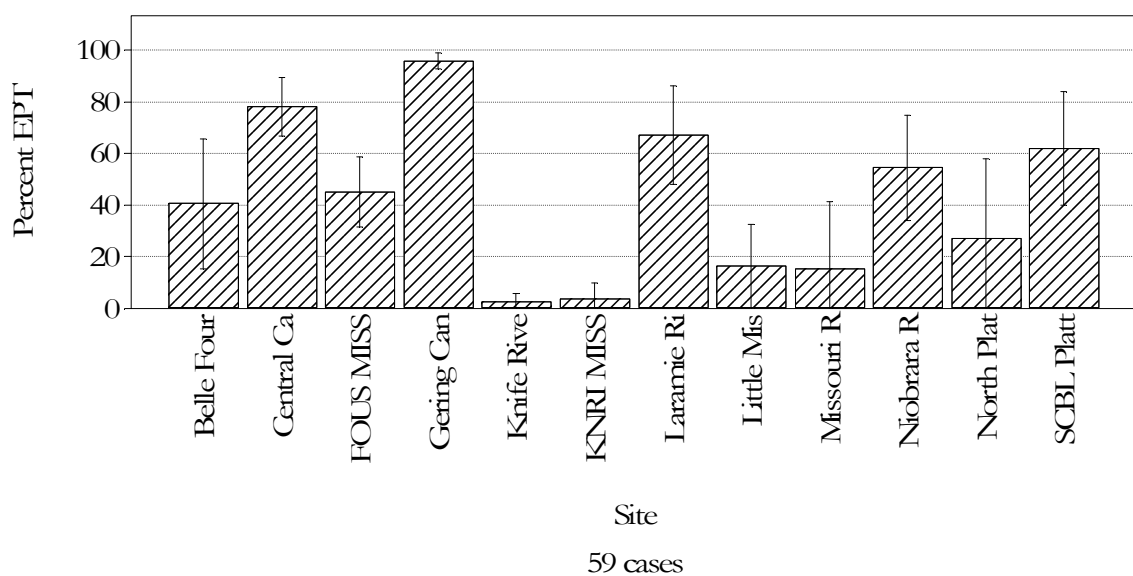


Figure 22. Mean (+/- 1 se) percent EPT for all river sites within the NGPN. Site abbreviations: BelFrc=Belle Fourche River at DETO, FlPlt=North Platte River at FOLA, FuMis=Missouri River at FOUS, KniRiv=Knife River at KNRI, KrMis=Missouri River at KNRI, LarRiv=Laramie River at FOLA, LitMis=Little Missouri River at THRO, MisRiv=Missouri River at MNRR, NioRiv=Niobrara River at NIOB, and SbPlt=North Platte River at SCBL.

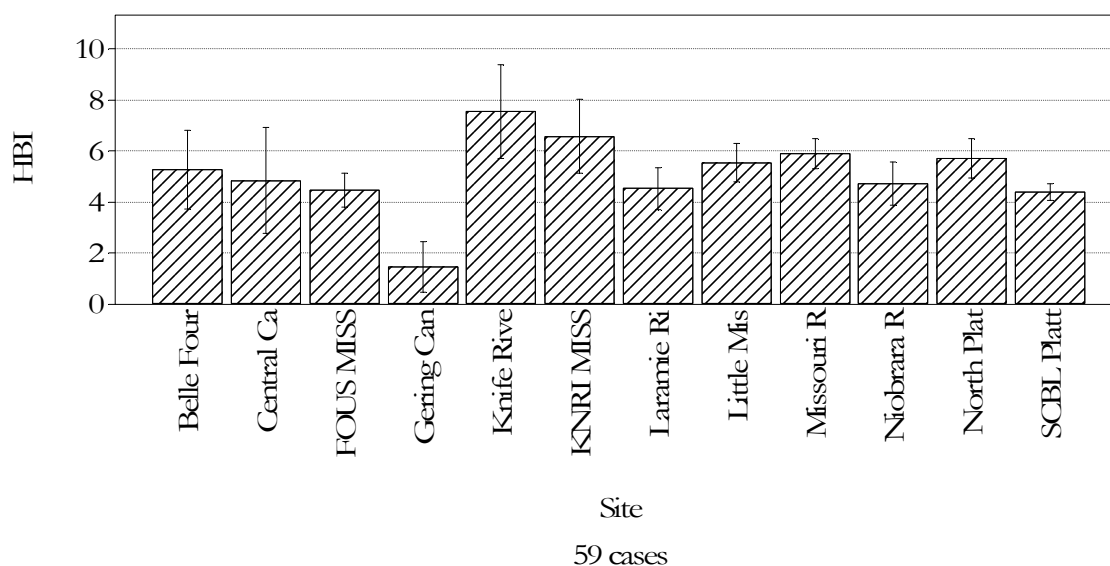


Figure 23. Mean (+/- 1 se) HBI for all river sites within the NGPN. Site abbreviations: BelFrc=Belle Fourche River at DETO, FIPlt=North Platte River at FOLA, FuMis=Missouri River at FOUS, KniRiv=Knife River at KNRI, KrMis=Missouri River at KNRI, LarRiv=Laramie River at FOLA, LitMis=Little Missouri River at THRO, MisRiv=Missouri River at MNRR, NioRiv=Niobrara River at NIOB, and SbPlt=North Platte River at SCBL.

Total taxa richness ($\rho=-0.517$, $p=0.025$), number of tolerant taxa ($\rho=-0.523$, $p=0.023$), and swimmer taxa richness ($\rho=-0.514$, $p=0.026$) were all negatively correlated with turbidity. HBI was negatively correlated with total suspended solids ($\rho=0.487$, $p=0.358$). Several metrics were significantly correlated with dissolved oxygen, including: collector-gatherer taxa (Figure 24), swimmer taxa ($\rho=0.856$, $p<0.001$), tolerant taxa ($\rho=0.443$, $p=0.040$), and total richness (Figure 25). EPT richness also displayed a threshold relationship with total Kjeldahl Nitrogen (TKN). EPT richness values ranged from 0 to 10 at TKN values below 0.7 mg/L but fell to 3 or fewer at higher levels of TKN (Figure 26).

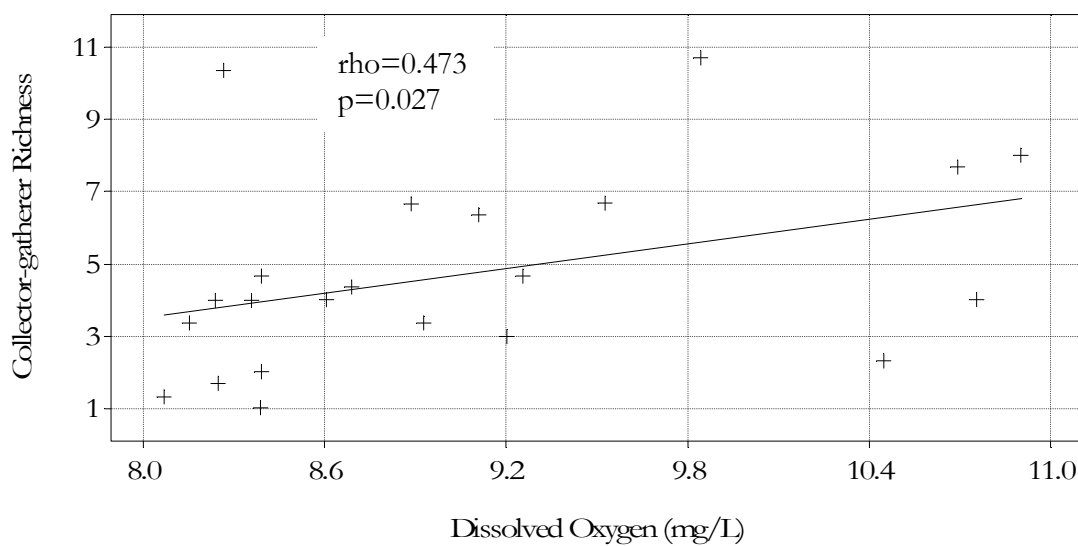


Figure 24. Scatter plot of collector-gatherer richness versus dissolved oxygen for large rivers of the NGPN.

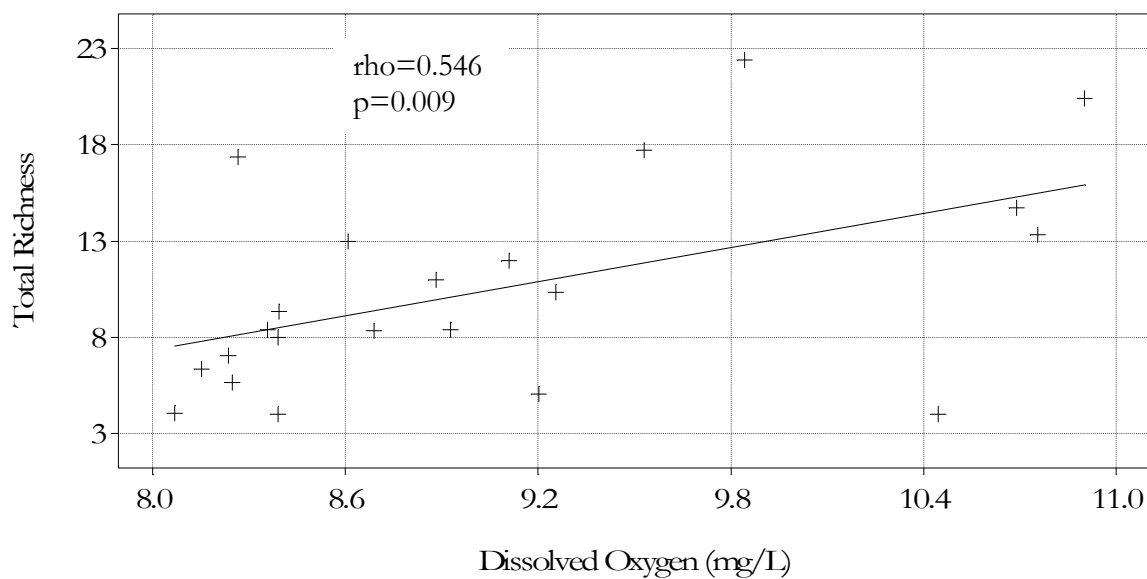


Figure 25. Scatter plot of total richness versus dissolved oxygen for large rivers of the NGPN.

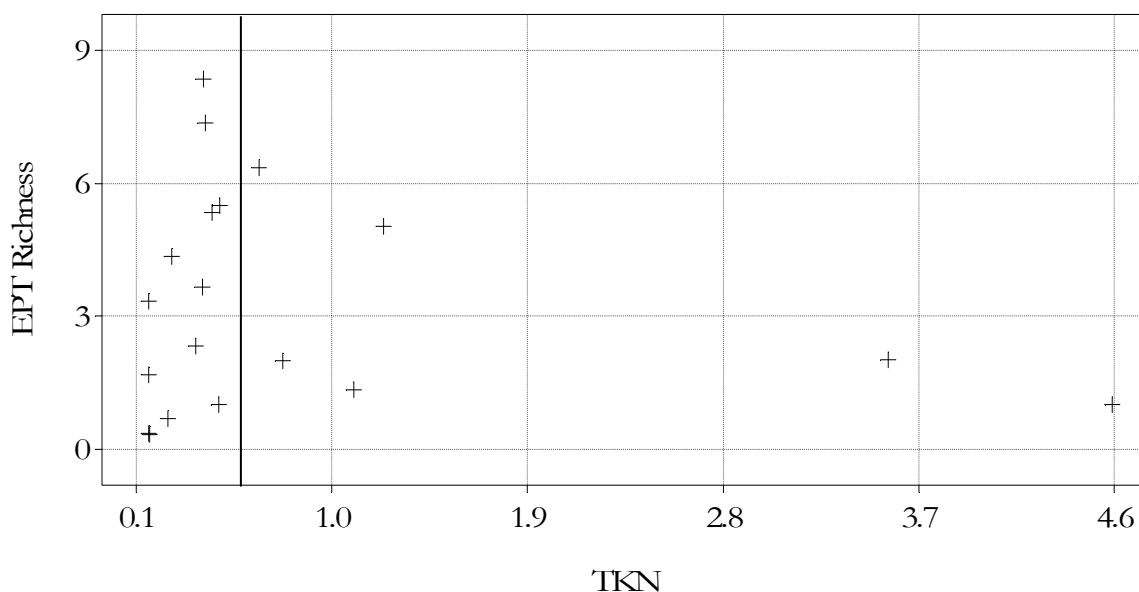


Figure 26. Scatter plot of river EPT taxa versus total Kjeldahl nitrogen for large rivers of the NGPN. EPT taxa display a richness threshold when approaching 0.8 mg/L TKN.

Springs

Physical and Chemical Parameters

Fecal coliform were mostly under detection. However, Jewel Cave Spring (JECA), had an enormous fecal coliform hit on one sampling date (160000/100mL, Table 20, Appendix G). All other samples from the same site (different dates) were below detection (<10/100ml). TSS was low among all spring samples. TDS reached 2635 mg/L at Spring S (DETO) and was consistently high through both sampling years. Conductivity was also highest at Spring S and lowest at Spring R (DETO, Figure 27). Total phosphorus reached relatively high levels (mean=0.113, max=0.855) and was highest at Spring R.

Table 20. Physical and chemical parameters for springs within the NGPN. Bolded parameters indicate areas above water quality standards.

Parameter	N	Mean	Min.	25%	Median	75%	Max
Dissolved Oxygen (mg/L)	23	9.0	5.3	7.6	8.8	10.1	13.8
Conductivity ($\mu\text{S}/\text{cm}$)	23	1099	175	332	934	1473	2926
pH (median)	23	--	6.9	7.2	7.6	7.9	9.0
Water Temperature ($^{\circ}\text{C}$)	23	11.9	7.2	10.0	12.1	13.6	17.0
Alkalinity (mg/L)	23	242	5	134	280	327	570
Turbidity (NTU)	23	37	0	1	6	19	346
TSS (mg/L)	23	47	0	7	18	76	184
TDS (mg/L)	23	766	160	291	606	787	2635
Total Phosphorus (mg/L)	23	0.113	0.005	0.015	0.073	0.112	0.855
TKN (mg/L)	23	0.29	<0.23	<0.23	0.25	0.33	0.77
NH ₃ (mg/L)	23	<0.02	<0.02	<0.02	<0.02	<0.02	0.02
NO₃ (mg/L)	23	1.5	<0.1	0.9	1.4	2.2	3.0
Fecal Coliform (org/100 mL)	27	6050	<10	<10	<10	90	160000

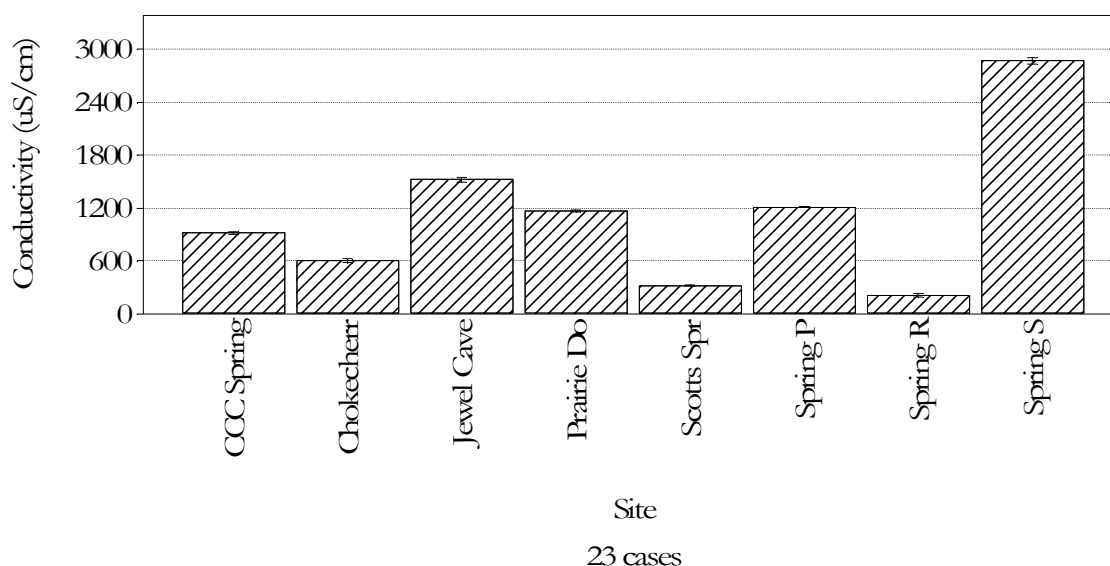


Figure 27. Mean (+/- 1 se) conductivity for spring sites within the NGPN.

Habitat

Spring habitats were sampled from grassland (SCBL), Black Hills (JECA, DETO), and badlands landscapes (BADL). CCC Spring (BADL) and Chokecherry Spring (JECA) flowed into stock tanks. Springs S, P, R (DETO) and Jewel Cave Spring (JECA) flowed from cisterns

or pipes. Habitat parameters were assessed from where these overflowed or flowed out of the pipe. Only Prairie Dog Spring and Scotts Spring appeared un-enhanced. Embeddedness ranged from 0 to 100% (Table 21, Appendix H), with CCC Spring (BADL) and Spring S (DETO) having the highest embeddedness. Discharge was highest at Chokecherry Spring (JECA, Figure 28). Bank slope ranged from 3% to 92% (mean=21%). All springs had a similar substrate types. The most common substrate encountered was gravel (47%) followed by sand (21%) and clay (13%)

Table 21. Habitat parameters for springs within the NGPN.

Parameter	N	Mean	Min.	25%	Median	75%	Max
Bank Slope (%)	22	21	3	8	13	25	92
Discharge (L/s)	23	0.69	0.00	0.01	0.02	0.71	9.30
Vegetation	23	12	0	9	15	18	21
Canopy Cover (%)	23	63	0	25	55	100	100
Bank erosion (%)	23	16	0	0	0	25	100
Embeddedness (%)	23	60	0	20	50	100	100

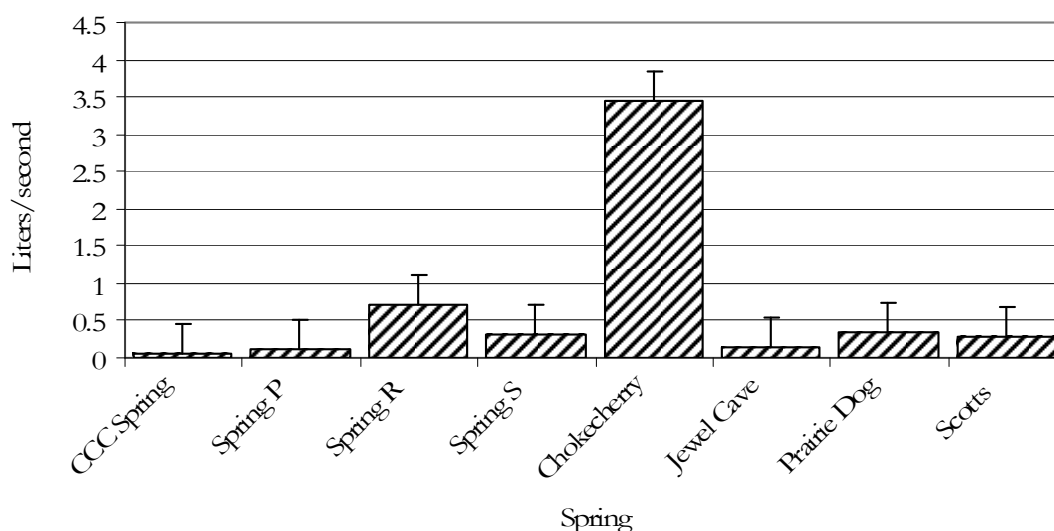


Figure 28. Mean (+ 1 s.e.) discharge for spring sites within the NGPN.

Invertebrate Composition and Abundance

Sixty-eight invertebrate taxa were identified from spring samples of the NGPN (Appendix E). These represented 13 orders, 31 families, and 64 genera. Of all invertebrates, 82% consisted of organisms from Class Insecta. Like streams and rivers, Diptera and Coleoptera were the most prevalent orders (Table 22). Nine invertebrate taxa were unique to springs (Appendix C). Diptera represented the majority of the unique taxa (4 genera), but Trichoptera also contributed 2 genera to the unique taxa. Tipulidae (Order: Diptera) and Limnephilidae (Order: Trichoptera) were the most frequent families encountered.

Table 22. Families and genera for Insecta orders of springs in the NGPN.

Order	Families	Genera
Diptera	7	26
Coleoptera	7	16
Trichoptera	2	6
Ephemeroptera	1	3
Hemiptera	1	1
Odonata	1	1
Plecoptera	2	3
Collembola	0	0
Lepidoptera	0	0
Megaloptera	0	0

Feeding guilds were dominated by collector-gatherers (45%), predators (21%) and shredders (22%) were also abundant (Figure 29). FFG diversity was highest at Prairie Dog Spring (JECA, 0.979), while FFG evenness was highest at Spring R (DETO, 0.887). Overall FFG diversity and evenness was 0.733 and 0.752. Habit guilds consisted primarily of sprawlers (39%), with burrowers (19%), swimmers (17%) and clingers (15%) making up much of the remaining guild structure. Habit guild diversity was highest at Spring R (1.150) and evenness was highest at Spring P (DETO, 0.885).

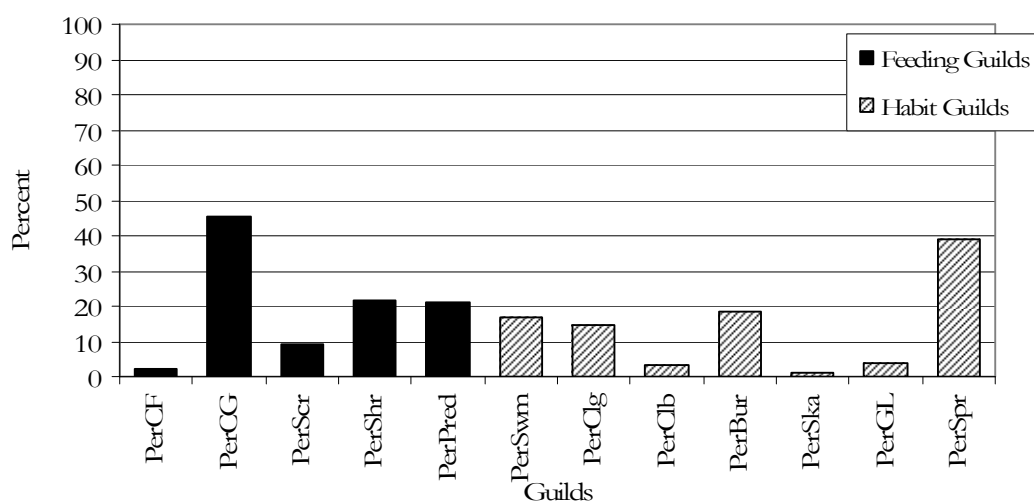


Figure 29. Feeding and habit guilds of springs within the NGPN.

Invertebrate Metrics

Ninety-eight metrics were screened for spring habitats (Appendix K). These metrics generally discriminated poorly among sites and displayed few significant correlations with water quality and habitat (Table 23). Ten metrics were chosen for future monitoring based on discriminatory power, correlations with habitat and chemical parameters and wide utilization throughout other monitoring networks (Table 24).

Table 23. Kruskal-Wallis (KW) F-values and their associated p-values for spring metrics of the NGPN.

Metric	KW F-value	P-value
% EPT	3.37	0.02
% Chironomidae	10.6	<0.001
EPT Richness	2.44	0.070
Chironomidae Richness	2.27	0.087
% Climbers	1.07	0.429
% Gliders	1.67	0.191
% Collector-gatherers	2.75	0.047
% Shredders	6.11	0.002
% Predators	2.75	0.047
Modified HBI	2.82	0.044

Table 24. Optimal invertebrate metrics for springs within the NGPN.

Metric	N	Mean	Min.	25%	Median	75%	Max.
% EPT	23	29.29.5	0.0	2.3	16.7	46.2	97.1
% Chironomidae	23	24.4	0.0	0.0	3.2	45.5	100.0
EPT Richness	23	1	0	1	1	2	4
Chironomidae Richness	23	1	0	0	1	2	4
% Climbers	23	2.0	0.0	0.0	0.0	0.0	45.5
% Gliders	23	3.6	0.0	0.0	0.0	3.8	27.8
% Collector-gatherers	23	45.5	14.3	27.3	36.4	54.5	100.0
% Shredders	23	21.7	0.0	0.0	9.1	38.9	85.7
% Predators	23	21.1	0.0	0.0	6.5	45.5	78.6
Modified HBI	23	5.6	2.0	5.0	5.6	6.6	8.9

Springs S, P, and R (DETO) all had higher percentages of intolerant taxa. Springs located within forested areas harbored higher percentages of shredder taxa (Figure 30) and shredder abundance. Shredders were found primarily in DETO and JECA springs, with most appearing in Springs S and R (DETO) and Jewel Cave Spring (JECA). DETO spring

communities had the highest habit guild diversity. HBI was highest at JECA and BADL springs and lowest at DETO (Figure 31).

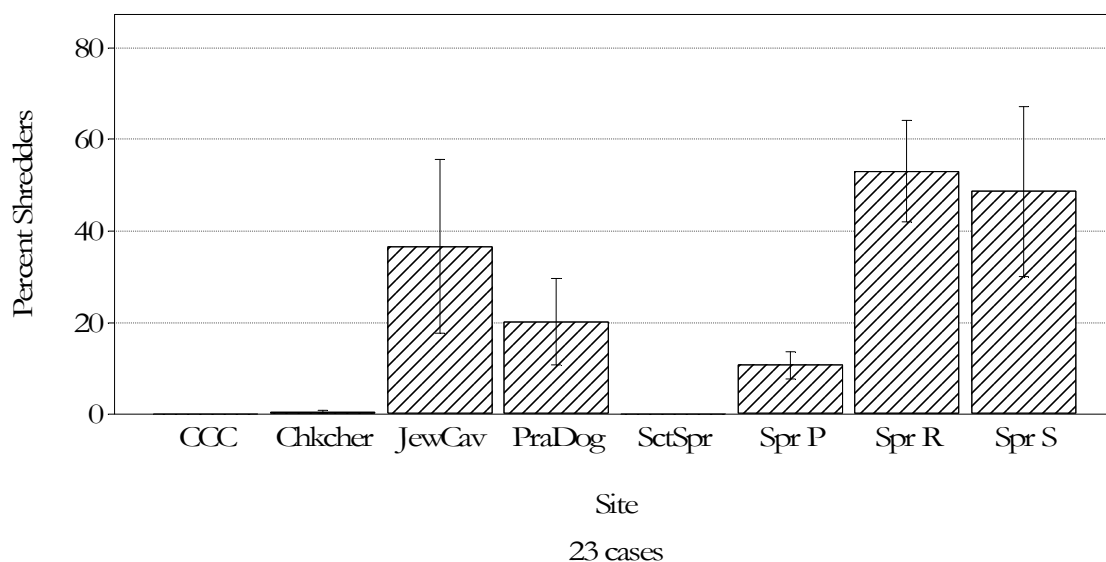


Figure 30. Mean (+/- 1 se) shredder richness for springs within the NPGN.

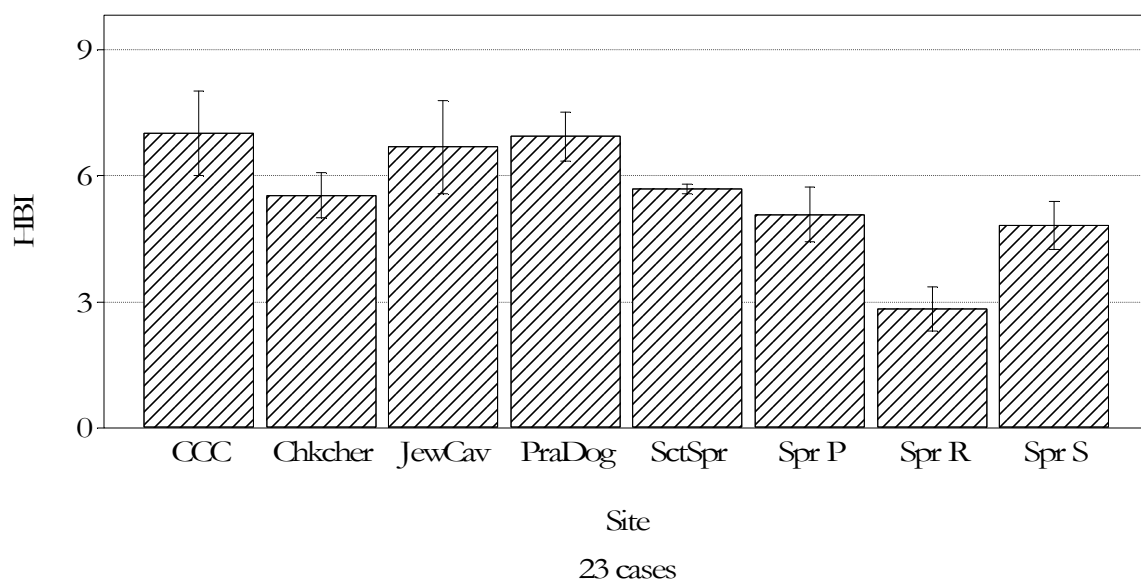


Figure 31. Mean (+/- 1 se) HBI values for spring sites within the NGPN.

Bison Watering Holes

Physical and Chemical Parameters

Although bison holes were all located in a single park, they varied greatly in nearly all physical and chemical parameters (Table 25, Appendix G). Bison watering holes are used primarily as water sources for bison and other park wildlife. Therefore, I referred to South Dakota's water quality standards for stock and wildlife propagation. Dissolved oxygen ranged from 0.7 to 14.3 mg/L with an average of 7.8 mg/L. Median pH was 8.0, but ranged from 6.6 to 10.0. The pH maximum value exceeded the state's water quality limits for stock and wildlife propagation limit of 9.5 units in 9% of the measurements. Stock Pond B exceeded stock propagation limits during one sampling visit (June 2005). Stock Dam L also exceeded pH stock propagation limits during one sampling visit (June 2004). Water temperature averaged 19.6 °C and ranged from 15.3 to 26.5 °C. Alkalinity ranged from 48 to 416 mg/L and averaged 115 mg/L. Fecal coliform averaged 179/100ml and ranged from below detection to 810/100ml.

Table 25. Summary statistics for physical and chemical parameters of watering holes at BADL. Parameters in bold indicate measurements exceeding South Dakota's stock and wildlife propagation limits.

Parameter	N	Mean	Min.	25%	Median	75%	Max
Dissolved Oxygen (mg/L)	14	7.8	0.7	5.6	7.4	9.3	14.3
Conductivity (µS/cm)	14	848	115	173	249	936	3246
pH	14	--	6.6	7.7	8.0	8.7	10.0
Water Temperature (°C)	14	19.6	15.3	16.9	17.6	23.3	26.5
Alkalinity (mg/L)	14	115	48	60	92	127	416
Turbidity (NTU)	14	161	6	34	64	286	586
TSS (mg/L)	14	94	5.2	50	66	161	228
TDS (mg/L)	14	797	56	114	196	1526	3051
Total Phosphorus (mg/L)	14	0.596	0.130	0.246	0.469	0.800	1.670
TKN (mg/L)	14	3.73	0.85	1.02	1.59	2.44	25.20
NH ₃ (mg/L)	14	0.11	0.01	<0.02	0.12	0.20	0.30
NO ₃ (mg/L)	14	0.82	<0.10	<0.10	0.15	0.98	5.90
Fecal Coliform (org/100 mL)	13	179	<10	10	50	305	810

Habitat

Habitat was strongly influenced by bison use as reflected by high embeddedness, high bank erosion, and little bank vegetation (Table 26, Appendix H). Canopy cover was expectedly low, with an average of 3% (range=0%-100%). Bank slope averaged 19% (range=3%-50%). Bank vegetation was sparse, leading to high density board values (0=abundant vegetation, 21=no vegetation). Bank erosion was also high averaging about 69%, but with a median value of 100% (range=0 to 100%). Substrate embeddedness averaged 98%. Silt/clay substrate was prevalent from 64% of sampled transects.

Table 26. Habitat characteristics for watering holes at BADL in the NGPN.

Parameter	N	Mean	Min	25%	Median	75%	Max
Bank Slope (%)	140	19	3	11	20	26	50
Canopy Cover (%)	140	3	0	0	0	0	100
Bank Vegetation	140	--	0	20	20	21	21
Bank erosion (%)	140	69	0	0	100	100	100
Embeddedness (%)	140	98	0	100	100	100	100
Substrate:							
<i>Bedrock (%)</i>	140	0	0	0	0	0	0
<i>Boulder (%)</i>	140	0	0	0	0	0	0
<i>Cobble (%)</i>	140	0	0	0	0	0	0
<i>Gravel (%)</i>	140	1	0	0	0	0	1
<i>Sand (%)</i>	140	34	0	0	0	100	100
<i>Fine (%)</i>	140	64	0	0	100	100	100

Invertebrate Composition and Abundance

Fifty-five different invertebrate taxa were collected within watering holes representing nine orders, 25 families, and 49 genera (Appendix E). Insects were the most prevalent, contributing 85% of all invertebrate taxa. Diptera and Coleoptera contributed the greatest number of families and genera (Table 27). Watering holes also supported 8 unique taxa (Appendix C). Hemiptera and Diptera contributed the greatest number of unique taxa. Pleidae

and Corixidae were the most abundant families of the unique taxa, while Dytiscidae (*Rhantus* sp.) was the only Coleoptera represented within the unique taxa.

Table 27. Families and genera for Insecta orders of watering holes in the NGPN.

Order	Families	Genera
Diptera	4	14
Coleoptera	5	12
Trichoptera	0	0
Ephemeroptera	2	4
Hemiptera	5	10
Odonata	1	2
Plecoptera	0	0
Collembola	0	0
Lepidoptera	0	0
Megaloptera	0	0

Invertebrate abundance averaged 155 organisms (range=9 to 166), and an average of seven species were found in watering holes. No intolerant species were found, but 61% of species collected were tolerant to organic pollution. Functional feeding guilds were comprised mainly of collector-gatherers (40%) and predators (38%, Figure 32). Clingers (18%) and burrowers (15%) were the prevalent habit guilds. FFG diversity and evenness was 0.775 and 0.714. Habit guild diversity and evenness was 0.761 and 0.590 for bison watering holes.

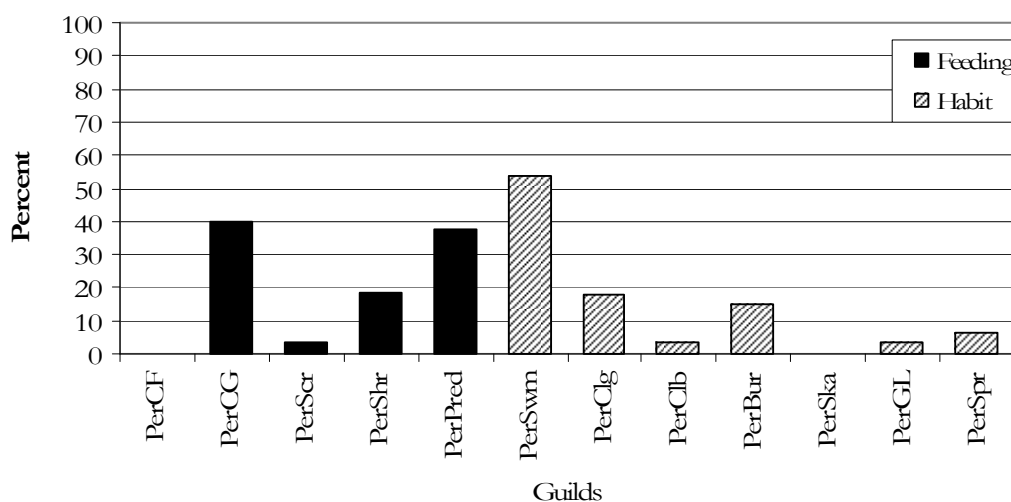


Figure 32. Functional feeding guilds and habit guilds of watering holes within the NGPN

Invertebrate Metrics

Eighty-seven metrics were screened for bison watering holes (Appendix L). As in spring habitats, these metrics displayed low discriminatory power and few significant correlations with water chemistry and habitat (Table 28). Ten metrics were chosen based on discriminatory power, correlations with habitat and chemical parameters, and wide utilization by other agencies (Table 29).

Percent contribution of dominant taxon was correlated negatively with total phosphorus ($\rho = -0.560$, $p = 0.040$). Margalef diversity ($\rho = 0.506$, $p = 0.067$, Figure 33) and number of shredder taxa ($\rho = 0.699$, $p = 0.007$) were positively correlated with alkalinity. Clinger taxa ($\rho = -0.730$, $p = 0.004$), functional feeding group diversity ($\rho = -0.635$, $p = 0.02$), and habit guild evenness ($\rho = -0.723$, $p = 0.005$) were all negatively correlated with total dissolved solids. Percent collector-gatherer taxa were also negatively correlated with water temperature ($\rho = 0.900$, $p = 0.017$). No habitat measurements were significantly correlated

with invertebrate metrics at watering holes, perhaps because all watering holes had similar habitats.

Table 28. Kruskal-Wallis (KW) F-values and their associated p-values for bison watering hole metrics of the NGPN.

Metric	KW F-value	P-value
% Dominant	3.45	0.057
% Chironomidae	3.13	0.072
Non-Insecta Richness	8.01	0.005
Margalef Diversity Index	4.99	0.021
Chironomidae Richness	4.11	0.036
Habit Evenness	2.94	0.083
Clinger Richness	3.60	0.051
FFG H'	2.83	0.090
Shredder Richness	3.60	0.051
Tolerant Taxa	5.29	0.018

Table 29. Invertebrate characteristics and optimized metrics for watering holes at BADL.

Metric	N	Mean	Min.	25%	Median	75%	Max
% Dominant	14	49.3	27.8	34.0	46.9	61.5	100.0
% Chironomidae	14	28.4	0.0	0.0	19.6	55.2	78.9
Non-Insecta Richness	14	1	0	1	1	2	4
Margalef Diversity Index	14	1.60	0.00	1.20	1.62	2.12	2.77
Chironomidae Richness	14	2	0	0	2	3	4
Habit Evenness	14	0.59	0.00	0.41	0.62	0.80	0.93
Clinger Richness	14	0	0	0	1	1	3
FFG H'	14	0.77	0.00	0.58	0.93	1.07	1.18
Shredder Richness	14	1	0	0	1	1	3
Tolerant Taxa	14	5	0	4	5	6	8

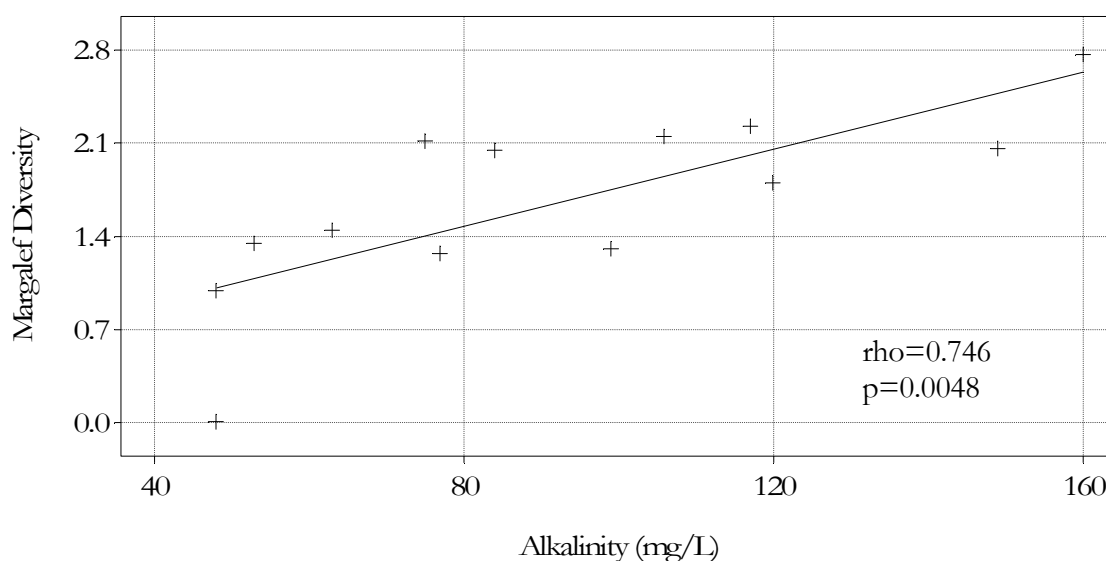


Figure 33. Scatter plot for Margalef diversity versus alkalinity for bison watering holes of the NGPN. One outlier (416mg/L) was omitted from scatter plot.

Results by Park

Agate Fossil Beds National Monument –Niobrara River

Physical and Chemical

The Niobrara River is classified by the Nebraska Department of Environmental Quality as Coldwater Class B. Coldwater Class B waters have potential to provide habitat that maintains year-round populations of coldwater fish and associated vertebrate and invertebrate organisms along with plants that support seasonal migrations of salmonids. These waters do not, however, support the reproduction of salmonid populations because of limited flow, substrate composition, or other limiting habitat conditions (NE DEQ 2002).

Dissolved oxygen was one of the few physical and chemical attributes that did not meet the limitations set by the NE DEQ (Table 30). One day minimums for coldwater class B waters should not fall below 4.0 mg/L. Dissolved oxygen at AGFO had a minimum of 0.5

mg/L, with 50% of the measurements falling below 4.0mg/L. Average dissolved oxygen on the Niobrara River reached 4.0 mg/L. Fecal coliform bacteria ranged from 30 to 80/100mL with an average of 47/100mL. These measurements are well below the limit for primary contact recreation.

Table 30. Descriptive statistics for the physical and chemical parameters of the Niobrara River (AGFO).

Parameter	N	Minimum	Mean	Median	Maximum
Dissolved Oxygen (mg/L)	30	0.5	4.0	4.0	6.3
Conductivity ($\mu\text{S}/\text{cm}$)	30	373	420	413	676
pH	30	7.3	--	7.5	7.8
Water Temperature ($^{\circ}\text{C}$)	30	14	17	17	20
Alkalinity (mg/L)	6	80	179	200	213
Turbidity (NTU)	6	1.1	4.6	4.0	10.7
TSS (mg/L)	6	3.0	7.7	4.8	18.8
TDS (mg/L)	6	242	273	268	439
Total Phosphorus (mg/L)	6	0.025	0.034	0.032	0.050
TKN (mg/L)	6	0.34	0.45	0.45	0.53
NH ₃ (mg/L)	6	0.01	0.01	0.01	0.01
NO ₃ (mg/L)	6	0.05	0.12	0.05	0.30
Fecal Coliform (org/100 mL)	3	30	47	30	80

Habitat

Habitat was unique at AGFO for the Niobrara River. Wetlands lined each bank throughout much of the park. These wetlands consisted of standing water early in the summer, but only moist soil in mid to late summer. The channel itself was relatively narrow (1 – 2 meters) but rather deep (1-3 meters). Bank slope was measured from the waters edge of the main channel. Because of the wetland nature of the banks, bank slope was low (mean = 16%), ranging from 0 to 38% (Table 31). Stream discharge ranged from 0.10 to 0.22 m³/s (mean 0.17 m³/s). Canopy cover consisted primarily of large cattails and ranged from 0 to 40% (mean 9%). Little erosion occurred along the banks (mean=1%). However, embeddedness was high (99%). Substrate consisted primarily of silt/clay (62%) with some sand (37%) and gravel (1%).

Table 31. Descriptive statistics for habitat characteristics of the Niobrara River (AGFO).

Parameter	N	Minimum	Mean	Median	Maximum
Bank Slope (%)	30	0	16	15	38
Discharge (m ³ /s)	30	0.10	0.17	0.20	0.22
Bank Vegetation	30	0	5	4	15
Canopy Cover (%)	30	0	9	0	40
Bank erosion (%)	30	0	0.5	0	5
Embeddedness (%)	30	82	99	100	100
Substrate:					
<i>Bedrock (%)</i>	30	0	0	0	0
<i>Boulder (%)</i>	30	0	0	0	0
<i>Cobble (%)</i>	30	0	0	0	0
<i>Gravel (%)</i>	30	0	1	0	40
<i>Sand (%)</i>	30	0	37	0	100
<i>Fine (%)</i>	30	0	62	100	100

Invertebrates

An average of 1019 invertebrates and 22 genera and species were collected from the Niobrara River (Table 32). Ten tolerant species and two intolerant species were collected. Percent tolerant abundance (mean=54%) far out-weighted intolerant abundance (mean=1%).

Habit guilds were comprised primarily of swimmers (37%) and burrowers (15%). However, sprawler (mean = 30%) and swimmer (mean = 23%) taxa numbers were greatest. Functional feeding guilds were dominated by collector-gatherers (mean=52%) and predators (mean=18%). Likewise, feeding guild taxa were composed of collector-gatherers (40%) and predators (35%). Shannon-Wiener diversity (H') and evenness were 2.00 and 0.70, respectively.

Percent EPT ranged from 0 to 3% (mean=2%). Diptera were most abundant (36%) and contributed the greatest number of taxa (47%). Chironomidae made up most of the Diptera taxa (80%).

Table 32. Summary statistics for optimized metrics for small and medium sized streams (AGFO).

Metric	N	Minimum	Mean	Median	Maximum
Total Abundance	3	688	1019	1025	1045
Total Richness	3	20	3	23	23
% Non-Insecta	3	48.7	56.9	58.4	60.6
EPT:Chironomidae	3	0.00	0.65	0.81	1.00
EPT Richness	3	1	2	2	3
Chironomidae Richness	3	8	9	9	11
Shannon Diversity	3	1.96	2.16	2.13	2.39
Habit Guild H'	3	1.33	1.43	1.43	1.54
% Sprawler	3	7.9	17.3	19.0	24.9
FFG H'	3	0.77	1.09	1.20	1.29
Predator Richness	3	6	8	7	10
Modified HBI	3	6.64	6.80	6.78	6.98

Badlands National Park-Sage Creek

Physical and Chemical

Dissolved oxygen ranged from 0.6 to 13.2 mg/L (mean=7.2 mg/L) (Table 33).

Twenty-five percent of the measurements for dissolved oxygen were below the South Dakota standard to support warm water fisheries (4.0mg/L). Not surprisingly, Sage Creek's suspended solids also exceeded South Dakota's marginal warmwater fishery standard (263 mg/L).

Additionally, average turbidity was 708 NTUs. TSS ranged from 4.7 to 1067 mg/L (mean=264 mg/L). TDS averaged 996 mg/L (range=453 to 2354 mg/L). Fecal coliform ranged from below detection (<10/100mL) and a maximum of 8900/100mL (mean=5026), well above the maximum value for limited human contact in one sample (200/100mL).

Table 33. Summary statistics of physical and chemical parameters for Sage Creek (BADL).

Parameter	N	Minimum	Mean	Median	Maximum
Dissolved Oxygen (mg/L)	70	0.6	7.2	7.6	13.2
Conductivity ($\mu\text{S}/\text{cm}$)	70	636	1790	1465	5158
pH	70	7.86	--	8.40	8.83
Water Temperature ($^{\circ}\text{C}$)	70	13.7	18.5	16.7	25.7
Alkalinity (mg/L)	5	127	243	177	420
Turbidity (NTU)	5	6	708	22	3280
TSS (mg/L)	6	4.7	264	43	1067
TDS (mg/L)	5	453	996	822	2354
Total Phosphorus (mg/L)	5	0.051	3.834	0.082	18.800
TKN (mg/L)	5	0.3	2.1	0.7	7.5
NH ₃ (mg/L)	5	0.01	0.02	0.01	0.04
NO ₃ (mg/L)	5	0.1	1.5	2.2	2.4
Fecal Coliform (org/100 mL)	4	<10	5026	5600	8900

Habitat

Bank slope was usually high, ranging from 9% to 100% (mean=51%) (Table 34).

Furthermore, over half of visited sites had at least one bank with vertical slopes. Discharge averaged $0.003 \text{ m}^3/\text{s}$ with a maximum discharge of $0.016 \text{ m}^3/\text{s}$. Water from Sage Creek periodically flowed underground (in dry part of year) and resurfaced downstream. This resulted in some stranded pools within the channel. Canopy cover was low, ranging from 0 to 50% cover (mean=1%). Bank erosion averaged 31% and ranged from 0 to 100% with 52% of the sites having at least one bank with 100% erosion.

Table 34. Summary statistics of habitat characteristics for Sage Creek (BADL).

Parameter	N	Minimum	Mean	Median	Maximum
Bank Slope (%)	70	9	51	55	100
Discharge (m ³ /s)	70	0.00	0.003	0.002	0.016
Canopy Cover (%)	70	0	1	0	50
Bank Vegetation	70	0	16	15	21
Bank erosion (%)	70	0	31	33	100
Embeddedness (%)	70	0	80	100	100
Substrate:					
<i>Bedrock (%)</i>	70	0	0	0	0
<i>Boulder (%)</i>	70	0	0.03	0	0.2
<i>Cobble (%)</i>	70	0	0.6	0	4.0
<i>Gravel (%)</i>	70	0	28.3	20.0	88.0
<i>Sand (%)</i>	70	0	9.4	10.0	30.0
<i>Fine (%)</i>	70	0	61.4	70.0	100.0

Invertebrates

An average of 426 invertebrates were collected from samples of Sage Creek. Sampled reaches averaged 7 species with a minimum of 1 species and a maximum of 11 (Table 35).

Abundance of species tolerant to organic pollution (38%) was far greater than abundance of intolerant species (1%). Habit guilds were dominated by clingers (69%) while feeding guilds were comprised mostly of collector filterers (48%) and predators (22%). Clingers dominated habit guild taxa (46%), while shredder taxa (39%) and predator taxa (31%) contributed the majority of feeding guild richness. Average Shannon-Wiener diversity was 0.66 and evenness averaged 0.31. Percent EPT taxa was also low (2%), and EPT abundance was generally less than 1%.

Table 35. Invertebrate abundance and stream optimized metrics for Sage Creek (BADL).

Metric	N	Minimum	Mean	Median	Maximum
Total Abundance	6	2	426	250	1142
Total Richness	6	1	7	8	11
% Non-Insecta	6	0.0	0.0	0.0	0.0
EPT:EPT+Chironomidae	6	0.00	0.08	0.00	0.50
EPT Richness	6	0	0	0	1
Chironomidae Richness	6	1	3	3	5
Shannon Diversity Index	6	0.00	0.66	0.23	1.86
Habit Guild H'	6	0.00	0.48	1.62	1.40
% Sprawler	6	0.0	6.5	1.3	31.8
FFG H'	6	0.00	0.34	1.07	0.21
Predator Richness	6	1	7	8	11
Modified HBI	6	4.81	6.04	5.43	8.73

Badlands National Park – CCC Spring

Physical and Chemical

CCC is an enhanced spring and is primarily used for bison stock watering. For this reason, I will refer to South Dakota's standards for stock watering and wildlife propagation. Conductivity was well below standards, ranging from 895 to 985 $\mu\text{S}/\text{cm}$ (mean=918 $\mu\text{S}/\text{cm}$, Table 36). Alkalinity was also below standards, ranging from 276 to 280 mg/L (mean=278 mg/L.) NO_3 averaged 2.5 and the average NH_3 was below detection. Fecal coliform exceeded water immersion limits for two of three samples (mean=750/100mL).

Table 36. Statistical summary of physical and chemical properties for CCC Spring (BADL).

Parameter	N	Minimum	Mean	Median	Maximum
Dissolved Oxygen (mg/L)	30	7.4	11.1	12.1	13.8
Conductivity (μ S/cm)	30	895	918	934	985
pH	30	7	--	8	8
Water Temperature ($^{\circ}$ C)	30	14	14	14	16
Alkalinity (mg/L)	3	276	278	277	280
Turbidity (NTU)	3	1.0	3.9	2.7	8.0
TSS (mg/L)	3	3	14	18	19
TDS (mg/L)	3	512	594	607	664
Total Phosphorus (mg/L)	3	0.105	0.112	0.113	0.118
TKN (mg/L)	3	0.25	0.44	0.77	0.29
NH ₃ (mg/L)	3	<0.02	<0.02	<0.02	<0.02
NO ₃ (mg/L)	3	2.2	2.5	2.4	2.8
Fecal Coliform (org/100 mL)	3	40	750	1100	1100

Habitat

CCC Spring flowed from a pipe into a stock tank. We measured habitat from the areas around the stock tank and some areas where the tank overflowed. Bison heavily trampled these areas, resulting in little vegetation (median=15), high embeddedness (100%) and silt/clay substrate (100%, Table 37). Bank erosion also averaged 67%. Canopy cover ranged from 0 to 100% (median=50%). Discharge from CCC Spring was very small and was not flowing during June 2005.

Table 37. Habitat characteristics for CCC Spring (BADL).

Parameter	N	Minimum	Mean	Median	Maximum
Bank Slope (%)	30	3	5	4	9
Discharge (L/s)	3	0.00	0.01	0.01	0.01
Vegetation	30	0	12	15	21
Canopy Cover (%)	30	0	33	50	50
Bank erosion (%)	30	0	67	100	100
Embeddedness (%)	30	100	100	100	100
Substrate:					
<i>Bedrock (%)</i>	30	0	0	0	0
<i>Boulder (%)</i>	30	0	0	0	0
<i>Cobble (%)</i>	30	0	0	0	0
<i>Gravel (%)</i>	30	0	0	0	0
<i>Sand (%)</i>	30	0	0	0	0
<i>Fine (%)</i>	30	100	100	100	100

Invertebrates

Invertebrate richness (5) and abundance (48) were low by comparison to Sage Creek (Table 38). A minimum of 1 taxa and a maximum of 8 were found from CCC Spring. No intolerant taxa were, while an average of 43% of the taxa and 61% of the total abundance of individuals were tolerant to organic pollution. Habit guilds consisted primarily of burrowers (50%) and sprawlers (37%), with most habit guild taxa consisting of sprawlers (47%). Feeding guild richness was dominated by collector-gatherer taxa (63%) which were also most abundant (92%). Shannon-Wiener H' and evenness values were low (0.6 and 0.3, respectively). Dominant species comprised 83% of the total abundance. EPT contributed about 6% of the total abundance.

Table 38. Invertebrate abundance and optimized spring metrics of CCC Spring (BADL).

Metric	N	Minimum	Mean	Median	Maximum
Total Abundance	3	2	48	62	80
Total Richness	3	1	5	6	8
% EPT	3	0.0	6.2	2.3	16.1
% Chironomidae	3	70.0	87.2	90.7	100.0
EPT Richness	3	0	1	1	1
Chironomidae Richness	3	1	2	3	3
% Climbers	3	0.0	0.0	0.0	0.0
% Gliders	3	0.0	5.6	7.0	9.7
% Collector-gatherers	3	85.5	92.1	90.7	100.0
% Shredders	3	0.0	0.0	0.0	0.0
% Predators	3	0.0	2.4	2.3	4.8
Modified HBI	3	5.00	7.00	8.00	8.01

Devils Tower National Monument - Springs

Physical and Chemical

Three springs were sampled at DETO and all were analyzed collectively. The Wyoming Department of Environmental Quality has identified all waterbodies that lie within National Park boundaries as “Class 1 Waters.”

Most spring physical and chemical measurements fell below the state limits for cold water life stages. Minimum dissolved oxygen was 5.3 mg/L (mean=8.1 mg/L), above the state limit of 4.0 mg/L. Ammonia was also well below the limit set for the presence of early life stages (Table 39).

Table 39. Physical and chemical parameters for springs (DETO).

Parameter	N	Minimum	Mean	Median	Maximum
Dissolved Oxygen (mg/L)	80	5.3	8.1	7.9	10.7
Conductivity (μ S/cm)	80	175	1459	1211	2926
pH	80	6.9	--	7.3	8.3
Water Temperature ($^{\circ}$ C)	80	7.2	10.1	9.5	14.7
Alkalinity (mg/L)	8	71	256	256	570
Turbidity (NTU)	8	1	9	9	19
TSS (mg/L)	8	7	62	46	161
TDS (mg/L)	8	160	1167	817	2635
Total Phosphorus (mg/L)	8	0.008	0.162	0.046	0.855
TKN (mg/L)	8	0.12	0.24	0.24	0.33
NH ₃ (mg/L)	8	0.01	0.01	0.01	0.02
NO ₃ (mg/L)	8	0.1	1.4	1.0	3.0
Fecal Coliform (org/100 mL)	7	<10	40	<10	140

Habitat

Since most springs were enhanced by pipes, cisterns, or wells, habitat measurements were taken from downstream of the enhancements. The springs were located in pine tree lined valleys, so canopy cover was understandably high, averaging 87% (Table 40). Bank erosion was low (mean=6%) and substrate consisted entirely of sand and gravel. Much of the substrate was embedded (mean=78%).

Table 40. Habitat Characteristics for DETO springs.

Parameter	N	Minimum	Mean	Median	Maximum
Bank Slope (%)	80	12	38	28	92
Discharge (L/s)	8	0.00	0.41	0.01	2.10
Canopy Cover (%)	80	25	87	100	100
Bank Vegetation	80	11	15	15	18
Bank erosion (%)	80	0	6	0	45
Embeddedness (%)	80	20	78	100	100
Substrate:					
<i>Bedrock (%)</i>	80	0	0	0	0
<i>Boulder (%)</i>	80	0	0	0	0
<i>Cobble (%)</i>	80	0	0	0	0
<i>Gravel (%)</i>	80	0	50	50	100
<i>Sand (%)</i>	80	0	50	50	100
<i>Fine (%)</i>	80	0	0	0	0

Invertebrate Characteristics

An average of 17 invertebrates were collected per sample from DETO springs (Table 41). A minimum of 2 and a maximum of 10 taxa were found at the springs (mean=7). Insecta comprised 87% of the total abundance and 85% of the total taxa. Intolerant taxa were prevalent (49%) compared with intolerant taxa (24%). Shredders comprised the majority of feeding guild abundance and richness (41% and 30%, respectively). Habit guilds were primarily sprawlers (mean=32%).

Table 41. Optimized invertebrate metrics for springs (DETO).

Metric	N	Minimum	Mean	Median	Maximum
Total Abundance	8	7	17	15	31
Total Richness	8	2	7	8	10
% EPT	8	3.8	41.3	33.8	85.7
% Chironomidae	8	0.0	15.6	11.0	45.5
EPT Richness	8	1	2	2	4
Chironomidae Richness	8	0	1	1	4
% Climbers	8	0.0	0.6	0.0	4.5
% Gliders	8	0.0	1.5	0.0	8.3
% Collector-gatherers	8	14.3	30.5	32.8	40.9
% Shredders	8	7.7	40.8	32.3	85.7
% Predators	8	0.0	21.1	12.8	53.8
Modified HBI	8	2.00	4.14	4.12	5.72

Devils Tower National Monument – Belle Fourche River

Physical and Chemical

Average fecal coliform bacteria was one of the few parameters from the Belle Fourch River that exceeded state standards (mean=405/100ml). pH was also high with a median of 9.4 units; the state standards are 9.0 units. TDS was high (mean=1437 mg/L. TSS was low (mean= 5 mg/L, Table 42).

Table 42. Physical and chemical parameters for the Belle Fourche River (DETO).

Parameter	N	Minimum	Mean	Median	Maximum
Dissolved Oxygen (mg/L)	30	8.3	11.4	11.1	14.3
Conductivity ($\mu\text{S}/\text{cm}$)	30	1549	1719	1710	1861
pH	30	8.4	--	9.4	8.6
Water Temperature ($^{\circ}\text{C}$)	30	13	24	24	29
Alkalinity (mg/L)	3	42	89	73	153
Turbidity (NTU)	3	2	2	2	3
TSS (mg/L)	3	2	5	4	7
TDS (mg/L)	3	1350	1437	1443	1517
Total Phosphorus (mg/L)	3	0.023	0.038	0.028	0.064
TKN (mg/L)	3	0.12	0.26	0.25	0.42
NH ₃ (mg/L)	3	0.01	0.01	0.01	0.01
NO ₃ (mg/L)	3	0.05	0.05	0.05	0.05
Fecal Coliform (org/100 mL)	2	<10	405	400	810

Habitat

Bank slope was relatively low for the Belle Fourche (mean=32%, Table 43). Concrete bank stabilizers were present on the Belle Fourche, some of which were leaning into the water and some were a few feet up the bank. Current velocity averaged 0.25 m/s and substrate was primarily cobble with some fine sediment. Snag counts were low, averaging less than one snag per transect.

Table 43. Habitat characteristics for the Belle Fourche River (DETO).

Parameter	N	Minimum	Mean	Median	Maximum
Bank Slope (%)	30	16	32	29	60
Max Current Velocity (m/s)	30	0.02	0.25	0.20	0.71
Vegetation Density	30	6	16	15	21
Canopy Cover (%)	30	0	0	0	0
Bank Full (m)	30	0.1	1.1	1.0	4.0
Snags	30	0	0.3	0	1
Substrate:					
<i>Bedrock (%)</i>	30	0	3	0	100
<i>Boulder (%)</i>	30	0	3	0	100
<i>Cobble (%)</i>	30	0	70	100	100
<i>Gravel (%)</i>	30	0	7	0	100
<i>Sand (%)</i>	30	0	3	0	100
<i>Fine (%)</i>	30	0	10	0	100

Invertebrates

An average of 108 invertebrates per sample were collected from the Belle Fourche River at DETO (Table 44). These invertebrates comprised an average of 13 different taxa. Seventy-seven percent of the richness and 63% of the abundance are attributed to insects. EPT were the most prevalent insect orders, comprising 40% of the total abundance. Tolerant taxa comprised 20% of the total richness while intolerant taxa comprised 25%. Habit guilds consisted primarily of clingers, making up 45% of the abundance and 44% of the total taxa. Collector-gatherers were the most prevalent feeding guild, contributing 27% of the richness.

Table 44. Large river optimized metrics for the Belle Fourche River (DETO).

Metric	N	Minimum	Mean	Median	Maximum
Total Abundance	3	60	108	101	162
Total Richness	3	10	13	13	17
% EPT	3	13.6	40.4	44.6	63.3
% Chironomidae	3	0.6	3.4	1.7	7.9
Non-Insecta Richness	3	2	3	3	3
EPT Richness	3	2	4	3	8
Clinger Richness	3	2	6	7	8
Swimmer Richness	3	0	2	3	3
Collector-gatherer Richness	3	1	4	3	8
Collector-filterer Richness	3	1	2	2	4
Modified HBI	3	3.74	5.27	5.23	6.83

Fort Laramie National Historic Site – Laramie River

Physical and Chemical

Physical, chemical, habitat, and biological measurements of the Laramie River (FOLA) indicate excellent water quality. Dissolved oxygen was high, with a mean measurement of 10.8 mg/L (range=9.6mg/L to 12.9mg/L, Table 45). All measurements were surprisingly steady, considering the mixture of riffles and pools in the river and the varying times of summer we sampled the area. Most chemistry measurements were at or below the minimum detection limit for Wyoming's water quality standards. Fecal coliform was above detection, but all measurements were well below standards set by the state of Wyoming.

Table 45. Physical and chemical summary for the Laramie River (FOLA).

Parameter	N	Minimum	Mean	Median	Maximum
Dissolved Oxygen (mg/L)	60	9.6	10.8	10.3	12.9
Conductivity ($\mu\text{S}/\text{cm}$)	60	671	750	785	802
pH	60	8.0	--	8.2	8.5
Water Temperature ($^{\circ}\text{C}$)	60	13.0	18.9	20.0	23.9
Alkalinity (mg/L)	6	91	180	198	206
Turbidity (NTU)	6	6	11	11	17
TSS (mg/L)	6	10	17	15	27
TDS (mg/L)	6	423	582	551	881
Total Phosphorus (mg/L)	6	0.027	0.041	0.039	0.055
TKN (mg/L)	6	0.25	0.44	0.35	0.71
NH ₃ (mg/L)	6	<0.02	<0.02	<0.02	<0.02
NO ₃ (mg/L)	6	<0.01	0.12	0.10	0.20
Fecal Coliform (org/100 mL)	4	10	35	35	60

Habitat

The Laramie River had a good mixture of riffles and pools. Current velocities varied greatly (range= 0.07m/s to 1.29m/s, Table 46). Cobble comprised the majority of substrate types (mean=60%). This stretch of the Laramie flowed through prairie. Thus, riparian canopy cover was low (mean=4%) Any measurable canopy cover came from riparian cottonwoods and small willows.

Table 46. Habitat characteristics for the Laramie River (FOLA)

Parameter	N	Minimum	Mean	Median	Maximum
Bank Slope (%)	60	4	32	22	100
Max Current Velocity (m/s)	60	0.07	0.47	0.35	1.29
Vegetation Density	60	0	12	15	21
Canopy Cover (%)	60	0	4	0	100
Bank Full (m)	60	0.1	1.9	1.2	7.0
Snags	60	0	2	2	7
Substrate:					
<i>Bedrock (%)</i>	60	0	0	0	0
<i>Boulder (%)</i>	60	0	0	0	0
<i>Cobble (%)</i>	60	0	63	100	100
<i>Gravel (%)</i>	60	0	3	0	100
<i>Sand (%)</i>	60	0	8	0	100
<i>Fine (%)</i>	60	0	0	0	0

Invertebrates

Invertebrate taxa reflected the water quality of the Laramie River (range=18 to 24 taxa, Table 47). EPT contributed 45% of the total abundance and 28% of the total taxa. Tolerant (20%) and intolerant (21%) taxa contributed similar abundances, but tolerant species (31%) contributed more to total richness than the intolerant species (23%). Clingers comprised most of the abundance and richness of the habit guilds (40% and 30%, respectively). Feeding guilds consisted primarily of collector-gatherers (63% abundance, 56% richness).

Table 47. Optimal large river metrics for the Laramie River (FOIA).

Metric	N	Minimum	Mean	Median	Maximum
Total Abundance	6	195	1312	1598	2272
Total Richness	6	10	18	17	24
% EPT	6	50.6	67.0	59.7	93.5
% Chironomidae	6	0.0	4.0	2.3	15.4
Non-Insecta Richness	6	1	4	5	5
EPT Richness	6	4	6	6	9
Clinger Richness	6	4	6	6	9
Swimmer Richness	6	2	5	5	6
Collector-gatherer Richness	6	4	8	8	12
Collector-filterer Richness	6	3	4	3	6
Modified HBI	6	3.44	4.52	4.56	5.76

Fort Laramie National Historic Site – North Platte River

Physical and Chemical

Dissolved oxygen was surprisingly high from the North Platte River, considering there was little to no flow (Table 48), range=8.2mg/L to =12.5mg/L). Ammonia was also below detection for all measurements (<0.02mg/L). Most chemistries remained relatively stable from visit to visit even though flow changed dramatically. Fecal coliform bacteria remained below state standards for limited contact and primary contact standards.

Table 48. Physical and chemical parameters for the North Platte River (FOIA).

Parameter	N	Minimum	Mean	Median	Maximum
Dissolved Oxygen (mg/L)	60	8.4	9.3	9.1	12.5
Conductivity ($\mu\text{S}/\text{cm}$)	60	728	774	732	857
pH	60	8.0	8.3	8.3	8.4
Water Temperature ($^{\circ}\text{C}$)	60	15.4	20.0	21.6	22.9
Alkalinity (mg/L)	6	59	137	150	162
Turbidity (NTU)	6	2	19	8	48
TSS (mg/L)	6	3	45	38	90
TDS (mg/L)	6	403	532	488	820
Total Phosphorus (mg/L)	6	0.022	0.060	0.038	0.133
TKN (mg/L)	6	0.12	0.38	0.57	0.42
NH ₃ (mg/L)	6	<0.02	<0.02	<0.02	<0.02
NO ₃ (mg/L)	6	<0.1	0.08	<0.1	0.2
Fecal Coliform (org/100 mL)	4	<10	36	30	80

Habitat

Current velocity varied greatly between site visits. Minimum values were in the negatives (min=-0.02m/s) while maximum values were above 1 m/s (max=1.14m/s). Canopy cover was low as the North Platte flows through a prairie landscape. The North Platte differed in that it had fewer young cottonwoods and willows growing in the riparian area than the Laramie River. Most riparian canopy was from mature cottonwoods. Woody debris and snags were also lacking from this stretch of the North Platte (Table 49). Cobble was the primary substrate (mean=90%). During low flow, however, the cobble was usually covered with a layer of fine sediment.

Table 49. Habitat characteristics for the North Platte River (FOLA).

Parameter	N	Minimum	Mean	Median	Maximum
Bank Slope (%)	60	5	32	31	80
Max Current Velocity (m/s)	60	-0.02	0.30	0.29	1.14
Vegetation Density	60	0	8	8	20
Canopy Cover (%)	60	0	14	0	100
Bank Full (m)	60	0.1	1.4	1.0	5.0
Snags	60	0	1	0	14
Substrate:					
<i>Bedrock (%)</i>	60	0	7	0	100
<i>Boulder (%)</i>	60	0	0	0	0
<i>Cobble (%)</i>	60	0	90	100	100
<i>Gravel (%)</i>	60	0	0	0	0
<i>Sand (%)</i>	60	0	3	0	100
<i>Fine (%)</i>	60	0	0	0	0

Invertebrates

An average of 328 invertebrates were collected at FOLA from the North Platte River representing an average of twelve taxa (Table 50). Tolerant organisms comprised the majority of taxa and abundance (34% and 35%) while intolerant taxa comprised 15% abundance and 24% of the total taxa. Habit guilds were dominated by burrowers (38% abundance, 20% richness) and clingers (34% abundance, 30% richness). The collector-gatherer feeding guild contributed the most abundance and richness (61% and 52%, respectively).

Table 50. Optimized large river invertebrate metrics for the North Platte (FOIA).

Metric	N	Minimum	Mean	Median	Maximum
Total Abundance	6	26	328	92	867
Total Richness	6	9	12	9	18
% EPT	6	2.2	27.3	18.1	61.5
% Chironomidae	6	34.6	63.4	67.6	88.0
Non-Insecta Richness	6	0	2	1	4
EPT Richness	6	1	2	2	4
Clinger Richness	6	2	3	4	4
Swimmer Richness	6	1	3	2	5
Collector-gatherer Richness	6	4	6	5	10
Collector-filterer Richness	6	1	2	2	2
Modified HBI	6	4.86	5.72	5.97	6.32

Fort Laramie National Historic Site – Deer Creek

Chemical and Physical Parameters

Deer Creek is a small stream that flows into the Laramie River. Horses use the stream during part of the year a short distance upstream from the sampling site. Only two fecal coliform samples were taken from Deer Creek during the sampling period, and one sample was above the water quality limit (250/100mL, Table 51). Dissolved oxygen levels were well above those required to support aquatic life (mean=11.0mg/L). All ammonia results were below the detection limit (<0.02 mg/L).

Table 51. Physical and chemical parameters for Deer Creek (FOLA).

Parameter	N	Minimum	Mean	Median	Maximum
Dissolved Oxygen (mg/L)	30	6.2	11.0	10.3	18.4
Conductivity ($\mu\text{S}/\text{cm}$)	30	460	574	580	830
pH	30	7.4	--	8.2	8.4
Water Temperature ($^{\circ}\text{C}$)	30	14.3	18.1	19.1	21.6
Alkalinity (mg/L)	3	149	192	212	214
Turbidity (NTU)	3	0	2	3	3
TSS (mg/L)	3	1	3	2	6
TDS (mg/L)	3	407	420	422	430
Total Phosphorus (mg/L)	3	0.052	0.113	0.062	0.220
TKN (mg/L)	3	<0.23	0.45	0.45	0.79
NH ₃ (mg/L)	3	<0.02	<0.02	<0.02	<0.02
NO ₃ (mg/L)	3	<0.1	<0.1	<0.1	<0.1
Fecal Coliform (org/100 mL)	2	20	135	135	250

Habitat

Deer Creek had little discharge during the sampling season (mean= 8.583 L/s).

Wetland areas existed within Deer Creek, so embeddedness was expectedly high, averaging 95%. Sand was the primary substrate (mean=69%, Table 52). Canopy was also predictably low (mean=14%). Bank erosion was low within the park boundaries (mean=0%), although just outside park boundaries it flowed through livestock pasture and that was more susceptible to bank erosion.

Table 52. Habitat parameters for Deer Creek (FOLA).

Parameter	N	Minimum	Mean	Median	Maximum
Bank Slope (%)	30	10	37	h36	82
Discharge (L/s)	3	0.950	8.583	12.300	12.500
Bank Vegetation	30	0	11	11	18
Canopy Cover (%)	30	0	14	0	100
Bank erosion (%)	30	0	0	0	0
Embeddedness (%)	30	0	95	100	100
Substrate:					
<i>Bedrock (%)</i>	30	0	3	0	100
<i>Boulder (%)</i>	30	0	0	0	0
<i>Cobble (%)</i>	30	0	1	0	20
<i>Gravel (%)</i>	30	0	17	0	100
<i>Sand (%)</i>	30	0	69	100	100
<i>Fine (%)</i>	30	0	0	0	0

Invertebrates

An average of 927 organisms per sample comprising 26 taxa were found in Deer Creek (Table 53). Invertebrate communities were predominantly comprised of Diptera, Coleoptera, and Ephemeroptera. *Tricorythodes sp.* and *Baetis brunneicolor* contributed the most to the order Ephemeroptera. Deer Creek was one of the few systems that contained a large number of non-insect species (amphipods (*Hyalella azteca*) and gastropods (*Physa sp.*). Tolerant organisms were predominant (47% of the total abundance) while intolerant organisms were rare (0.26%). Collector-gatherers composed 64% of feeding guild abundance while habit guilds were comprised primarily of burrowers (38%) and swimmers (35%).

Table 53. Optimal stream invertebrate metrics for Deer Creek (FOLA).

Metric	N	Minimum	Mean	Median	Maximum
Total Abundance	3	509	927	982	1290
Total Richness	3	18	26	23	37
% Non-Insecta	3	9.1	40.8	46.9	66.5
EPT:Chironomidae	3	0.06	0.40	0.33	0.80
EPT Richness	3	1	2	2	3
Chironomidae Richness	3	2	4	4	5
Shannon Diversity Index	3	1.40	1.72	1.76	2.00
Habit Guild H'	3	1.05	1.17	1.13	1.34
% Sprawler	3	2.1	6.8	10.4	7.9
FFG H'	3	0.68	0.85	0.81	1.07
Predator Richness	3	4	6	6	7
Modified HBI	3	8.76	6.65	6.57	7.62

Fort Union Trading Post National Historic Site – Missouri River

Physical and Chemical Parameters

This small stretch of the Missouri River next to Fort Union was a narrow, deep, and fast flowing channel. The channel had moderately high turbidity (74 NTUs) and suspended solids (98mg/L) compared to other stretches of the Missouri River. Dissolved oxygen, pH, ammonia, and nitrates all met North Dakota state water quality standards. The Missouri River at Fort Union had higher levels of total phosphorus (mean=0.27mg/L, Table 54).

Table 54. Chemical and physical characteristics of the Missouri River (FOUS).

Parameter	N	Minimum	Mean	Median	Maximum
Dissolved Oxygen (mg/L)	30	8.4	8.9	9.0	9.4
Conductivity ($\mu\text{S}/\text{cm}$)	30	573	598	599	618
pH	30	7.7	8.2	8.3	8.4
Water Temperature ($^{\circ}\text{C}$)	30	16.5	19.1	17.5	23.8
Alkalinity (mg/L)	4	154	173	156	225
Turbidity (NTU)	4	47	74	48	152
TSS (mg/L)	4	73	98	87	144
TDS (mg/L)	4	357	409	402	476
Total Phosphorus (mg/L)	4	0.113	0.266	0.193	0.566
TKN (mg/L)	4	0.12	0.30	0.18	0.70
NH ₃ (mg/L)	4	<0.02	0.02	<0.02	0.05
NO ₃ (mg/L)	4	<0.1	0.06	<0.1	0.1
Fecal Coliform (org/100 mL)	3	10	17	20	20

Habitat

For the most part, the Missouri River at FOUS had steep banks, with nearly half the transects adjacent to vertical banks (Table 55). Because of the high velocity and narrow channel, both sides of the bank dropped very quickly a few meters off-shore. Current velocity in this area reached 1.15 m/s with 11 of 30 measurements reaching to 1.0 m/s or more. Sand was the primary cross-channel substrate, with silt/clay making up a small part in the slower moving areas. An average of 3 snags per transect were spotted from this reach.

Table 55. Habitat characteristics for the Missouri River (FOUS).

Parameter	N	Minimum	Mean	Median	Maximum
Bank Slope (%)	30	2	51	58	100
Max Current Velocity (m/s)	30	0.29	0.81	0.82	1.15
Vegetation Density	30	0	12	17	21
Canopy Cover (%)	30	0	1	0	20
Bank Full (m)	30	0	2.7	1.5	8.5
Snags	30	0	3	3	5
Substrate:					
<i>Bedrock (%)</i>	30	0	0	0	0
<i>Boulder (%)</i>	30	0	0	0	0
<i>Cobble (%)</i>	30	0	0	0	0
<i>Gravel (%)</i>	30	0	0	0	0
<i>Sand (%)</i>	30	0	83	100	100
<i>Fine (%)</i>	30	0	17	0	100

Invertebrates

An average of 52 invertebrates per sample were collected from the Missouri River, comprising 8 different taxa (Table 56). Nearly all invertebrates were insects (94%). Forty-five percent of the total abundance was contributed by EPT. *Isoperla nana* and *Baetis intercalaris* were frequent and abundant contributors to Plecoptera and Ephemeroptera, respectively. Intolerant taxa were more abundant than tolerant taxa by 27% (Intolerant=35%, tolerant=8%). Feeding guilds were dominated by collector-gatherers (39%) and predators (38%), while clingers (32%) and swimmers (24%) contributed the most to habit guild richness.

Table 56. Optimal large river metrics for the Missouri River (FOUS).

Metric	N	Minimum	Mean	Median	Maximum
Total Abundance	3	13	52	39	115
Total Richness	3	7	8	9	9
% EPT	3	29.6	45.0	51.7	53.8
% Chironomidae	3	3.5	9.5	7.7	17.2
Non-Insecta Richness	3	0	1	1	1
EPT Richness	3	2	3	3	5
Clinger Richness	3	2	3	3	3
Swimmer Richness	3	2	2	2	2
Collector-gatherer Richness	3	2	3	2	5
Collector-filterer Richness	3	0	1	0	2
Modified HBI	3	3.72	4.46	4.71	4.97

Jewel Cave National Monument - Springs

Physical and Chemical

Most physical and chemical parameters met South Dakota's standards from spring sites (Table 57). One of 14 fecal coliform samples (Jewel Cave Spring, July 2004) provided an extremely high value (160,000/100mL). The remaining fecal results were all below 200/100mL. The state health lab ran this particular sample three times with the same results. Samples taken a week later and also on our last site visit yielded results well below 200/100mL.

Nitrate levels in springs were listed as a concern by park staff and levels were high relative to other aquatic systems in the area. However, measured concentrations were still well below standards for drinking water.

Table 57. Physical and chemical parameters for Chokecherry, Jewel Cave, and Prairie Dog Spring (JECA).

Parameter	N	Minimum	Mean	Median	Maximum
Dissolved Oxygen (mg/L)	9	7.6	9.3	9.3	10.9
Conductivity (μ S/cm)	9	562	1098	1170	1572
pH	9	7.1	--	7.9	9.0
Water Temperature ($^{\circ}$ C)	9	7.2	11.8	12.1	15.7
Alkalinity (mg/L)	9	5	252	310	352
Turbidity (NTU)	9	0	76	2	346
TSS (mg/L)	9	0	18	9	65
TDS (mg/L)	9	256	611	606	1066
Total Phosphorus (mg/L)	9	<0.002	0.030	0.020	0.080
TKN (mg/L)	9	0.12	0.27	0.25	0.54
NH ₃ (mg/L)	9	<0.02	<0.02	<0.02	<0.02
NO ₃ (mg/L)	9	1.1	1.5	1.5	1.7
Fecal Coliform (org/100 mL)	14	<10	11485	<10	160000

Habitat

Chokecherry spring flowed from a pipe into a stock tank. Jewel Cave Spring was enhanced with a cistern and flowed from a pipe approximately 100m downhill from the cistern. Prairie Dog Spring flowed through a natural channel. Substrate for all springs was primarily gravel (mean=56%) but other substrates such as metal (stock tank at Chokecherry) and cement (Jewel Cave Spring) were also present. Canopy cover was high (mean=56%) even though much of the park was burned in the Jasper Fire of 2000 (Table 58). Discharge was highest at Chokecherry Spring (max=9.3L/s, mean=3.4L/s). Jewel cave spring had the lowest discharge (mean=0.14L/s).

Table 58. Habitat characteristics for Chokecherry, Jewel Cave, and Prairie Dog Spring (JECA).

Parameter	N	Minimum	Mean	Median	Maximum
Bank Slope (%)	9	4	15	13	34
Discharge (L/s)	9	0.00	1.31	0.03	9.30
Canopy Cover (%)	9	8	56	50	100
Bank Vegetation	9	0	11	13	20
Bank erosion (%)	9	0	14	0	50
Embeddedness (%)	9	0	31	12	100
Substrate:					
<i>Bedrock</i> (%)	9	0	0	0	0
<i>Boulder</i> (%)	9	0	0	0	0
<i>Cobble</i> (%)	9	0	11	0	100
<i>Gravel</i> (%)	9	0	56	100	100
<i>Sand</i> (%)	9	0	0	0	0
<i>Fine</i> (%)	9	0	0	0	0
<i>Other</i> (%)	9	0	33	0	100

Invertebrates

Invertebrate abundances varied from spring to spring and between site visits. Average abundance was 43 organisms per sample (range=3 to 162, Table 59). Chokecherry and Jewel Cave Spring harbored the most invertebrates with maximum counts of 162 and 137, respectively. Chokecherry Spring invertebrates consisted of *Sphaerium* *sp.* bivalves and *Callibaetis* *sp.* (Ephemeroptera). Likewise, *Callibaetis* *sp.* made up the majority of invertebrates at Jewel Cave Spring. *Hesperophylax* *sp.* (Trichoptera) was also consistently found at Jewel Cave and Prairie Dog springs. Tolerant taxa comprised 41% of the total abundance and 29% of the total taxa. Feeding guilds consisted mainly of collector gatherers (48%) and shredders (19%). Sprawlers (39%) and swimmers (25%) contributed the highest abundance for habit guilds.

Table 59. Optimal spring metrics for Chokecherry, Jewel Cave, and Prairie Dog Spring (JECA).

Metric	N	Minimum	Mean	Median	Maximum
Total Abundance	9	3	43	13	162
Total Richness	9	2	4	4	8
% EPT	9	0.0	35.5	38.9	97.1
% Chironomidae	9	0.0	0.5	0.0	4.9
EPT Richness	9	0	1	1	2
Chironomidae Richness	9	0	0	0	2
% Climbers	9	0.0	5.9	0.0	45.5
% Gliders	9	0.0	6.1	0.0	27.8
% Collector-gatherers	9	16.7	48.3	38.5	97.1
% Shredders	9	0.0	19.1	9.1	63.6
% Predators	9	0.0	11.3	3.1	45.5
Modified HBI	9	5.00	6.38	5.82	8.88

Knife River Indian Villages National Historic Site – Knife River

Physical and Chemical

Total phosphorus was the only parameter that exceeded water quality standards set by the state of North Dakota for the Knife River (Table 60). Total phosphorus (mean=0.29 mg/L) surpassed the limit of 0.1 mg/L. Problems with overnight shipping prevented us from analyzing more than one fecal coliform sample. However, results of this single analysis were below the state water quality standard.

Table 60. Summary of physical and chemical parameters of the Knife River (KNRI).

Parameter	N	Minimum	Mean	Median	Maximum
Dissolved Oxygen (mg/L)	30	6.9	8.4	8.4	10.8
Conductivity ($\mu\text{S}/\text{cm}$)	30	1044	1338	1312	1685
pH	30	7.7	8.2	8.3	8.5
Water Temperature ($^{\circ}\text{C}$)	30	16.3	21.7	21.6	27.9
Alkalinity (mg/L)	3	222	360	427	431
Turbidity (NTU)	3	5	14	17	20
TSS (mg/L)	3	10	31	32	52
TDS (mg/L)	3	91	848	1217	1237
Total Phosphorus (mg/L)	3	0.058	0.290	0.120	0.692
TKN (mg/L)	3	0.61	1.10	2.08	0.63
NH ₃ (mg/L)	3	<0.02	<0.02	<0.02	<0.02
NO ₃ (mg/L)	3	<0.1	0.2	<0.1	0.4
Fecal Coliform (org/100 mL)	1	90	90	90	90

Habitat

The Knife River flows into the Missouri River just outside park boundaries, but often had backflow from the Missouri River. This backflow is reflected in some of the current velocity measurements (Table 61). Up to 30 snags per transect were observed within this reach (mean=9). Substrate consisted of sand and silt/clay, but boulders occurred sporadically throughout the river, especially farther from the confluence with the Missouri River.

Table 61. Habitat characteristics for the Knife River (KNRI).

Parameter	N	Minimum	Mean	Median	Maximum
Bank Slope (%)	30	25	79	100	100
Max Current Velocity (m/s)	30	-0.05	0.07	0.03	0.35
Vegetation Density	30	0	11	15	20
Canopy Cover (%)	30	0	5	0	90
Bank Full (m)	30	1	6	6	11
Snags	30	0	9	8	30
Substrate:					
Bedrock (%)	30	0	0	0	0
Boulder (%)	30	0	3	0	100
Cobble (%)	30	0	0	0	0
Gravel (%)	30	0	0	0	0
Sand (%)	30	0	60	100	100
Fine (%)	30	0	37	0	100

Invertebrates

Invertebrate samples averaged 132 organisms and 9 taxa per sample for the Missouri River (Table 62). Insects contributed 98% of total abundance. Corixidae (Hemiptera) contributed the largest percentage of organisms (69%). Not surprisingly, swimmers were very abundant (mean=74%) and predators the most abundant feeding guilds (mean=82%). Tolerant taxa were more abundant than intolerant taxa (49%, 3%, respectively).

Table 62. Optimal large river metrics for Knife River (KNRI).

Metric	N	Minimum	Mean	Median	Maximum
Total Abundance	3	56	132	93	247
Total Richness	3	5	9	7	16
% EPT	3	0.0	2.7	1.5	6.5
% Chironomidae	3	0.0	12.0	7.5	28.6
Non-Insecta Richness	3	0	1	1	2
EPT Richness	3	0	1	1	3
Clinger Richness	3	0	1	2	2
Swimmer Richness	3	1	3	4	5
Collector-gatherer Richness	3	3	5	4	7
Collector-filterer Richness	3	0	0	0	0
Modified HBI	3	5.46	7.55	8.81	8.38

Knife River Indian Villages National Historic Site - Missouri River

Physical and Chemical

Most physical and chemical parameters met standards set by the state of North Dakota (Table 63). Ammonia samples, in particular, were all below detection. Only two fecal samples were analyzed due to problems with overnight shipping to the state health lab. However, the samples that were collected were well below that state's water quality standards.

Table 63. Physical and chemical parameters for the Missouri River (KNRI).

Parameter	N	Minimum	Mean	Median	Maximum
Dissolved Oxygen (mg/L)	60	8.0	9.8	9.8	12.3
Conductivity ($\mu\text{S}/\text{cm}$)	60	589	619	630	651
pH	60	7.6	8.1	8.2	8.3
Water Temperature ($^{\circ}\text{C}$)	60	11.7	15.4	14.9	22.4
Alkalinity (mg/L)	6	135	162	166	179
Turbidity (NTU)	6	3	34	8	173
TSS (mg/L)	6	2	11	12	21
TDS (mg/L)	6	383	459	466	523
Total Phosphorus (mg/L)	6	0.015	0.024	0.034	0.024
TKN (mg/L)	6	<0.23	0.16	<0.23	0.25
NH ₃ (mg/L)	6	<0.02	<0.02	<0.02	<0.02
NO ₃ (mg/L)	6	<0.1	0.07	<0.1	0.1
Fecal Coliform (org/100 mL)	2	10	10	10	10

Habitat

The banks of the Missouri River were primarily prairie with a few older stands of cottonwood trees. Understandably, canopy cover was low (mean=5%, Table 64). Bank slope was high (mean=56%), and over half our transects fell on vertical banks. Substrate was almost entirely sand (98%) with small areas of gravel (2%). Current velocity averaged 0.48 m/s with a maximum velocity of 1.80 m/s. Snag habitat was moderately abundant (mean=6 snags per transect).

Table 64. Habitat characteristics for the Missouri River (KNRI).

Parameter	N	Minimum	Mean	Median	Maximum
Bank Slope (%)	60	0	56	56	100
Max Current Velocity (m/s)	60	0.09	0.48	0.40	1.80
Vegetation Density	60	0	14	18	21
Canopy Cover (%)	60	0	5	0	90
Bank Full (m)	60	0	4.1	4.3	11
Snags	60	0	6	5	25
Substrate:					
<i>Bedrock (%)</i>	60	0	0	0	0
<i>Boulder (%)</i>	60	0	0	0	0
<i>Cobble (%)</i>	60	0	0	0	0
<i>Gravel (%)</i>	60	0	2	0	100
<i>Sand (%)</i>	60	0	98	100	100
<i>Fine (%)</i>	60	0	0	0	0

Invertebrates

Few invertebrates were found in the Missouri River at KNRI. An average of 12 invertebrates per sample representing 5 taxa were collected. The majority of these invertebrates belonged to Oligochaeta and Diptera (Chironomidae). Tolerant organisms contributed the most taxa (34%) and abundance (39%). Habit guilds were dominated by burrowers (38%) and swimmer taxa (28%). Collector-gatherers contributed the highest number of taxa (56%) and abundance (51%, Table 65).

Table 65. Optimal large river metrics for the Missouri River (KNRI).

Metric	N	Minimum	Mean	Median	Maximum
Total Abundance	6	2	12	13	21
Total Richness	6	2	5	5	7
% EPT	6	0.0	3.8	0.0	14.3
% Chironomidae	6	0.0	33.0	22.0	100.0
Non-Insecta Richness	6	0	2	2	3
EPT Richness	6	0	0	0	1
Clinger Richness	6	0	1	1	1
Swimmer Richness	6	0	1	1	2
Collector-gatherer Richness	6	1	3	3	4
Collector-filterer Richness	6	0	0	0	0
Modified HBI	6	5	7	7	9

Missouri National Recreational River – Missouri River

Physical and Chemical

All physical and chemical measurements from the Missouri River were below standards set by both South Dakota and Nebraska (Table 66). One reach was above the Gavins Point Dam and at the Niobrara River confluence, while the last two reaches were below the dam. Consequently, several measurements varied between reaches. Water temperatures above the dam averaged 20.0°C while temperatures below the dam were higher at 22.3°C.

Table 66. Physical and chemical parameters for the Missouri River (MNRR).

Parameter	N	Minimum	Mean	Median	Maximum
Dissolved Oxygen (mg/L)	90	8.0	8.9	9.1	10.0
Conductivity ($\mu\text{S}/\text{cm}$)	90	272	689	699	837
pH	90	7.7	8.2	8.3	8.5
Water Temperature ($^{\circ}\text{C}$)	90	15.7	21.5	22.4	25.2
Alkalinity (mg/L)	9	143	177	176	241
Turbidity (NTU)	9	3	17	10	66
TSS (mg/L)	9	2	22	14	60
TDS (mg/L)	9	371	469	439	641
Total Phosphorus (mg/L)	9	0.004	0.070	0.040	0.290
TKN (mg/L)	9	<0.23	0.30	<0.23	0.99
NH ₃ (mg/L)	9	<0.02	<0.02	<0.02	<0.02
NO ₃ (mg/L)	9	<0.10	0.08	<0.10	0.20
Fecal Coliform (org/100 mL)	8	<10	28	10	110

Habitat

Reach one was above the dam and at the confluence of the Niobrara River. The banks were mostly lined with wetland areas and cattails. These had low sloping banks and high bank vegetation. Reaches two and three were below Gavins Point Dam and were lined with steep banks and lower vegetation density. Bank full was also much higher at reaches two and three than reach one. Substrate was primarily sand and sand bars were common both above and below the dam. Some sandbar islands had older stands of cottonwood and willow tress which may indicate low flood frequency. Maximum current velocity reached 2.6 m/s with an average of 0.87 m/s (Table 67). Snags varied greatly between transects (range=0 to 75 snags per transect). Most snag habitats were observed below Gavins Point Dam (reach 2 mean = 18 snags).

Table 67. Habitat characteristics for the Missouri River (MNRR)

Parameter	N	Minimum	Mean	Median	Maximum
Bank Slope (%)	90	0	29	15	100
Max Current Velocity (m/s)	90	0.13	0.87	0.84	2.60
Vegetation Density	90	0	11	15	21
Canopy Cover (%)	90	0	11	0	100
Bank Full (m)	90	0.0	1.9	1.0	10.0
Snags	90	0	14	11	75
Substrate:					
<i>Bedrock (%)</i>	90	0	0	0	0
<i>Boulder (%)</i>	90	0	0	0	0
<i>Cobble (%)</i>	90	0	0	0	0
<i>Gravel (%)</i>	90	0	0	0	0
<i>Sand (%)</i>	90	0	99	100	100
<i>Fine (%)</i>	90	0	0	0	0

Invertebrates

An average of 54 invertebrates per sample were collected from the Missouri River at MNRR (Table 68). These invertebrates comprised an average of 8 different taxa. Reach one averaged a lower number of organisms (33 compared to 64 for reaches 2 and 3), but averaged the same number of taxa. Diptera taxa were more abundant in reaches 2 and 3 (45% compared to 24% for reach 1). EPT taxa were higher for reach 1 (mean=13%) than for reaches 2 and 3 (mean=10%). Missouri River samples were comprised of 38% tolerant abundance and 34% tolerant species. Dominant habit guilds included swimmers (27% abundance, 22% richness), burrowers (23% abundance, 25% richness), and sprawlers (22% abundance, 19% richness). Functional feeding guilds were comprised mostly of collector-gatherers (49% abundance, 54% richness).

Table 68. Optimal large river metrics for the Missouri River (MNRR).

Metric	N	Minimum	Mean	Median	Maximum
Total Abundance	9	9	54	19	282
Total Richness	9	4	8	5	22
% EPT	9	0.0	15.4	1.8	80.0
% Chironomidae	9	0.0	39.5	47.4	85.7
Non-Insecta Richness	9	0	2	1	5
EPT Richness	9	0	1	1	5
Clinger Richness	9	0	2	1	6
Swimmer Richness	9	0	2	1	4
Collector-gatherer Richness	9	1	4	4	7
Collector-filterer Richness	9	0	1	0	3
Modified HBI	9	4.60	5.89	6.07	6.48

Mount Rushmore National Memorial – Beaver Dam Creek

Physical and Chemical

Beaver Dam Creek's physical and chemical parameters varied widely (Table 69).

Dissolved oxygen averaged 5.6 mg/L (range=0.2 mg/L to 15.3 mg/L). Dissolved oxygen fell below 5.0 mg/L (state water quality standard) 44% of the time. Several measurements were below 1.0 mg/L. Total dissolved solids (TDS) also fluctuated widely (range=50mg/L to 7631mg/L). Total phosphorus averaged 2.46 mg/L and had a maximum measurement of 4.31 mg/L. These measurements of total phosphorus are very high compared to other streams in the region.

Table 69. Physical and chemical parameters of Beaver Dam Creek (MORU).

Parameter	N	Minimum	Mean	Median	Maximum
Dissolved Oxygen (mg/L)	50	0.2	5.6	5.4	15.3
Conductivity ($\mu\text{S}/\text{cm}$)	50	69	146	159	291
pH	50	5.6	--	6.5	7.3
Water Temperature ($^{\circ}\text{C}$)	50	9.5	14.0	13.1	24.4
Alkalinity (mg/L)	5	25	40	37	55
Turbidity (NTU)	5	3	148	21	675
TSS (mg/L)	5	3	305	10	1418
TDS (mg/L)	5	51	1596	103	7631
Total Phosphorus (mg/L)	5	0.012	0.970	0.052	4.310
TKN (mg/L)	5	0.25	2.46	0.32	10.6
NH ₃ (mg/L)	5	<0.02	0.07	<0.02	0.26
NO ₃ (mg/L)	5	<0.10	<0.10	<0.10	<0.10
Fecal Coliform (org/100 mL)	5	<10	8	<10	20

Habitat

Beaver Dam Creek contained an old beaver dam, creating a large pool. A small volume of water trickled from the dam into a narrow channel (mean discharge=1.733L/s). The pool area consisted mainly of highly embedded sand and gravel, while the narrow channel had somewhat embedded gravel, cobble and boulder. Bank erosion was low with a maximum of 2.5% bank erosion (mean=0.1%, Table 70).

Table 70. Habitat characteristics for Beaver Dam Creek at (MORU).

Parameter	N	Minimum	Mean	Median	Maximum
Bank Slope (%)	50	4	23	25	49
Discharge (m^3/s)	50	6.550E-04	1.733E-03	1.589E-03	3.400E-03
Bank Vegetation	50	0	10	9	19
Canopy Cover (%)	50	0	35	28	100
Bank erosion (%)	50	0	0.1	0.0	2.5
Embeddedness (%)	50	0	83	100	100
Substrate:					
<i>Bedrock (%)</i>	50	0	0	0	0
<i>Boulder (%)</i>	50	0	1.2	0	40
<i>Cobble (%)</i>	50	0	2.4	0	40
<i>Gravel (%)</i>	50	0	23	0	100
<i>Sand (%)</i>	50	0	52	60	100
<i>Fine (%)</i>	50	0	0	0	0

Invertebrates

An average of 276 invertebrates representing 20 taxa were collected from Beaver Dam Creek (Table 71). Many of these invertebrates came from the well vegetated pool area above the dam and consisted of several genera of Odonata. Several species of Diptera were also abundant at Beaver Dam Creek. Tolerant organisms were more abundant (mean=39%) and comprised the majority of the richness (46%). Feeding guild abundance and richness consisted primarily of collector-gatherers (49% and 40%). Habit guilds were mostly swimmers (24% abundance, 27% richness) and sprawlers (32% abundance, 31% taxa).

Table 71. Optimal small and medium sized stream metrics for Beaver Dam Creek at (MORU).

Metric	N	Minimum	Mean	Median	Maximum
Total Abundance	5	158	276	199	433
Total Richness	5	13	20	21	26
% Non-Insecta	5	5.1	22.1	43.6	46.7
EPT:Chironomidae	5	0.05	0.40	4.3	1.00
EPT Richness	5	1	2	2	5
Chironomidae Richness	5	0	7	7	14
Shannon Diversity Index (H')	5	2.27	2.49	2.45	2.80
Habit Guild H'	5	1.11	1.30	1.30	1.52
% Sprawler	5	13.1	32.4	32.5	44.7
FFG H'	5	0.96	1.09	1.10	1.27
Predator Richness	5	5	8	8	12
Modified HBI	5	5.51	5.99	5.87	6.57

Mount Rushmore National Memorial – Grizzly Creek

Physical and Chemical

Physical and chemical properties of Grizzly Creek were excellent; many chemical measurements were well below water quality standards or below detection (Table 72).

Dissolved oxygen was high (mean=9.6 mg/L). Turbidity and suspended solids were low (mean= 2 NTUs and 5 mg/L, respectively).

Table 72. Physical and chemical parameters for Grizzly Creek (MORU).

Parameter	N	Minimum	Mean	Median	Maximum
Dissolved Oxygen (mg/L)	30	7.8	9.6	9.7	11.3
Conductivity (μ S/cm)	30	62	74	80	82
pH	30	6.9	7.7	7.8	8.6
Water Temperature ($^{\circ}$ C)	30	10.0	12.5	12.7	14.6
Alkalinity (mg/L)	3	23	25	25	27
Turbidity (NTU)	3	1	2	1	4
TSS (mg/L)	3	3	5	4	7
TDS (mg/L)	3	5	26	21	51
Total Phosphorus (mg/L)	3	0.026	0.027	0.028	0.028
TKN (mg/L)	3	<0.23	0.16	<0.23	0.25
NH ₃ (mg/L)	3	<0.02	<0.02	<0.02	<0.02
NO ₃ (mg/L)	3	<0.10	<0.10	<0.10	<0.10
Fecal Coliform (org/100 mL)	2	<10	53	53	100

Habitat

Grizzly Creek flows through much of the Black Elk Wilderness Area and a corner of MORU. These pristine areas have helped keep the habitat in superb condition. Grizzly Creek has a good mixture of riffles and pools. The stream substrate consisted mainly of boulders, both in and lining the stream, but cobble and gravel also composed much of the substrate material (Table 73). Average discharge was 70L/s. Embeddedness was low (mean=16%). No bank erosion was observed from this Grizzly Creek reach, and bank vegetation (density board and canopy cover) was high (mean=5).

Table 73. Habitat characteristics for Grizzly Creek (MORU).

Parameter	N	Minimum	Mean	Median	Maximum
Bank Slope (%)	30	12	34	21	100
Discharge (m ³ /s)	30	0.0106	0.0658	0.0453	0.1417
Bank Vegetation	30	0	5	0	21
Canopy Cover (%)	30	20	63	64	100
Bank erosion (%)	30	0	0	0	0
Embeddedness (%)	30	2	16	12	50
Substrate:					
<i>Bedrock (%)</i>	30	0	0	0	0
<i>Boulder (%)</i>	30	0	47	40	100
<i>Cobble (%)</i>	30	0	21	20	60
<i>Gravel (%)</i>	30	0	31	40	80
<i>Sand (%)</i>	30	0	1	0	20
<i>Fine (%)</i>	30	0	0	0	0

Invertebrates

An average of 211 invertebrates representing 19 taxa were collected from Grizzly Creek (Table 74). EPT comprised 61% of the total abundance, while Diptera comprised 23%. Intolerant organisms (31%) were more abundant than tolerant to (10%). Average HBI was also low compared to other Black Hills streams (4.4). Collector-gatherers dominated feeding guilds in abundance (59%) and richness (49%). Habit guilds were dominated by sprawlers (23% abundance, 30% richness). Shannon-Wiener Diversity was high compared to other Black Hills streams (2.34).

Table 74. Optimal small and medium sized stream metrics for Grizzly Creek (MORU).

Metric	N	Minimum	Mean	Median	Maximum
Total Abundance	3	145	211	175	312
Total Richness	3	13	19	19	25
% Non-Insecta	3	1.1	2.8	1.3	6.0
EPT:Chironomidae	3	0.70	0.78	0.72	0.92
EPT Richness	3	5	8	8	11
Chironomidae Richness	3	4	6	5	8
Shannon Diversity Index (H')	3	2.05	2.34	2.32	2.64
Habit Guild H'	3	1.21	1.34	1.40	1.42
% Sprawler	3	3.8	30.2	26.2	60.6
FFG H'	3	0.98	1.08	1.09	1.18
Predator Richness	3	2	5	5	8
Modified HBI	3	4.12	4.41	4.36	4.74

Mount Rushmore National Memorial – Lafferty Gulch

Physical and Chemical

Although a small amount of water is discharged from Mount Rushmore's wastewater treatment facility into Lafferty Gulch, levels of fecal coliform were well below South Dakota's state standards during the sampling period. Dissolved oxygen was high (mean=9.9mg/L). All ammonia levels were also below detection (Table 75).

Table 75. Chemical and physical parameters for Lafferty Gulch (MORU).

Parameter	N	Minimum	Mean	Median	Maximum
Dissolved Oxygen (mg/L)	60	8.5	9.9	10.1	11.1
Conductivity (μ S/cm)	60	398	502	530	590
pH	60	7.4	--	8.4	8.9
Water Temperature ($^{\circ}$ C)	60	10.0	12.5	13.6	14.0
Alkalinity (mg/L)	6	8	142	177	185
Turbidity (NTU)	6	5	38	10	179
TSS (mg/L)	6	7	16	14	28
TDS (mg/L)	6	263	315	312	386
Total Phosphorus (mg/L)	6	1.520	1.977	2.050	2.350
TKN (mg/L)	6	<0.23	0.21	0.24	0.25
NH ₃ (mg/L)	6	<0.02	<0.02	<0.02	<0.02
NO ₃ (mg/L)	6	1.30	1.87	1.90	2.40
Fecal Coliform (org/100 mL)	4	5	13	8	30

Habitat

Lafferty Gulch was a heavily wooded area (canopy mean=100%) with steep slopes on each side of the stream. Large boulders lined the stream and also composed a large portion of the stream's substrate (mean=33%, Table 76). Gravel contributed the most to substrate (mean=41%) and embeddedness was low (mean=25%). Discharge was also low (mean=0.88 L/s).

Table 76. Habitat characteristics for Lafferty Gulch (MORU).

Parameter	N	Minimum	Mean	Median	Maximum
Bank Slope (%)	60	11	45	40	100
Discharge (m ³ /s)	60	3.675E-04	8.812E-04	1.788E-03	6.750E-04
Bank Vegetation	60	0	5	3	21
Canopy Cover (%)	60	100	100	100	100
Bank erosion (%)	60	0	0	0	0
Embeddedness (%)	60	0	25	12	100
Substrate:					
<i>Bedrock</i> (%)	60	0	4	0	100
<i>Boulder</i> (%)	60	0	33	20	100
<i>Cobble</i> (%)	60	0	6	0	60
<i>Gravel</i> (%)	60	0	41	40	100
<i>Sand</i> (%)	60	0	16	0	100
<i>Fine</i> (%)	60	0	0	0	0

Invertebrates

An average of 334 invertebrates representing 11 taxa were collected from Lafferty Gulch (Table 77). Diptera taxa contributed much of the overall richness (mean=46%). Intolerant organisms were abundant (51%). Intolerant and tolerant taxa species contributed an average of 25% and 21%, respectively. Collector-gatherer abundance was the most abundant feeding guild (70%) and clinger abundance was highest for habit guilds (50%). The contribution of the three most abundant taxa was also high (76%).

Table 77. Optimal small and medium sized stream metrics for Lafferty Gulch (MORU).

Metric	N	Minimum	Mean	Median	Maximum
Total Abundance	6	45	334	266	690
Total Richness	6	9	11	11	14
% Non-Insecta	6	0.0	13.5	11.5	29.2
EPT:Chironomidae	6	0.40	0.68	0.64	0.95
EPT Richness	6	1	3	3	4
Chironomidae Richness	6	1	4	4	6
Shannon Diversity Index	6	1.08	1.58	1.46	2.18
Habit Guild H'	6	0.84	1.04	0.99	1.24
% Sprawler	6	0.6	5.0	4.6	12.5
FFG H'	6	0.31	0.72	0.75	1.12
Predator Richness	6	8	11	11	14
Modified HBI	6	4.03	4.56	4.59	5.13

Niobrara National Scenic River – Niobrara River

Physical and Chemical

Niobrara River physical and chemical measurements all met state water quality standards (Table 78). Fecal coliform bacteria were below state water quality standards for all samples (range=10-140/100 mL). Water temperature was warm (range=16°-23.5°C).

Table 78. Physical and chemical parameters of the Niobrara River (NIOB).

Parameter	N	Minimum	Mean	Median	Maximum
Dissolved Oxygen (mg/L)	90	7.6	9.3	9.5	11.2
Conductivity (µS/cm)	90	169	218	216	275
pH	90	7.5	8.3	8.4	8.8
Water Temperature (°C)	90	18.5	23.5	23.5	18.3
Alkalinity (mg/L)	6	78	107	106	139
Turbidity (NTU)	6	3	8	7	15
TSS (mg/L)	6	1	36	45	51
TDS (mg/L)	6	61	151	160	240
Total Phosphorus (mg/L)	6	0.107	0.134	0.123	0.171
TKN (mg/L)	6	0.23	0.45	0.39	0.71
NH ₃ (mg/L)	6	<0.02	<0.02	<0.02	<0.02
NO ₃ (mg/L)	6	0.20	0.32	0.30	0.40
Fecal Coliform (org/100 mL)	4	10	55	35	140

Habitat

Habitat varied among reaches. Reaches 1 and 2 had primarily bedrock substrate.

Vegetation density and bank slopes were higher on these two reaches. Reach 3 substrate was primarily sand. Grasses and shrubs accounted for the lower vegetation density. Canopy cover and bank vegetation were moderate (mean=23% and 9, respectively). Current velocity also slowed at reach three since the river widened in this area considerably. Overall, current velocity reached 6.2m/s (mean=0.63m/s). Snags averaged 6 per transect (Table 79). Snags were also more prevalent in reach three as sand bars and slow, shallow water became more common.

Table 79. Habitat characteristics for the Niobrara River at (NIOB).

Parameter	N	Minimum	Mean	Median	Maximum
Bank Slope (%)	90	0	38	32	100
Max Current Velocity (m/s)	90	0.10	0.63	1.2	6.2
Vegetation Density	90	0	9	11	21
Canopy Cover (%)	90	0	23	0	100
Bank Full (m)	90	0	3.8	2	30
Snags	90	0	6	3	32
Substrate:					
Bedrock (%)	90	0	38	0	100
Boulder (%)	90	0	1	0	100
Cobble (%)	90	0	1	0	100
Gravel (%)	90	0	0	0	0
Sand (%)	90	0	60	100	100
Fine (%)	90	0	0	0	0

Invertebrates

An average of 1773 invertebrates per sample were collected from the Niobrara representing 18 species (Table 80). Dominant invertebrates included Ephemeroptera (*Tricorythodes sp.*, *Traverella albertana*) and non-insects (Platyhelminthes: *Girardia sp.* and Mollusca: *Physa sp.*). More invertebrates were found in reaches 1 and 2 (reach 1 and 2 mean=2206 organisms) compared to reach 3 (reach 3 mean=473 organisms). Intolerant organisms (22%)

outnumbered tolerant (17%) in abundance and richness (31% and 22%, respectively).

Collector-gatherers contributed the most to feeding guilds abundance (52%), while swimmers (41%) and clingers (31%) were the most abundant of habit guilds.

Table 80. Optimal large river metrics for the Niobrara River (NIOB).

Metric	N	Minimum	Mean	Median	Maximum
Total Abundance	8	83	1773	835	9047
Total Richness	8	6	18	21	26
% EPT	8	20.2	54.4	61.2	79.5
% Chironomidae	8	2.0	7.2	7.3	12.6
Non-Insecta Richness	8	1	3	3	6
EPT Richness	8	2	7	7	10
Clinger Richness	8	2	6	7	9
Swimmer Richness	8	2	4	4	6
Collector-gatherer Richness	8	3	8	7	13
Collector-filterer Richness	8	1	2	3	3
Modified HBI	8	2.91	4.72	4.83	5.56

Niobrara National Scenic River – Berry Falls

Physical and Chemical

Fecal coliform bacteria was the only physical/chemical parameter surpassing state water quality standards at Berry Falls (mean=255/100mL, Table 81). Nitrates were also high compared to other NIOB streams (mean=1.07mg/L). Turbidity was very low (mean=3 NTU).

Table 81. Optimal small-to-medium sized stream metrics for Berry Falls (NIOB).

Parameter	N	Minimum	Mean	Median	Maximum
Dissolved Oxygen (mg/L)	30	8.5	9.0	9.1	9.2
Conductivity ($\mu\text{S}/\text{cm}$)	30	138	149	146	187
pH	30	7.4	--	8.1	8.3
Water Temperature ($^{\circ}\text{C}$)	30	17.2	19.6	19.9	21.6
Alkalinity (mg/L)	3	57	61	61	65
Turbidity (NTU)	3	2	3	3	5
TSS (mg/L)	3	12	24	26	34
TDS (mg/L)	3	85	138	155	173
Total Phosphorus (mg/L)	3	0.111	0.112	0.111	0.136
TKN (mg/L)	3	<0.23	0.16	<0.23	0.25
NH ₃ (mg/L)	3	<0.02	<0.02	<0.02	<0.02
NO ₃ (mg/L)	3	1.00	1.07	1.10	1.10
Fecal Coliform (org/100 mL)	2	150	255	255	360

Habitat

High canopy cover and bank vegetation was the typical riparian condition for Berry Falls (mean=99% and 4). Substrate consisted primarily of bedrock (mean=89%, Table 82). Flow was relatively fast (mean=178 L/s), embeddedness was low (mean=13%) and bank erosion was moderate (mean=33%).

Table 82. Habitat characteristics for Berry Falls (NIOB).

Parameter	N	Minimum	Mean	Median	Maximum
Bank Slope (%)	30	24	56	57	98
Discharge (m^3/s)	30	0.109	0.178	0.126	0.299
Bank Vegetation	30	0	4	0	11
Canopy Cover (%)	30	83	99	100	100
Bank erosion (%)	30	0	33	34	100
Embeddedness (%)	30	0	13	0	60
Substrate:					
<i>Bedrock (%)</i>	30	0	89	100	100
<i>Boulder (%)</i>	30	0	0	0	0
<i>Cobble (%)</i>	30	0	0	0	0
<i>Gravel (%)</i>	30	0	1	0	20
<i>Sand (%)</i>	30	0	7	0	80
<i>Fine (%)</i>	30	0	0	0	0

Invertebrates

An average of 989 organisms comprising 11 taxa were collected from Berry Falls (Table 83). On the first site visit, Simuliidae was by far the dominant invertebrate family, composing nearly 80% of the invertebrate abundance. By the second and third visit, Simuliidae dwindled to 5% and 9%, and Ephemeroptera contributed the greatest to invertebrate abundance (mean=50%). Intolerant taxa comprised 44% of the total taxa and 17% of the total abundance. Tolerant taxa comprised 13% of the total taxa and 9% of the total abundance. HBI values were moderate (5.13). Feeding guild abundance was dominated by collector gatherers (59%) and collector-filterers (35%). Habit guild abundance was comprised primarily of swimmers (48%) and clingers (45%).

Table 83. Optimal small-to-medium sized stream metrics for Berry Falls (NIOB).

Metric	N	Minimum	Mean	Median	Maximum
Total Abundance	3	41	989	316	2609
Total Richness	3	7	11	7	19
% Non-Insecta	3	0.0	16.0	22.7	25.3
EPT:Chironomidae	3	0.94	0.98	1.00	1.00
EPT Richness	3	2	3	3	5
Chironomidae Richness	3	0	1	0	4
Shannon Diversity Index	3	0.54	1.37	1.53	2.03
Habit Guild H'	3	0.30	0.66	0.65	1.02
% Sprawler	3	0.0	4.8	4.5	10.0
FFG H'	3	0.37	0.54	0.47	0.79
Predator Richness	3	1	2	1	3
Modified HBI	3	4.45	5.13	5.17	5.78

Niobrara National Scenic River – Fort Falls

Physical and Chemical

Fort Falls' physical and chemical parameters were similar to other streams at NIOB.

All parameters met water quality standards (Table 84). Water temperature was highest at Fort Falls compared to other NIOB streams (mean=20.4°C).

Table 84. Physical and chemical parameters for Fort Falls (NIOB).

Parameter	N	Minimum	Mean	Median	Maximum
Dissolved Oxygen (mg/L)	60	8.0	8.8	8.8	9.5
Conductivity (µS/cm)	60	159	180	181	201
pH	60	7.2	--	8.2	8.6
Water Temperature (°C)	60	18.4	20.4	18.9	24.1
Alkalinity (mg/L)	3	92	111	115	126
Turbidity (NTU)	2	2	3	3	4
TSS (mg/L)	3	18	30	20	50
TDS (mg/L)	3	27	111	153	154
Total Phosphorus (mg/L)	3	0.065	0.084	0.067	0.120
TKN (mg/L)	3	<0.23	0.29	0.25	0.50
NH ₃ (mg/L)	3	<0.02	<0.02	<0.02	<0.02
NO ₃ (mg/L)	3	0.10	0.13	0.10	0.20
Fecal Coliform (org/100 mL)	2	10	60	60	110

Habitat

Fort Falls riparian condition was characterized by high canopy cover (mean=95%) and bank vegetation (mean=8, Table 85). Most bank erosion at Fort Falls was associated with visitor use, much of it adjacent to the falls. Embeddedness was low (mean=31%) with much of the substrate composed of bedrock (mean=45%) and gravel (mean=37%).

Table 85. Habitat characteristics for Fort Falls (NIOB).

Parameter	N	Minimum	Mean	Median	Maximum
Bank Slope (%)	60	16	61	69	100
Discharge (m ³ /s)	60	0.025	0.034	0.030	0.047
Bank Vegetation	60	0	8	9	21
Canopy Cover (%)	60	61	95	100	100
Bank erosion (%)	60	0	31	34	75
Embeddedness (%)	60	0	24	23	100
Substrate:					
<i>Bedrock (%)</i>	60	0	45	30	100
<i>Boulder (%)</i>	60	0	0	0	20
<i>Cobble (%)</i>	60	0	4	0	60
<i>Gravel (%)</i>	60	0	37	40	100
<i>Sand (%)</i>	60	0	13	0	100
<i>Fine (%)</i>	60	0	0	0	20

Invertebrates

Fifteen taxa and an average of 411 invertebrates were collected from Fort Falls (Table 86). EPT comprised 41% of the abundance and Diptera comprised another 41%. Intolerant organisms outnumbered tolerant in abundance (9% intolerant and 3% tolerant) and richness (32% intolerant and 22% tolerant). Collector-gatherers contributed the most to feeding guild abundance (53%) and richness (39%). Clingers contributed 50% of the total habit guild abundance and 33% of the richness.

Table 86. Optimal small-to-medium sized stream metrics for Fort Falls (NIOB).

Metric	N	Minimum	Mean	Median	Maximum
Total Abundance	6	116	411	427	701
Total Richness	6	8	15	13	26
% Non-Insecta	6	0.27	2.32	2.30	4.44
EPT:Chironomidae	6	0.18	0.76	0.90	1.00
EPT Richness	6	3	4	4	6
Chironomidae Richness	6	0	2	2	3
Shannon Diversity Index	6	1.11	1.53	1.93	1.56
Habit Guild H'	6	0.73	0.97	0.96	1.28
% Sprawler	6	1.3	5.7	3.9	13.4
FFG H'	6	0.58	0.84	0.89	0.98
Predator Richness	6	0	3	3	6
Modified HBI	6	3.74	4.57	4.63	5.06

Niobrara National Scenic River – Smith Falls

Physical and Chemical

Smith Falls physical and chemical parameters all met state water quality standards. Low turbidity (mean=2 NTUs), suspended solids (mean=5 mg/L), and dissolved oxygen (mean=9.7mg/L) were observed at Smith Falls (Table 87). Water temperature was lowest at Smith Falls compared to other NIOB streams (mean=16.7).

Table 87. Physical and chemical parameters for Smith Falls (NIOB).

Parameter	N	Minimum	Mean	Median	Maximum
Dissolved Oxygen (mg/L)	60	8.8	9.7	9.7	10.7
Conductivity (µS/cm)	60	75	131	130	146
pH	60	7.1	8.2	8.2	8.4
Water Temperature (°C)	60	13.3	16.7	16.8	18.8
Alkalinity (mg/L)	4	56	95	78	167
Turbidity (NTU)	3	1	2	1	6
TSS (mg/L)	3	3	5	5	7
TDS (mg/L)	3	57	179	135	344
Total Phosphorus (mg/L)	3	0.087	0.375	0.109	0.930
TKN (mg/L)	3	<0.23	0.24	0.25	0.35
NH ₃ (mg/L)	3	<0.02	<0.02	<0.02	<0.02
NO ₃ (mg/L)	3	0.20	0.73	1.00	1.00
Fecal Coliform (org/100 mL)	2	50	140	140	230

Habitat

Smith Falls is located within a Nebraska State Park just off the Niobrara River.

Canoers and rafters would often pull their canoes into the park area below the falls and walk to the falls. Most bank erosion observed at Smith Falls occurred just below the falls where visitors leave the wooden walkway and walk into the stream. This area is completely devoid of vegetation. However, overall bank erosion, however, was low (mean=18%, Table 88).

Substrate was composed primarily of gravel (mean=47%) and bedrock (mean=24%). Canopy cover was high (mean=81%).

Table 88. Habitat characteristics for Smith Falls (NIOB) for the NGPN.

Parameter	N	Minimum	Mean	Median	Maximum
Bank Slope (%)	60	35	71	71	100
Discharge (m ³ /s)	60	0.027	0.072	0.066	0.124
Bank Vegetation	60	0	6	6	20
Canopy Cover (%)	60	10	81	89	100
Bank erosion (%)	60	0	18	6	95
Embeddedness (%)	60	0	21	14	100
Substrate:					
<i>Bedrock (%)</i>	60	0	24	20	100
<i>Boulder (%)</i>	60	0	2	0	20
<i>Cobble (%)</i>	60	0	8	0	60
<i>Gravel (%)</i>	60	0	47	40	100
<i>Sand (%)</i>	60	0	13	0	100
<i>Fine (%)</i>	60	0	0	0	0

Invertebrates

An average of 333 invertebrates representing 17 taxa were collected from Smith Falls (Table 89). Insects accounted for 92% of the total abundance of invertebrates. Trichoptera was the most dominant order (31%). Intolerant species were also dominant (richness=46%) compared to tolerant organisms (richness=13%). HBI was low (3.53). Collector-gatherers were the dominant feeding guild for abundance (53%) and richness (45%). Habit guilds abundance and richness consisted primarily of clingers (47% and 46%).

Table 89. Optimal small-to-medium sized stream metrics for Smith Falls (NIOB).

Metric	N	Minimum	Mean	Median	Maximum
Total Abundance	6	76	333	362	584
Total Richness	6	7	17	15	33
% Non-Insecta	6	3.6	8.5	7.5	14.8
EPT:Chironomidae	6	0.95	0.98	0.98	1.00
EPT Richness	6	2	5	5	8
Chironomidae Richness	6	0	1	1	3
Shannon Diversity Index	6	1.67	1.81	1.83	1.93
Habit Guild H'	6	0.76	1.04	0.99	1.43
% Sprawler	6	0.5	5.8	3.0	19.5
FFG H'	6	0.78	0.99	1.01	1.17
Predator Richness	6	0	2	2	4
Modified HBI	6	3.07	3.53	3.38	4.53

Scott's Bluff National Monument – North Platte River

Physical and Chemical

Fecal coliforms exceeded state water quality standards in 2 of the 4 samples collected (200/100mL and 300/100mL) from the North Platte River. These samples were both collected in July of 2004. All other physical/chemical parameters met state water quality standards (Table 90).

Table 90. Physical and chemical parameters for the North Platte River (SCBL).

Parameter	N	Minimum	Mean	Median	Maximum
Dissolved Oxygen (mg/L)	30	8.2	8.9	8.8	10.0
Conductivity (µS/cm)	30	797	959	1020	1031
pH	30	8.0	--	8.1	8.4
Water Temperature (°C)	30	17.4	20.4	20.1	22.8
Alkalinity (mg/L)	6	115	191	200	248
Turbidity (NTU)	6	1	29	10	80
TSS (mg/L)	6	8	51	30	124
TDS (mg/L)	6	580	703	659	896
Total Phosphorus (mg/L)	6	0.027	0.100	0.058	0.224
TKN (mg/L)	6	<0.23	0.41	0.52	0.65
NH ₃ (mg/L)	6	<0.02	<0.02	<0.02	<0.02
NO ₃ (mg/L)	6	1.00	2.38	2.35	3.79
Fecal Coliform (org/100 mL)	4	80	175	160	300

Habitat

The North Platte River flowed adjacent to the northern edge of the park and consisted of sand substrate (mean=93%), few snags (mean=2.1 per transect) and little canopy cover (mean=20%, Table 91). Bank slopes were relatively low (mean=31%). Maximum current velocities reached 0.91 m/s.

Table 91. Habitat characteristics for the North Platte River (SCBL).

Parameter	N	Minimum	Mean	Median	Maximum
Bank Slope (%)	30	3	31	28	68
Max Current Velocity (m/s)	30	0.23	0.50	0.47	0.91
Vegetation Density	30	0	9	6	21
Canopy Cover (%)	30	0	20	0	100
Bank Full (m)	30	0.1	2.1	2	7.5
Snags	30	0	2	2	5
Substrate:					
<i>Bedrock (%)</i>	30	0	0	0	0
<i>Boulder (%)</i>	30	0	0	0	0
<i>Cobble (%)</i>	30	0	3	0	100
<i>Gravel (%)</i>	30	0	3	0	100
<i>Sand (%)</i>	30	0	93	100	100
<i>Fine (%)</i>	30	0	0	0	0

Invertebrates

An average of 185 invertebrates were collected from the North Platte River representing 11 different taxa (Table 92). Ephemeroptera (primarily *Baetis spp*) made up 62% of the total invertebrates, and Diptera (primarily *Simulium sp*) contributed another 34% of the total abundance. Intolerant organisms comprised 27% of the abundance and 21% of the richness, while tolerant organisms contributed 6% to the total abundance and 27% to the total richness. Feeding guilds were dominated by collector gatherers (65% abundance, 60% taxa). Habit guild abundance was primarily comprised of swimmers (36%) and clingers (47%). Richness, however, was comprised mostly of clingers (32%) and sprawler taxa (24%).

Table 92. Optimal large river metrics for the North Platte River (SCBL).

Metric	N	Minimum	Mean	Median	Maximum
Total Abundance	3	101	185	119	336
Total Richness	3	9	11	12	12
% EPT	3	43.5	62.0	56.3	86.1
% Chironomidae	3	2.1	9.7	12.9	14.1
Non-Insecta Richness	3	0	1	1	2
EPT Richness	3	3	4	4	4
Clinger Richness	3	2	3	4	4
Swimmer Richness	3	1	2	1	3
Collector-gatherer Richness	3	5	7	6	9
Collector-filterer Richness	3	1	2	2	2
Modified HBI	3	4.15	4.41	4.29	4.78

Scotts Bluff National Monument – Central Canal

Physical and Chemical

The Central Canal receives its water from the North Platte River. This irrigation canal flows continuously throughout the year if water is present in the North Platte River. Physical and chemical parameters mostly met water quality standards. Fecal coliform samples, however, were above Nebraska water quality standards for primary contact recreation in two samples collected during July 2004 (Table 93).

Table 93. Physical and chemical parameters for Central Canal (SCBL).

Parameter	N	Minimum	Mean	Median	Maximum
Dissolved Oxygen (mg/L)	30	5.7	8.3	8.7	9.4
Conductivity (µS/cm)	30	822	976	1032	1052
pH	30	8.1	--	8.2	8.4
Water Temperature (°C)	30	20.4	23.2	23.2	26.2
Alkalinity (mg/L)	7	116	181	186	249
Turbidity (NTU)	8	5	34	10	88
TSS (mg/L)	8	9	62	29	174
TDS (mg/L)	8	253	607	690	719
Total Phosphorus (mg/L)	8	0.037	0.151	0.066	0.470
TKN (mg/L)	8	0.25	0.60	0.50	1.38
NH ₃ (mg/L)	8	<0.02	0.02	<0.02	0.03
NO ₃ (mg/L)	8	1.60	2.92	3.45	3.70
Fecal Coliform (org/100 mL)	6	50	290	205	700

Habitat

Central Canal has sandy substrate (mean=100%) and low canopy cover (mean=12%).

Average current velocity was 0.61 m/s (range=0.42m/s to 0.85m/s). No snags were observed within the canal (Table 94).

Table 94. Habitat characteristics for Central Canal of (SCBL).

Parameter	N	Minimum	Mean	Median	Maximum
Bank Slope (%)	30	12	37	36	62
Max Current Velocity (m/s)	30	0.42	0.61	0.60	0.85
Vegetation Density	30	0	12	15	21
Canopy Cover (%)	30	0	12	0	100
Bank Full (m)	30	0.5	2.4	2.5	6.0
Snags	30	0	0	0	0
Substrate:					
Bedrock (%)	30	0	0	0	0
Boulder (%)	30	0	0	0	0
Cobble (%)	30	0	0	0	0
Gravel (%)	30	0	0	0	0
Sand (%)	30	100	100	100	100
Fine (%)	30	0	0	0	0

Invertebrates

Invertebrate counts ranged from 144 to 595 (mean=301, Table 95), and richness averaged 17 with Diptera and EPT taxa making up 32% and 38% of the total richness, respectively. *Traverella albertana* (Leptophlebiidae) comprised the majority of Ephemeroptera (97 organisms). Intolerant organisms (35%) had higher abundance than tolerant organisms (24%). Fifty-seven percent of the feeding guild abundance was comprised of collector-gatherers. Habit guild abundance was dominated by swimmers and clingers (43% and 38%, respectively).

Table 95. Optimal large river metrics for Central Canal at (SCBL).

Metric	N	Minimum	Mean	Median	Maximum
Total Abundance	3	144	301	165	595
Total Richness	3	15	17	18	19
% EPT	3	64.8	77.9	83.3	85.5
% Chironomidae	3	3.5	9.0	9.5	13.9
Non-Insecta Richness	3	2	3	3	4
EPT Richness	3	4	6	7	8
Clinger Richness	3	5	5	5	6
Swimmer Richness	3	3	4	3	5
Collector-gatherer Richness	3	9	10	10	12
Collector-filterer Richness	3	2	2	2	3
Modified HBI	3	3.35	4.85	3.97	7.23

Scotts Bluff National Monument – Gering Canal

Physical and Chemical

The Gering Canal flowed through the interior of the park. Flow in the canal was regulated and during much of the year no water was present. The canal could only be sampled one time due to limited flow (July 2004). Fecal coliform bacteria was the only measurement exceeding state water quality standards (mean=700/100mL) and was above standards for all samples (Table 96). Dissolved oxygen only varied slightly among transects (range=8.1mg/L to 8.6mg/L).

Table 96. Physical and chemical parameters for Gering Canal at (SCBL).

Parameter	N	Minimum	Mean	Median	Maximum
Dissolved Oxygen (mg/L)	30	8.1	8.4	8.4	8.6
Conductivity ($\mu\text{S}/\text{cm}$)	30	707	783	786	789
pH	30	8.2	--	8.3	8.4
Water Temperature ($^{\circ}\text{C}$)	30	19.6	20.9	20.9	22.1
Alkalinity (mg/L)	2	175	181	181	186
Turbidity (NTU)	2	351	400	400	449
TSS (mg/L)	2	479	507	507	535
TDS (mg/L)	2	459	467	467	474
Total Phosphorus (mg/L)	2	0.776	0.799	0.799	0.822
TKN (mg/L)	2	0.78	1.01	1.01	1.24
NH ₃ (mg/L)	2	<0.02	<0.02	<0.02	<0.02
NO ₃ (mg/L)	2	0.30	0.30	0.30	0.30
Fecal Coliform (org/100 mL)	2	400	700	700	1000

Habitat

The Gering Canal is characterized by steep banks (mean= 67%) and silt/clay substrate (mean=83%). Little canopy cover was observed along the canal (mean=2%, Table 97). Most trees and vegetation are managed (burned, cut) by canal management to reduce the water intake by the vegetation (pers communication) and reduce obstruction to flow. Snags in the canal were also removed to maximize flow (mean=0 per transect).

Table 97. Habitat characteristics for Gering Canal (SCBL)

Parameter	N	Minimum	Mean	Median	Maximum
Bank Slope (%)	30	28	67	64	100
Max Current Velocity (m/s)	30	0.12	0.40	0.35	0.86
Vegetation Density	30	0	16	18	21
Canopy Cover (%)	30	0	2	0	30
Bank Full (m)	30	1.5	3.5	3.5	7.5
Snags	30	0	0	0	0
Substrate:					
Bedrock (%)	30	0	0	0	0
Boulder (%)	30	0	0	0	0
Cobble (%)	30	0	0	0	0
Gravel (%)	30	0	0	0	0
Sand (%)	30	0	0	0	0
Fine (%)	30	0	83	100	100
Other (%)	30	0	16	0	100

Invertebrates

Average abundance reached 101 invertebrates, while richness averaged 6 taxa (Table 98). Intolerant taxa (57%) outnumbered tolerant taxa (9%). Intolerant abundance was 81% while tolerant organisms composed less than 1% of the total abundance (0.55%).

Heptageniidae mayflies accounted for almost all of the intolerant organisms (92% of intolerant organisms). Collector-gatherers contributed the most to feeding guild richness (38%), while habit guild richness was comprised primarily of clingers (61%). Percent EPT was surprisingly high at Gering Canal (95%), where flows are strictly regulated or absent during some parts of the year.

Table 98. Optimal large river invertebrate metrics for Gering Canal (SCBL).

Metric	N	Minimum	Mean	Median	Maximum
Total Abundance	3	47	101	96	159
Total Richness	3	4	6	7	8
% EPT	3	92.7	95.7	95.7	98.7
% Chironomidae	3	0.0	0.3	0.0	1.0
Non-Insecta Richness	3	0	1	0	2
EPT Richness	3	3	4	4	5
Clinger Richness	3	2	4	4	6
Swimmer Richness	3	0	1	1	1
Collector-gatherer Richness	3	1	2	2	4
Collector-filterer Richness	3	0	1	2	2
Modified HBI	3	0.87	1.47	0.94	2.60

Scotts Bluff National Monument – Scotts Spring

Physical and Chemical

Scotts Spring had no physical or chemical attributes that exceeded state water quality standards (Table 99). Water temperature was moderate (mean=14.4°C) and alkalinity was comparable to other SCBL systems (mean=143).

Table 99. Physical and chemical parameters of Scott's Spring at (SCBL).

Parameter	N	Minimum	Mean	Median	Maximum
Dissolved Oxygen (mg/L)	3	8.2	8.4	8.3	8.6
Conductivity ($\mu\text{S}/\text{cm}$)	3	309	321	322	332
pH	3	7.9	--	7.9	8.1
Water Temperature ($^{\circ}\text{C}$)	3	12.8	14.4	13.3	17.0
Alkalinity (mg/L)	3	134	143	147	148
Turbidity (NTU)	3	28	31	33	33
TSS (mg/L)	3	88	124	99	185
TDS (mg/L)	3	251	331	313	429
Total Phosphorus (mg/L)	3	0.081	0.209	0.112	0.442
TKN (mg/L)	3	<0.23	0.30	<0.23	0.68
NH ₃ (mg/L)	3	<0.02	<0.02	<0.02	<0.02
NO ₃ (mg/L)	3	0.70	0.80	0.80	0.90
Fecal Coliform (org/100 mL)	3	<10	10	<10	20

Habitat

Scott's Spring is a small spring located just off a walking path at SCBL. Very little flow was discharged from the spring in our study years (mean=0.279 L/s). Bank slope was low (mean=6%) and erosion was low (mean=2%, Table 100).

Table 100. Habitat characteristics for Scott's Spring (SCBL).

Parameter	N	Minimum	Mean	Median	Maximum
Bank Slope (%)	2	5.0	5.5	5.5	6
Discharge (L/s)	3	0.02	0.28	0.02	0.80
Canopy Cover (%)	3	0	50	50	100
Bank Vegetation	3	0	9	9	18
Bank erosion (%)	3	0	2	0	5
Embeddedness (%)	3	30	63	60	100
Substrate:					
<i>Bedrock (%)</i>	3	0	0	0	0
<i>Boulder (%)</i>	3	0	0	0	0
<i>Cobble (%)</i>	3	0	0	0	0
<i>Gravel (%)</i>	3	0	67	100	100
<i>Sand (%)</i>	3	0	33	0	100
<i>Fine (%)</i>	3	0	0	0	0
<i>Other (%)</i>	3	0	0	0	0

Invertebrates

An average of 20 invertebrates were collected from Scotts Spring representing 4 taxa (Table 101). Nearly 50% of the abundance consisted of *Thienemaanimyia sp* (Chironomidae). Another 20% of the total abundance was attributed to *Paracymus sp* (Hydrophilidae). Tolerant species were just as abundant as intolerant species (mean for both=7%). Feeding guild taxa were comprised primarily of predators (59%) and collector-gatherers (41%). Habit guild richness was comprised primarily of sprawlers (33%) and burrowers (28%).

Table 101. Optimal spring invertebrate metrics for Scotts Spring (SCBL).

Metric	N	Minimum	Mean	Median	Maximum
Total Abundance	3	14	20	21	24
Total Richness	3	3	4	4	5
% EPT	3	0.0	3.2	38.9	97.1
% Chironomidae	3	0.0	0.5	0.0	4.9
EPT Richness	3	0	1	1	2
Chironomidae Richness	3	0	0	0	2
% Climbers	3	0.0	5.9	0.0	45.5
% Gliders	3	0	0	0	0
% Collector-gatherers	3	16.7	48.3	38.5	97.1
% Shredders	3	0	0	0	0
% Predators	3	58.3	69.4	71.4	78.6
Modified HBI	3	5.55	5.69	5.60	5.93

Theodore Roosevelt National Park – Little Missouri River

Physical and Chemical

The Little Missouri is a turbid river (mean turbidity=20632NTU) with high TKN (mean=4.08mg/L) and high total phosphorus (mean=1.91mg/L, Table 102). Fecal coliform was above state water quality standards from 1 of the 3 samples taken (June 2005). Dissolved oxygen ranged from 7.2 mg/L to 9.1 mg/L. Nitrates exceeded North Dakota water quality

standards in 2 instances (June 2005 and July 2004). Total phosphorus exceeded water quality standards in 8 of 9 samples (range=0.222-4.650 mg/L).

Table 102. Physical and chemical parameters for the Little Missouri River (THRO).

Parameter	N	Minimum	Mean	Median	Maximum
Dissolved Oxygen (mg/L)	90	7.2	8.2	8.3	9.1
Conductivity (μ S/cm)	90	167	1289	1303	1684
pH	90	7.6	--	8.5	8.6
Water Temperature ($^{\circ}$ C)	90	12.1	20.5	20.6	29.2
Alkalinity (mg/L)	6	170	285	224	620
Turbidity (NTU)	6	157	20632	1430	116000
TSS (mg/L)	6	40	116	113	181
TDS (mg/L)	6	19	294	73	841
Total Phosphorus (mg/L)	6	0.222	1.907	1.240	4.650
TKN (mg/L)	6	0.75	4.08	4.18	8.90
NH ₃ (mg/L)	6	<0.02	0.05	0.04	0.13
NO ₃ (mg/L)	6	<0.10	0.70	0.85	1.20
Fecal Coliform (org/100 mL)	3	20	787	40	2300

Habitat

The Little Missouri River flowed through a badlands landscape. The river in the northern unit of the park was frequented by bison. Vegetation density was low (mean=17) and canopy cover were low (mean=9%, Table 103). Substrate was mixed, with approximately 30% each of gravel, sand, and fine substrate. Current velocity ranged from 0.04m/s to 0.83m/s.

Table 103. Habitat characteristics for the Little Missouri River (THRO).

Parameter	N	Minimum	Mean	Median	Maximum
Bank Slope (%)	90	4	39	33	100
Max Current Velocity (m/s)	90	0.04	0.29	0.29	0.83
Vegetation Density	90	0	17	20	21
Canopy Cover (%)	90	0	9	0	100
Bank Full (m)	90	0	2	2	10
Snags	90	0	1	1	5
Substrate:					
<i>Bedrock (%)</i>	90	0	0	0	0
<i>Boulder (%)</i>	90	0	0	0	0
<i>Cobble (%)</i>	90	0	9	0	100
<i>Gravel (%)</i>	90	0	33	0	100
<i>Sand (%)</i>	90	0	32	0	100
<i>Fine (%)</i>	90	0	26	0	100

Invertebrates

Few invertebrates were collected from the Little Missouri (mean abundance=25). Total richness was also low (mean=6 species, Table 104). Forty-seven percent of abundance was composed of Diptera, while 24% was attributed to EPT. Tolerant and intolerant richness were similar (mean=1.3 and 1.5, respectively). Forty percent of feeding guilds were attributed to collector-gatherer taxa, while 30% of habit guilds were attributed to clingers.

Table 104. Optimal large river invertebrate metrics for the Little Missouri River (THRO).

Metric	N	Minimum	Mean	Median	Maximum
Total Abundance	9	3	25	24	100
Total Richness	9	2	6	5	12
% EPT	9	0.0	16.5	11.5	48.1
% Chironomidae	9	0	31.7	31.0	100.0
EPT Richness	9	0	1	1	4
Non-Insecta Richness	9	0	1	1	4
Clinger Richness	9	0	2	1	4
Swimmer Richness	9	0	1	1	3
Collector-gatherer Richness	9	1	2	1	6
Collector-filterer Richness	9	0	1	0	3
Modified HBI	9	4.62	5.54	5.48	6.86

Wind Cave National Park – Beaver Creek

Physical and Chemical

Most Beaver Creek physical and chemical parameters were below state water quality standards (Table 105). However, fecal coliform bacteria samples averaged above state standards, with three of the samples being over 1000/100 mL (all from July 2004).

Table 105. Physical and chemical parameters for Beaver Creek (WICA).

Parameter	N	Minimum	Mean	Median	Maximum
Dissolved Oxygen (mg/L)	90	7.9	9.9	10.1	11.8
Conductivity (μ S/cm)	90	348	506	500	844
pH	90	7.2	--	8.5	9.7
Water Temperature ($^{\circ}$ C)	90	10.2	16.7	15.1	23.5
Alkalinity (mg/L)	6	35	179	203	252
Turbidity (NTU)	6	3	17	9	42
TSS (mg/L)	6	3	21	6	75
TDS (mg/L)	6	238	280	277	342
Total Phosphorus (mg/L)	6	0.042	0.079	0.066	0.174
TKN (mg/L)	6	<0.23	0.36	0.24	1.08
NH ₃ (mg/L)	6	<0.02	<0.02	<0.02	<0.02
NO ₃ (mg/L)	6	<0.1	<0.1	<0.1	<0.1
Fecal Coliform (org/100 mL)	6	50	547	130	1800

Habitat

Beaver Creek flowed through much of the park and the landscape ranged from open meadows to coniferous forest cover. Canopy cover ranged from 0 to 100 percent (mean=33%). Although bison utilized the stream for water, bank erosion remained relatively low (mean=11%). Substrate consisted of a relatively even mix of sand, gravel, cobble and boulder (Table 106).

Table 106. Habitat characteristics of Beaver Creek (WICA).

Parameter	N	Minimum	Mean	Median	Maximum
Bank Slope (%)	90	13	26	21	80
Discharge (L/s)	9	3.44	10.20	9.04	21.00
Bank Vegetation	90	0	10	10	20
Canopy Cover (%)	90	0	33	10	100
Bank erosion (%)	90	0	11	0	95
Embeddedness (%)	90	2	66	74	100
Substrate:					
<i>Bedrock (%)</i>	90	0	0	0	4
<i>Boulder (%)</i>	90	2	20	18	40
<i>Cobble (%)</i>	90	12	23	20	60
<i>Gravel (%)</i>	90	2	26	26	44
<i>Sand (%)</i>	90	10	28	32	50
<i>Fine (%)</i>	90	0	0	0	2

Invertebrates

An average of 393 invertebrates representing 25 different taxa were collected from Beaver Creek (Table 107). Thirty-two percent of the total abundance consisted of EPT, while 11% consisted of Diptera. Tolerant taxa contributed 23%, while intolerant only contributed 12%. HBI was moderate (mean=5.43). Feeding guild taxa consisted mostly of collector gatherers (mean=54%). Habit guild taxa consisted primarily of sprawlers (mean=25%) and clingers (mean=25%).

Table 107. Optimal small and medium sized stream metrics for Beaver Creek (WICA).

Metric	N	Minimum	Mean	Median	Maximum
Total Abundance	9	128	393	327	985
Total Richness	9	10	25	23	49
% Non-Insecta	9	0.8	28.2	29.2	56.5
EPT:Chironomidae	9	0.26	0.80	0.86	1.00
EPT Richness	9	2	3	3	5
Chironomidae Richness	9	0	3	3	7
Shannon Diversity Index	9	1.00	1.91	1.82	2.66
Habit Guild H'	9	0.86	1.19	1.16	1.51
% Sprawler	9	1.4	17.3	17.8	28.9
FFG H'	9	0.12	0.65	0.69	1.00
Predator Richness	9	2	4	4	7
Modified HBI	9	4.35	5.43	5.01	6.71

Wind Cave National Park – Cold Spring Creek

Physical and Chemical

Most Cold Spring Creek physical and chemical parameters met state water quality standards (Table 108). Fecal coliform bacteria were above South Dakota standards in 3 out of 6 samples (all collected in July 2004). Turbidity and suspended solids were both low (8 NTU and 30 mg/L).

Table 108 Physical and chemical parameters of Cold Spring Creek (WICA).

Parameter	N	Minimum	Mean	Median	Maximum
Dissolved Oxygen (mg/L)	87	5.3	9.3	9.3	15.3
Conductivity (µS/cm)	87	493	590	598	675
pH	87	7.1	--	8.1	8.7
Water Temperature (°C)	87	11.1	15.0	14.5	20.1
Alkalinity (mg/L)	6	203	248	255	280
Turbidity (NTU)	6	1	8	4	28
TSS (mg/L)	6	1	30	17	79
TDS (mg/L)	6	348	374	374	403
Total Phosphorus (mg/L)	6	0.020	0.114	0.077	0.423
TKN (mg/L)	6	<0.23	0.45	0.40	0.76
NH ₃ (mg/L)	6	<0.02	<0.02	<0.02	<0.02
NO ₃ (mg/L)	6	<0.1	<0.1	<0.1	<0.1
Fecal Coliform (org/100 mL)	6	<10	304	7.5	1300

Habitat

Cold Spring Creek was frequented by bison, but bank erosion was low (mean=15%) (Table 109). Embeddedness was high (mean=77%) and sand was the primary substrate (mean=44). Cold Spring Creek flowed primarily through meadow areas in WICA and average canopy was low (mean=20%).

Table 109. Habitat characteristics for Cold Spring Creek (WICA).

Parameter	N	Minimum	Mean	Median	Maximum
Bank Slope (%)	90	8	29	24	65
Discharge (L/s)	9	0.220	14.000	1.21	68.900
Bank Vegetation	90	0	13	15	19
Canopy Cover (%)	90	0	20	10	100
Bank erosion (%)	90	0	15	0	100
Embeddedness (%)	90	2	77	90	100
Substrate:					
<i>Bedrock (%)</i>	90	0	0	0	0
<i>Boulder (%)</i>	90	0	5	6	14
<i>Cobble (%)</i>	90	4	19	24	40
<i>Gravel (%)</i>	90	0	26	28	56
<i>Sand (%)</i>	90	20	44	94	34
<i>Fine (%)</i>	90	0	0	0	4

Invertebrates

Twenty-one taxa contributing an average of 578 invertebrates were collected from Cold Spring Creek (Table 110). EPT contributed 34% of the total taxa, while Diptera contributed 25%. Tolerant taxa were also more abundant than intolerant (35% and 8%, respectively). Collector-gatherer and predator taxa dominated feeding guild richness (44% and 37%), while habit guild richness was dominated by sprawlers (28%) and swimmer taxa (24%). Shannon-Wiener diversity was highest at Cold Spring Creek compared to other WICA streams ($H' = 2.17$).

Table 110. Optimal small and medium sized stream invertebrate metrics for Cold Spring Creek (WICA).

Metric	N	Minimum	Mean	Median	Maximum
Total Abundance	9	89	578	485	1652
Total Richness	9	10	21	22	30
% Non-Insecta	9	0.0	24.6	25.0	45.8
EPT:Chironomidae	9	0.15	0.64	0.71	1.00
EPT Richness	9	2	4	4	6
Chironomidae Richness	9	0	5	5	12
Shannon Diversity Index	9	1.26	2.17	2.37	2.77
Habit Guild H'	9	1.01	1.27	1.29	1.52
% Sprawler	9	16.7	37.5	34.8	66.1
FFG H'	9	0.48	0.95	0.97	1.25
Predator Richness	9	3	8	8	14
Modified HBI	9	4.6	5.9	6.3	7.0

Wind Cave National Park – Highland Creek

Physical and Chemical

Most Highland Creek physical/chemical parameters met state water quality standards.

Ammonia readings were all below detection (mean=<0.02mg/L, Table 111). Fecal coliform exceeded South Dakota's standards twice (July 2004, mean=165/100mL). pH reached the upper limit of state water quality standards (maximum=9.0).

Table 111. Physical and chemical parameters for Highland Creek (WICA).

Parameter	N	Minimum	Mean	Median	Maximum
Dissolved Oxygen (mg/L)	60	6.2	8.5	8.2	10.7
Conductivity (µS/cm)	60	240	271	264	291
pH	60	7.9	--	8.7	9.0
Water Temperature (°C)	60	9.8	20.0	20.8	26.7
Alkalinity (mg/L)	6	103	130	130	161
Turbidity (NTU)	6	3	4	3	6
TSS (mg/L)	6	5	11	9	19
TDS (mg/L)	6	117	165	133	252
Total Phosphorus (mg/L)	6	0.020	0.029	0.029	0.036
TKN (mg/L)	6	<0.23	0.16	<0.23	0.25
NH ₃ (mg/L)	6	<0.02	<0.02	<0.02	<0.02
NO ₃ (mg/L)	6	<0.1	0.13	0.15	0.20
Fecal Coliform (org/100 mL)	5	20	192	40	500

Habitat

Highland Creek flowed through meadow areas. Canopy cover was low (mean=17%) Highland Creek had the highest discharge of all WICA streams sampled (mean=18.2 L/s, Table 112). Bank erosion was primarily due to bison utilization (mean=33%). Embeddedness averaged 54% with gravel (mean=41%) and sand (mean=41%) the primary substrate.

Table 112. Habitat characteristics of Highland Creek (WICA).

Parameter	N	Minimum	Mean	Median	Maximum
Bank Slope (%)	60	12	20	18	53
Discharge (m ³ /s)	6	0.007	0.0182	0.0195	0.0242
Bank Vegetation	60	9	19	20	20
Canopy Cover (%)	60	0	17	0	90
Bank erosion (%)	60	0	33	35	95
Embeddedness (%)	60	0	54	60	100
Substrate:					
<i>Bedrock</i> (%)	60	0	0	0	0
<i>Boulder</i> (%)	60	0	6	5	18
<i>Cobble</i> (%)	60	4	10	10	16
<i>Gravel</i> (%)	60	2	41	82	44
<i>Sand</i> (%)	60	14	41	66	37
<i>Fine</i> (%)	60	1	2	2	3

Invertebrates

Highland Creek contained the highest average abundance of invertebrates for all WICA streams (mean=1144 organisms, Table 113). However, it contained the smallest average number of taxa (mean=17 species). Shannon-Wiener diversity index was also lowest of all WICA streams ($H' = 1.22$). Ephemeroptera taxa contributed the highest percentage to the abundance (mean=61%), with *Tricorythodes sp.* and *Baetis brunneicolor* the dominant mayfly taxa. Tolerant taxa were also dominant (38%) and outnumbered intolerant taxa (12%). Collector-gatherers contributed 64% of the total taxa and 85% of total abundance. Sprawlers (28% taxa, 22% abundance) and burrowers (35% taxa, 21% abundance) dominated habit guilds.

Table 113. Optimal small and medium sized stream invertebrate metrics for Highland Creek (WICA).

Metric	N	Minimum	Mean	Median	Maximum
Total Abundance	6	6	1144	540	4464
Total Richness	6	1	17	14	44
% Non-Insecta	6	0.0	4.3	2.3	16.7
EPT:Chironomidae	6	0.86	0.96	0.98	1.00
EPT Richness	6	0	4	3	6
Chironomidae Richness	6	0	2	2	3
Shannon Diversity Index	6	0.00	1.22	1.29	2.06
Habit Guild H'	6	0.00	0.85	0.96	1.28
% Sprawler	6	0.0	22.1	23.7	39.6
FFG H'	6	0.00	0.46	0.36	1.08
Predator Richness	6	0	2	2	5
Modified HBI	6	4.61	5.69	5.62	9.60

Discussion

Diptera and EPT taxa were usually the most common invertebrate orders among sampled lotic systems. Diptera were common among all systems, and Chironomidae especially contributed to Diptera richness. Diptera are a very diverse group of insects and they respond differently to anthropogenic and natural disturbance (Lenat 1983, Gronke 2004, Foley 1997, Yoder and Rankin 1995). Crane flies (Tipulidae), for example, are usually found in moderately clean water (Mandaville 1999), while the rat-tailed maggot (Syrphidae) is characterized by its ability to live in highly polluted systems with low dissolved oxygen (Mackie 2004).

Chironomidae contribute approximately 2,000 species of known Diptera. They are extremely diverse in habit use, feeding and tolerance (Mandaville 1999). Chironomidae can occupy a much wider range of physical and chemical gradients than EPT taxa (Mackie 2004).

EPT were common among most streams and rivers within the NGPN and EPT metrics often displayed high discriminatory power among lotic sites. Percent EPT and EPT richness have been selected as metrics for use in other lotic systems (Plafkin et al. 1989,

Hannaford and Resh 1995, Maxted et al. 2000, Zweig and Rabeni 2001). EPT metrics do well for monitoring programs because these insect groups are pollution sensitive. Mayflies, stoneflies and caddisflies all have gills that allow them to absorb oxygen from the water (Resh and Rosenberg 1984). If oxygen is depleted from organic pollution or temperature increases, fewer EPT organisms will be present in the stream. Mayflies generally are intolerant of low pH and enrichment (Mackie 2004). Plecoptera reside in cool, well-oxygenated waters and have lower diversities in eutrophic streams (Resh and Rosenberg 1984, Mackie 2004). Caddisflies (Trichoptera) display a large diversity of habitat and functional feeding behavior (Mackie 2004, Mandaville 1999). They inhabit cool, running waters and their presence reflects good water quality (Mackie 2004).

Plecoptera were not as commonly encountered as Ephemeroptera and Trichoptera, but they are still of importance to stream ecosystems and important for determining water quality. Stoneflies were most abundant in Beaver Creek and Grizzly Creek, making up about 3% of each system. Grizzly Creek, especially, was characterized by low water temperature and embeddedness and high dissolved oxygen. These three characteristics have repeatedly been shown to influence the abundance of stonefly nymphs (Buss et al. 2002, Kondratieff and Bauman 2000, Mandaville 1999, Merritt and Cummins 1996, Rosenberg and Resh 1993).

Embeddedness was one of the few habitat parameters with significant correlations to several invertebrate metrics. Embeddedness and silt/clay substrate were often related to areas where bison utilized the stream. Furthermore, HBI, Chironomidae taxa and Chironomidae abundance were all positively correlated with embeddedness, while EPT abundance was inversely correlated. Fritz et al. (1999) observed that prairie streams associated with buffalo crossings had 10% higher fine substrate. EPT richness and total richness were higher above

buffalo crossings then below. Some Diptera taxa were also more prevalent at buffalo crossings (*Bezzia* sp., *Culicoides* sp.). Invertebrate community structure recovered downstream of bison crossings. Stewart et al. (2001) saw negative relationships between EPT richness and embeddedness and also indicated that embeddedness greatly influenced fish IBI, macroinvertebrate EPT communities and HBI. Weigel et al. (2003) used comparisons of redundancy analysis to show that, in general, EPT, scrapers and filterers tend to inhabit erosional zones with little embeddedness while predators and gatherers tend to occupy depositional sites where embeddedness tends to be higher.

Total dissolved solids (TDS) were also highly correlated with several invertebrate metrics. Leland and Fend (1998) observed negative relationships between TDS and taxa richness, EPT richness, and community structure. Ndaruga et al. (2004) also saw inverse correlations between stream diversity and TDS in Kenya streams.

Streams located within forested areas generally displayed lower embeddedness, silt/clay substrate, and HBI compared to plains streams. Forested streams also displayed higher canopy cover, Shannon-Wiener Diversity, and EPT taxa. Weigel et al. (2003) observed that forest-dominated catchments corresponded highly with dissolved oxygen, woody debris and canopy shading and in turn, affected macroinvertebrate assemblages. The authors found that forested streams were related to minimal sediment delivery and coarser substrate. Corkum (1991) recorded significant differences in streams located in forested versus grassland areas. Shredders were more abundant in forested areas, while predators and collector-gatherers were more prevalent in grassland areas. Stagliano and Whiles (2002) estimated secondary production and consumption by functional groups in prairie headwater streams. Stagliano and Whiles reported

that prairie streams had greater production and functional structure than that of forested streams.

Functional guilds summarize feeding and habit guild structure within the macroinvertebrate community. These guilds are based on the premise that invertebrates evolved with their morphological and behavioral adaptations for food gathering or locomotion/attachment (Rosenberg and Resh 1996). Functional guilds varied depending on system type, land-use, and landscape attributes. Swimmers were most common in bison watering holes where disturbance from bison was a regular occurrence. Clingers and climbers were most prevalent in streams and rivers with good water and habitat quality (Grizzly Creek, Smith Falls, Laramie River). Swimmers are thought to increase with system impairment, while climbers and clingers often decrease with system impairment (Maxted et al. 2000, Merritt et al. 2002, Mackie 2004). Corixidae (a swimmer), especially abundant in stock ponds, were also observed to occur in extremely high numbers in nutrient enriched lakes (Gronke 2004).

Glider abundance was especially high at the Niobrara River at AGFO. The Niobrara River contained 4 different taxa of gastropods and one bivalve making up 16% of the total abundance, many of which were physids and planorbids of Gastropoda. This is not surprising since snails often feed on detritus or feed on the periphyton covering macrophytes (Thorp and Covich 1991), which were abundant in the wetland areas surrounding and within the stream.

Percent intolerant invertebrates and HBI were especially affected by riparian vegetation. Both HBI and percent intolerant invertebrate abundance were strongly correlated with canopy cover and riparian ground cover density. Invertebrates are strongly influenced by riparian vegetation and condition because the vegetation provides food inputs (Vannote et al. 1980) and traps or filters run-off that may enter streams (Lowrance et al. 1985). Stewart et al.

(2001) also found that longitudinal fragmentation of riparian areas was negatively related to biotic integrity and habitat quality, which can further affect macroinvertebrate assemblages. Findlay et al. (2001) found that dissolved organic carbon (DOC), a significant energy source in streams, was indirectly affected by riparian vegetation. Temperature is also affected by riparian vegetation, especially canopy cover. Higher temperature fluctuations throughout the day or season can directly influence stream biota (Maloney et al. 2004; Tait 1994). Reduction in light reaching the aquatic system can also prevent periphyton growth. Zimmerman and Death (2002) placed baskets of natural substrate in a spring-fed Taranaki Ring Plain stream, Taranaki, New Zealand. Baskets were placed in the open or under cover and half were disturbed every week for 4 weeks. The artificial cover reduced periphyton biomass and also influenced what invertebrate taxa were present in the baskets, most likely as a result of differences in food resources. The filter feeding *Coloburiscus humeralis* dominated numerically in the covered baskets, whereas the generalist grazers *Deleatidium* spp., *Beraeoptera roria*, Orthocladiinae, and Diamesinae dominated numerically in the open baskets

Two intolerant genera of Tipulidae (*Cryptolabis* sp. and *Dicranota* sp.) were only collected from Spring R and Spring S of DETO. *Cryptolabis* sp. is a shredder and *Dicranota* sp. is an active predator and they both may be found in seepages (Byers 1996). Furthermore, two Limnephilidae (Trichoptera) taxa were unique to springs (*Moseleyana* sp. and *Philarctus quaeris*). These are tube-case makers and construct tubular portable retreats of various shapes and materials (Wiggins 1996). These two genera are not always limited to springs, however, and may also reside in clear streams with highly oxygenated water. Little research has been done on spring biology, especially in regards to aquatic macroinvertebrates. However, these aquatic systems may provide unique plant and animal fauna (Hubbs 1995). Many cold water springs

have water temperatures that reflect the average annual air temperature (Hubbs 1995). These temperatures will sometimes fluctuate less than 1°C. Spring waters are usually clear and have little flow variation (Hubbs 1995). Smith and Wood (2002) recorded unique macroinvertebrates found only at a spring source. Smith and Wood (2002) also state that intermittent springs can be quickly colonized by invertebrates. Iverson (1988) found shredders, collector-gatherers and predators to be prevalent in springs he studied. Iverson (1998) found several Tipulidae larvae (including *Dicranota sp.*) and several Trichoptera species within springs of Denmark. Springs contained the highest percentages of shredders and may be considered headwater streams. Headwater streams are often influenced by riparian vegetation (Vannote 1980) and springs could be considered headwaters. This vegetation delivers large inputs of coarse particulate organic matter (CPOM) to the stream. Shredders and collectors are characteristic of headwater streams and utilize CPOM as a food source (Vannote et al. 1980).

Stream site metrics varied depending on drainage basin landscape features. In this study, invertebrate diversity was greatest in the Black Hills areas, but some prairie streams also displayed high diversity. Shannon-Wiener diversity was high in the Niobrara River (AGFO) and Deer Creek (FOLA) relative to Black Hills streams. Both of these systems flow through prairie landscapes. However, plains streams, while diverse, had higher abundances of Diptera and Mollusca (e.g. Niobrara River at AGFO, and Deer Creek at FOLA), while most Black Hills streams and NIOB streams had higher numbers of EPT taxa. Plains streams have been shown to display smaller numbers of genera and families than mountain streams (Tate and Heiny 1995), but have also been shown to have higher production than forested streams during times of stable flow (Stagliano and Whiles 2002). Landscapes and land uses can greatly

affect the habitat conditions of the site and the quality of the water (Carr et. al 2005, Jones et al. 2004).

Taxa tolerant to organic pollution also dominated plains streams and streams utilized by bison. Beaver Dam Creek of MORU had similar characteristics to plains streams as it had higher Diptera taxa, lower EPT taxa, and high tolerant taxa. Streams with higher numbers of tolerant organisms were found primarily in plains areas and streams with bison or livestock using the stream. The plains areas in this study were primarily used for livestock grazing. WICA streams were utilized by bison, and Beaver Dam Creek at MORU had a heavily used horse trail along a portion of the stream. Zamora-Munez and Alba-Tercedor (1996) observed a replacement of species from less tolerant to more tolerant organisms in organically polluted streams. Livestock (or bison) grazing along the riparian area can also influence the structure of aquatic invertebrate communities by physically altering the habitat through trampling or foraging or by adding nutrients (through manure). For example, Del Rosario et al. (2002) observed a 5-fold increase in Chironomidae larvae, a characteristically organic-enrichment tolerant group, after four weeks of organic enrichment from manure.

Large rivers varied in size and several metrics were correlated to river watershed drainage area. The Missouri River ranged from hundreds of meters wide and several meters deep, while the North Platte and Laramie Rivers were shallow enough for wading during mid to late summer. Furthermore, some large river sites only included 1 reach and some of those reaches were short in length (e.g. Missouri River at FOUS).

The Missouri River communities in North Dakota had slightly fewer total taxa than the lower reaches in South Dakota, but had 10% more intolerant taxa, 2% more EPT abundance and 6% more EPT taxa. The Missouri River in MNRR had higher percentages of

collector gatherers and clingers, but smaller percentages of swimmers. HBI was nearly equal for all Missouri River sites. Plecoptera was not collected from MNRR sites, but added over 6% to the total abundance for North Dakota Missouri River sites. Higher numbers of intolerant taxa may in part, be due to lower average temperature, higher dissolved oxygen, lower conductivity and dissolved solids from North Dakota sites (Weiel et al. 2003). Brinck (1949) states that ideal temperatures for maximum growth of stoneflies falls between 5°C and 12°C. Heiman and Knight (1975) evaluated the influence of temperature on one species of stonefly and found that ideal summer temperatures for that species were between 16° and 22°C. Summer temperatures of MNRR were at the high end of that range while summer temperatures in North Dakota sites were at the low end of that range.

Reference site data is normally used to define optimal metric suites for IBI development (Lorenzen 2006; Gronke 2004; Reynoldson 1997; Karr et al. 1986; Larson and Troelstrup 2001). Metrics are commonly tested for discriminatory power against reference sites (Gronke 2004; Lorenzen 2006; Braskamp 2002; Larson and Troelstrup 2001; Barbour et al. 1995; Barbour et al. 1999; Barbour and Yoder 2000). Metrics with high discriminatory power are best able to discriminate between impacted and reference sites. Reference sites provide an attainable standard for impaired sites (Hughes et al 1986, Hughes et al 1995). Metric selection processes used in this study had high between-site discriminatory power and low within site variability. Kruskal-Wallis F-values were utilized in comparing metrics by sites to determine discriminatory power. Subsequently, Pearson-rank correlations metrics with high F-Values were employed to evaluate habitat and water quality correlations. This process is similar to one recently employed to define optimal metrics in Montana streams (Bramblett et al. 2005).

Reference sites can be described as sites that represent minimally disturbed systems and are most effective when grouped by ecoregion (Reynoldson et al 1997). The reference site is used by comparing biological data from test sites (or study sites) to a group of reference sites. National parks represent some of the last remnant natural ecosystems in the country. Aquatic systems that flow through these areas could potentially reflect the minimal human disturbance that the National Parks offer. Because of the park staff's management toward minimal human disturbance, aquatic systems within the park may represent reference sites that state and federal agencies can utilize for comparison and seek to emulate. However, some sites within or bordering the parks are prone to several types of disturbance and may not be appropriate reference sites. Beaver Dam Creek invertebrate assemblages and habitat quality were much different than Grizzly Creek and Lafferty Gulch, even though all three flow through Mount Rushmore National Monument. Heavily used horse trails adjacent to the Beaver Dam Creek could increase organic enrichment. Run-off from the trails could also send silt/clay into the stream, resulting in higher embeddedness, turbidity, and TSS. Several systems that were utilized by buffalo or livestock (Deer Creek, Highland Creek, Cold Spring Creek, Sage Creek, CCC Spring, Little Missouri River) may also be prone to organic enrichment, habitat degradation, and altered invertebrate assemblages. Several reaches of large rivers have also been influenced by impoundments upstream from the parks. The Missouri River, the North Platte River, the Laramie River, and the Belle Fourche River all have impoundments upstream from their parks. Springs that have been altered by humans are also poor candidates for reference data. Several springs (all but Scotts Spring and Prairie Dog Spring) have been hydrologically altered which in turn can alter other physical and chemical attributes (e.g. temperature, dissolved oxygen). Several stream sites, however, display the attributes of a

reference site. Grizzly Creek, Lafferty Gulch, Smith, Berry, and Fort Falls, Laramie River, Prairie Dog Spring measurements indicate good habitat and water quality. Furthermore, their macroinvertebrate communities reflect the quality of the habitat and water. The Laramie River could be considered one of the better quality rivers even though it has been impounded upstream, as it had one of the lowest HBI for rivers, high EPT richness, and high Shannon-Wiener diversity. This river site may be a good candidate as a reference site for either medium-sized streams or large rivers. Overall, several NPS aquatic systems show the potential for utilization as a reference condition.

Little water quality data exist for many of the aquatic systems sampled in this study and even fewer have macroinvertebrate data. Nebraska has identified four invertebrate metrics for use within the entire state. Of the four metrics used by Nebraska, EPT Richness, HBI, and Total Richness are also included in our lotic optimal sets. Furthermore, Pietz (2003) has been monitoring the macroinvertebrates of AGFO since 1988. Hester-Dendy samplers have been used to sample invertebrates from several sites on the Niobrara River. Pietz (2003) also defined six metrics using past literature that included total density, family biotic index, generic diversity, Shannon-Wiener diversity, generic evenness and EPT richness. Although Pietz (2003) used different techniques for developing metrics, generic diversity and EPT richness were common with our selection for streams. Pietz (2003) also only used six metrics covering richness and abundance community attributes. Selecting only a few indicators can oversimplify the understanding of the system and can lead to poorly informed management decisions (Karr et al. 1986; Dale and Beyeler 2001). A good mixture of measures that monitor several levels of ecological complexity would be appropriate for thorough ecological monitoring (Dale and Beyeler 2001). Furthermore, density of invertebrates may not indicate stress to the system.

Lower macroinvertebrate densities do not necessarily indicate the system has been subjected to a stressor. Gronke (2004) found similar invertebrate abundance from an impaired lake and reference lakes, but one species indicative of degraded conditions (*Trichocoixa borealis*) was dominant in the impaired lake. Cuffney et al. (1984) treated headwater streams with the insecticide methoxychlor. Invertebrates drifted initially, but the treated stream was recolonized with Chironomidae and Turbellaria. Total invertebrate density increased in the treated stream after 117 days, even though biomass was consistently lower. Pietz's (2003) data suggest higher EPT richness, but lower overall richness from the Niobrara at AGFO than we observed. These differences may be in part due to sampling methods. Hester-Dendy's are more likely to sample EPT taxa and less likely to sample active swimmers and sediment dwelling taxa (Barbour et al. 1999; Lorenzen 2006). Turner and Trexler (1997) found that a D-frame net sampling resulted in higher total numbers, taxa, and evenness than a Hester-Dendy sampler and recommended the D-frame net for highly vegetated areas.

The state of Wyoming has also developed metrics for water quality monitoring. The Wyoming Department of Natural Resources developed several metrics for systems within the state, but did not narrow metrics to those that best characterize streams in a specific area. Thirty taxa were collected at the Belle Fourche River for this project compared to Wyoming's 29 taxa. Slightly lower levels for percent EPT and HBI were collected from this study, but higher EPT richness and percent Diptera were observed. Wyoming personnel also sampled the North Platte downstream from Fort Laramie. Again, we had slightly lower total richness, much lower percent EPT and EPT richness, and higher HBI values. These differences may be due, in part to sampling methods, but may also be due to sampling year. We sampled during

relatively dry years and flow may have been below normal for the Belle Fourche River and especially the North Platte on two of our sampling dates.

South Dakota Department of Environment and Natural Resources (DENR) personnel have not developed invertebrate monitoring protocols and data are lacking for the National Parks (SD DENR). North Dakota personnel have been trying to develop optimal metrics for their states but no metric sets have been defined for areas within our sampled parks. Bramblett et al. (2003) developed metrics for the Northwestern Glaciated Plains and the Northwestern Great Plains ecoregion areas of Montana. Bramblett et al. (2003) produced several metrics for pools and riffles of streams for that area based on metric range, responsiveness, precision and redundancy. Three of their metrics were similar to ours (percent EPT, swimmer richness, and collector-filterer richness).

Some park staff expressed concerns over specific chemical disturbances to aquatic systems to the park. Several of these chemical parameters were not sampled due to cost. Data suggests that most physical and chemical parameters we did sample did not fall above water quality standards, although there were exceptions. Jewel Cave staff, in particular, was concerned with their sewage system effluents. A fecal result of 160,000/100mL was found in one instance at Jewel Cave Spring. Although the source of the fecal coliform is unclear, fecal coliform may be a potential problem. Sage Creek also had fecal hits above water quality standards and these were likely due to heavy use of aquatic sites by bison. Other parks were concerned with flow regulations upstream from parks. Although parks may have little influence on flows within these aquatic systems, the altered hydrograph can have many effects on biological assemblages (Bowen et al. 1998; Pringle et al. 2000) and riparian conditions (Brinson 1990; Johnson 1992).

Several park personnel expressed concern with the riparian condition of their aquatic systems. Among the most serious impacts to riparian ecosystems are water impoundment and diversion, groundwater pumping from alluvial aquifers, livestock grazing, land clearing for agriculture or to increase water yield, mining, road development, heavy recreational demand, and overall watershed degradation (Stromberg 1993). Density board measurements at BADL systems may have indicated poor riparian condition. Although canopy cover is likely naturally low in this area, ground cover density was especially low, particularly around stock ponds. The density board measurements reflected the heavy bison use in and around these systems. Furthermore, several of the large rivers lack new growth of cottonwood and willow trees on sandbars and shoreline areas. This is likely due to the lack of flood surges that are regulated by the impoundments upstream (Nilsson and Berggren 2000).

Developing a monitoring program requires thorough knowledge of management issues and objectives. Several steps must be followed for a technically sound monitoring design (Wolfe et al. 1973, Kondolf 1995, Larsen et al. 1995, Schaeffer et al. 1985). First, a definite set of objectives and questions must be defined for each park in quantitative terms. Secondly, the overall design must account for both ecological issues and agency policy. Third, the objectives must be regionally and temporally significant. Finally, objectives must be clearly linked to the needs of management. For the National Park Service, specific objectives should be determined early in the development process to focus monitoring on management issues. Those objectives should be tied to both short and long-term goals. Specific management issues must be clear, and specific criteria for management objectives must be defined. The quantity and quality of data collected must reflect the specific management issues. Monitoring should allow managers to assess the effectiveness of management decisions, increase their understanding of natural

system changes, and establish areas that need further research. Chemical and physical descriptions don't completely encompass problems within aquatic ecosystems (Karr and Chu 1999). Biological monitoring can effectively indicate problems within these systems that may not be detected with chemical and physical assessments alone. By determining optimal metrics for specific systems and regions, monitoring programs can more effectively determine stressors and managers can streamline their efforts (Karr 1991, Hughes et al 1986, Hughes et al 1995, Fausch 1984, Omernik and Bailey 1997).

The NPS wishes to design their monitoring program to allow other entities to utilize and compare data that the NPS collects since many agencies share a common goal. This entails quantitative, objective sampling methods that reflect the common and widely used protocols that partnering water quality agencies employ. The NPS could also work with these agencies to optimize time, money, and other monitoring resources.. Optimized macroinvertebrate metrics can be used for aquatic system monitoring within the NGPN. Employing these metrics will allow managers to apply the benefits of using a suite of metrics to assess gradients of disturbance, but will also organize and streamline their efforts (Yoder 1994, Karr 1991, Barbour et al. 1995).

Exploratory baseline studies are often required to initiate new monitoring programs (NRC 1990). In this study, baseline data was produced for all aquatic systems of the network using consistent methodology. This data may be applied to future monitoring of chemical, physical, habitat, and invertebrate vital signs in each park. Optimal metric sets recommended from this effort are those likely to detect change in water quality and habitat. However, further exploratory data is probably needed to fully describe the fauna of these systems. Three samples from each site over two summers are probably not sufficient to completely assess the

condition of these systems or define the biological assemblages within them. Knowledge of the fauna is critical before an effective biomonitoring program can be launched.

The success of management actions can only be determined by repeated, regular monitoring over time. Basic descriptions are essential to see future change on aquatic systems, whether it's from management decisions, natural fluctuations, or anthropogenic disturbance. This study was a comprehensive effort to develop and identify potential macroinvertebrate metrics for utilization in evaluating aquatic systems within the NGPN. During the course of this project, optimal metrics were selected from over 80 candidates. This is a baseline effort, intended to provide background information on aquatic systems within the NGPN and suggest an initial set of metrics that display the ability to discern anthropogenic disturbance from natural variability.

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