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Bioassessment of aquatic invertebrates along the Belle Fourche River at Devils Tower National Monument

Natural Resource Technical Report NPS/NGPN/NRTR—2014/838

ON THIS PAGE
Ed Eberhardy and Ken Brown sampling aquatic invertebrates using a Hess sampler in the Belle Fourche River at Devils Tower National Monument.
Photograph by: Lusha Tronstad, WYNDD, University of Wyoming

ON THE COVER
The Belle Fourche River flowing through Devils Tower National Monument with Devils Tower in the background.
Photograph by: Lusha Tronstad, WYNDD, University of Wyoming

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Lusha Tronstad

Wyoming Natural Diversity Database
University of Wyoming
1000 East University Avenue
Laramie, Wyoming 82071

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This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

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Abstract

The Belle Fourche River runs through Devils Tower National Monument in northeastern Wyoming and is an important source of water for the area. To estimate the ecosystem quality of the Belle Fourche River within the park, I collected aquatic invertebrates at three sites using a Hess sampler. Invertebrates were identified and counted under a dissecting microscope. Each taxon was assigned a functional feeding group, habit, and tolerance value based on published categories and I calculated 24 bioassessment metrics. Total invertebrate density in the Belle Fourche River was 3760 individuals/m^2. I identified at least 31 different taxa that lived in the river and about 13 taxa were collected in each sample. Bioassessment metrics indicated that the ecosystem quality of the river was good, especially at sites #1 and #2. However, site #3 often showed more impacted values compared to the other two sites. Site #3 had a higher % Chironomidae and % tolerant (tolerance values of 6.0-7.0) individuals, and lower % clinger taxa, % EPT (Ephemeroptera, Plecoptera, and Trichoptera), % filterers, % intolerant, EPT/Chironomidae ratio, and taxa diversity compared to the other two sites. The lower metric values at site #3 may be attributed to different substrate or anthropogenic disturbance from a large campground located near site #3. The average tolerance value of an invertebrate in the assemblage was 5.4 on a scale of 0 (intolerant to pollution) to 10 (tolerant to pollution). Overall, the Belle Fourche River appears to have good ecosystem quality.

Acknowledgments

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Introduction

About half of the land on earth is thought to be altered by anthropogenic activities (Vandewalle et al. 2010). Fortunately, land has been set aside around the globe to protect natural places. In the United States, lands managed by the National Park Service preserve natural and cultural resources for the enjoyment, education, and inspiration of current and future generations. The National Park Service cares for 401 units that have over 136,794 km of streams and are home to 400 endangered species. Protecting these natural resources can be difficult, especially in small parks that are surrounded by a sea of anthropogenic disturbances. Streams are highly influenced by the surrounding landscape and land use in the watershed can strongly impact stream health (e.g., Hynes 1975, Feld 2013).

About 40% of streams in the plains and lowland regions of the United States were considered in poor condition (Paulsen et al. 2008). The main stressors to these streams were high concentrations of nutrients, the loss of in-stream habitat, riparian disturbances, and an increase in fine sediments. Land use within a watershed can impact all of these stressors and can strongly alter stream ecosystems. Most studies investigating the connection between land use and stream health separate land use into urban, agricultural, and forested areas, and found that urban areas can have unproportionally large effects on downstream communities (Allan 2004). Within the agricultural category, studies generally found that farming had a larger effect compared to rangeland. Interestingly, an intact riparian area can buffer the land use effects within the watershed (Feld 2013).

Invertebrates are widely used to assess the ecosystem quality of streams (Rosenberg and Resh 1993). Aquatic invertebrates have been used to monitor ecosystems since the 12th century in Europe (Cairns and Pratt 1993). The methods used to assess quality have changed over time starting with the Saprobien system (Cairns and Pratt 1993) and evolving to multimetric (e.g., Kerans and Karr 1994) and multivariate models (e.g., Ode et al. 2008). Biomonitoring is widely used throughout the United States, because aquatic invertebrates have several characteristics making them good indicators of ecosystem quality. Aquatic invertebrates are relatively long-lived (weeks to 100 years) and live in the waterbody through most their lives. Periodically collecting water samples can miss discrete discharges of pollution, but aquatic invertebrates respond to such events. These animals are rather sedentary and move only short distances; therefore, they continuously monitor the ecosystem quality at a particular site. Aquatic invertebrates are easy to collect, abundant, and diverse. Finally, numerous studies have shown that lower ecosystem quality (e.g., pollution, habitat degradation, invasive species) decreased the fitness, reproduction, and survival of aquatic invertebrates (Johnson et al. 1993).

Devils Tower National Monument is a small park (545 hectares) that preserves the unique natural and cultural features of the area. The park sits among working ranches and farmland in the Black Hills region of northeastern Wyoming. The Belle Fourche River flows through Devils Tower National Monument and is likely influenced by the activities in the watershed. I estimated the current ecosystem quality of the Belle Fourche River within the park by collecting aquatic invertebrates at 3 sites. My questions were: 1.) What is the ecosystem quality of the Belle Fourche River at Devils Tower National Monument according to the invertebrates?, 2.) How do the bioassessment metrics at the three sites compare?, and 3.) How do these metrics compare to other rivers in the region?

Study Area

The Belle Fourche River is a ~470 km long tributary within the Missouri River Basin in northeastern Wyoming and northwestern South Dakota. The Belle Fourche River originates in southern Campbell County, Wyoming flowing northeast and turning southeast near the Montana border. The river flows into the Cheyenne River east of Rapid City, South Dakota. Many small tributary streams flow into the Belle Fourche River. Annual average flow of the river from 1991 to 2010 near Alva, Wyoming (downstream of Devils Tower National Monument) was 2.6 m^3/sec (USGS; http://waterdata.usgs.gov/usa/nwis/rt). Keyhole Dam was constructed upstream of Devils Tower National Monument along the Belle Fourche River in 1952 and regulates the flow of the river.

Under the Clean Water Act of 1972, each river in the United States is assigned a class based on the designated uses of the water (e.g., drinking water, industry). The Belle Fourche River in Wyoming is a Class 2AB water with designated uses of agriculture, aquatic life other than fish, drinking water, fish consumption, industry, non-game fish, recreation, scenic value, warm water fishery, and wildlife. Water quality criteria in the Belle Fourche River were not suitable for recreation because of elevated fecal coliform concentrations (Wyoming Department of Environmental Quality; http://deq.state.wy.us/wqd/watershed/TMDL/TMDL.htm). Additionally, concentrations of ammonia and chloride have exceeded water quality criteria. High concentrations of ammonia can harm aquatic life and excessive chloride can reduce the weight and reproduction of animals. Fecal coliform probably came from animal waste (cats, dogs, horses, and cattle), ammonia may have been from wastewater treatment, and chloride may have originated from deicing activities in Gillette, Wyoming. The Belle Fourche River currently exceeds water quality standards for fecal coliform from the confluence with Arch Creek downstream to the confluence with Sourdough Creek, which includes the reach at Devils Tower National Monument. Ammonia and chloride concentrations are not exceeded along the reach of river flowing through Devils Tower National Monument.

About 3.6 km of the Belle Fourche River (elevation ~1200 m) flows through Devils Tower National Monument (Figure 1). The Nation's first National Monument was established in 1906 and encompasses 545 hectares. Devils Tower is igneous, but the tower is surrounded by sedimentary rock. The forests are primarily Ponderosa pine (*Pinus ponderosa*), oak (*Quercus* sp.), ash (*Fraxinus* sp.), cedar (*Cedrus* sp.), and juniper (*Juniperus* sp.). The vegetation in the floodplain along the Belle Fourche River is mainly cottonwood (*Populus* sp.), sedges, and grasses. I sampled three sites along the Belle Fourche River (Figure 1) on 7 September 2011: where the river flows into the park (site #1), below the Devils Tower National Monument campground (site #2) and where the river flows out of the park (site #3).

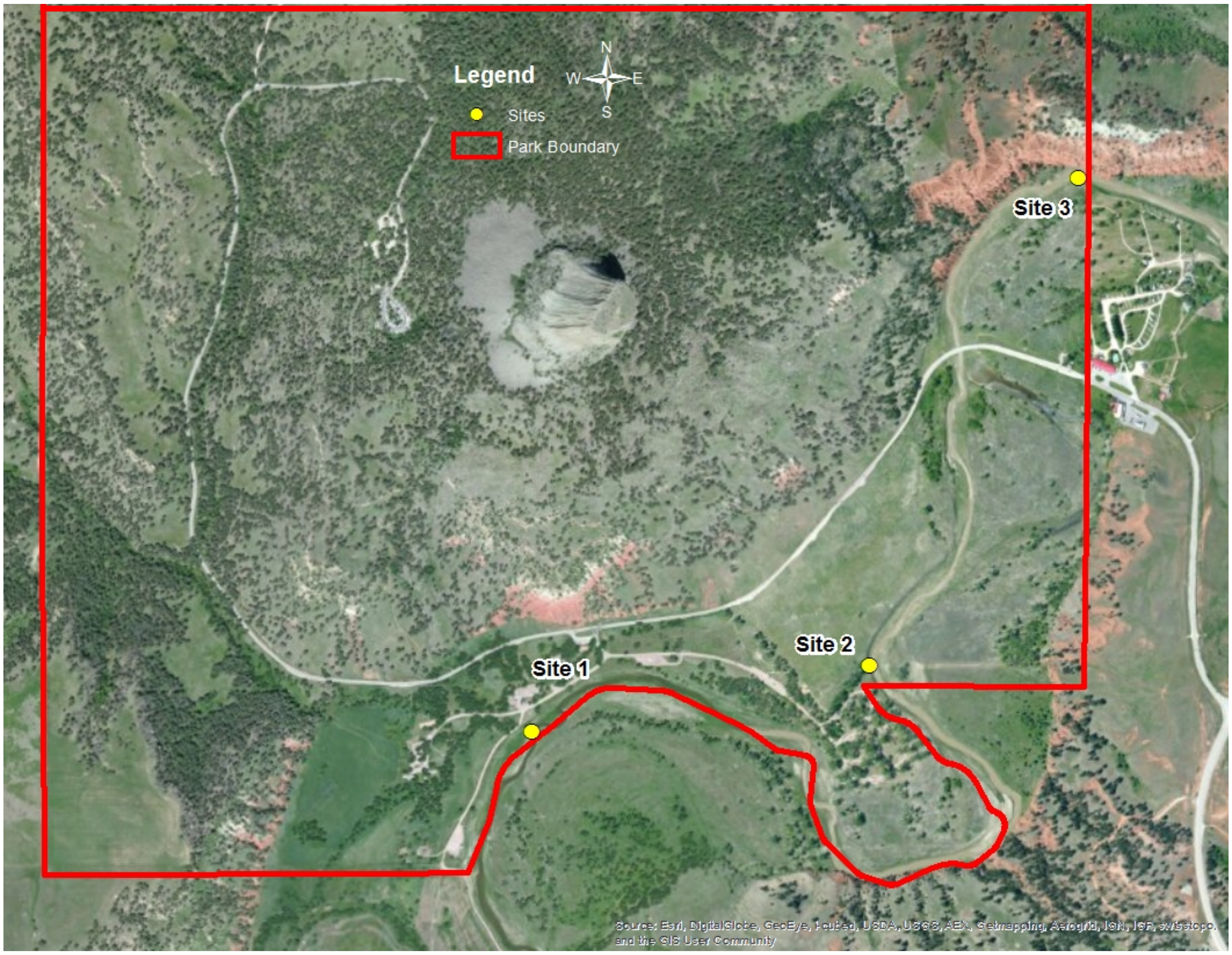

Figure 1. Map of Devils Tower National Monument showing aquatic invertebrate sample sites.

Methods

I measured basic water quality and water clarity to estimate conditions at each site. I measured basic water quality using a Yellow Springs Instrument (YSI) Professional Plus, which was calibrated daily. Water clarity was estimated by lowering a Secchi disk into the water until the disk disappeared from sight.

To measure the abundance and diversity of invertebrates in the Belle Fourche River, I collected aquatic invertebrates using a Hess sampler. I collected five samples at each of the three sites along the river within Devils Tower National Monument (Figure 1). I placed the Hess sampler (500 µm mesh, 860 cm^2 sampling area, Wildlife Supply Company) into the substrate, scrubbed the substrate, and agitated the sediment. Samples were preserved with ~75% ethanol and transported to the laboratory where invertebrates were sorted from debris. Each sample was checked by two qualified individuals to insure that all invertebrates were removed. Invertebrates were counted and identified under a dissecting microscope using appropriate keys (Larson et al. 2000, Needham et al. 2000, Smith 2001, Merritt et al. 2008, Thorp and Covich 2010).

To estimate ecosystem quality at each site, I calculated several bioassessment metrics using the invertebrate data. Based on the data collected and previous studies (e.g., Resh and Jackson 1993, Kerans and Karr 1994), I selected 24 metrics to compare sites (Table 1). I chose a variety of metrics including measures of richness, abundance, community diversity, functional feeding group, habit, and pollution tolerance. Pollution tolerance values of invertebrate taxa were taken from Barbour et al. (1999) and a mean assemblage tolerance value was calculated according to Hilsenhoff (1987, 1988). Functional feeding group and habit of invertebrates were from Merritt et al. (2008) and Barbour et al. (1999). Invertebrate density (individuals/m^2 or ind/m^2) and bioassessment metrics were calculated using R (R Development Core Team 2013) with the *plyr* (Wickham 2011), *Matrix* (Bates and Maechler 2013), and *vegan* (Oksanen et al. 2013) packages. To investigate site differences, I used ANOVA to compare abundance and bioassessment metrics for each sample with R. Differences among sites were distinguished using multiple comparison tests with Bonferroni adjusted values.

Table 1. Invertebrate bioassessment metrics used to compare sites at Devils Tower National Monument.

Metric	Equation	Predicted response to impact
% Chironomidae	$= \left(\frac{density_{Chironomidae}}{total\ density}\right) \times 100$	Increase
% Clingers	$= \left(\frac{density_{clingers}}{total\ density}\right) \times 100$	Decrease
% Clingers taxa	$= \left(\frac{richness_{clingers}}{taxa\ richness}\right) \times 100$	Decrease
% EPT	$= \frac{density_{EPT}}{total\ density} \times 100$	Decrease
% EPT taxa	$= \left(\frac{richness_{EPT}}{taxa\ richness}\right) \times 100$	Decrease
% Filterers	$= \left(\frac{density_{filterers}}{total\ density}\right) \times 100$	Decrease
% Gatherers	$= \left(\frac{density_{gatherers}}{total\ density}\right) \times 100$	Decrease
% Intolerant (0-5)	$= \left(\frac{density_{tolerance0-5}}{total\ density}\right) \times 100$	Decrease
% Intolerant taxa (0-5)	$= \left(\frac{richness_{tolerance0-5}}{taxa\ richness}\right) \times 100$	Decrease
% Non-insects	$= \left(\frac{density_{non-insects}}{total\ density}\right) \times 100$	Increase
% Predator taxa	$= \left(\frac{richness_{predators}}{taxa\ richness}\right) \times 100$	Decrease
% Predators	$= \left(\frac{density_{predators}}{total\ density}\right) \times 100$	Decrease
% Tolerant (6.0-7.0)	$= \left(\frac{density_{tolerance6-7}}{total\ density}\right) \times 100$	Increase

Metric	**Equation**	**Predicted response to impact**
% Tolerant (≥8)	$= \left(\frac{density_{tolerance\geq 8}}{total\ density}\right) \times 100$	Increase
% Tolerant taxa (≥8)	$= \left(\frac{richness_{tolerant\geq 8}}{taxa\ richness}\right) \times 100$	Increase
% Tolerant individuals (≥7)	$= \left(\frac{density_{tolerant\geq 7}}{total\ density}\right) \times 100$	Increase
% Tolerant taxa (≥7)	$= \left(\frac{richness_{tolerant\geq 7}}{taxa\ richness}\right) \times 100$	Increase
EPT richness	Richness of mayflies, stoneflies, and caddisflies	Decrease
EPT/midge abundance	$= \frac{density_{EPT}}{density_{Chironomidae}}$	Decrease
HBI	$= \sum_{i=1}^{n} \frac{density_i \times tolerance_i}{total\ density}$	Increase
Taxa diversity	$= -\sum_{i=1}^{s} p_i \times \ln(p_i)$ Where p_i is the proportion of the i^{th} taxa	Decrease
Taxa evenness	$= \frac{taxa\ diversity}{\ln(taxa\ richness)}$	Decrease
Taxa richness	Number of taxa in a sample	Decrease
Total density	Total number of individuals per square meter (ind/m^2)	Decrease

Results

Basic water quality was similar among the three sites. Water temperatures were coolest at site #2 and warmest at site #1 (Table 2), which is probably due to sampling order (I sampled site #2 in the morning and site #1 in the afternoon). Dissolved oxygen was highest at site #1 and lowest at site #2, but all values indicated that the water had adequate oxygen for aquatic life (Table 2). Specific conductivity and pH were similar among sites. The Belle Fourche River was basic as is common for rivers in Wyoming. Oxidation-reduction potential was highest at site #1, but all sites were <200 mV indicating a reducing environment in the river. I could see the bottom of the river at all sites and water depth was between 45 and 70 centimeters.

Table 2. Site locations and basic water quality at each site along the Belle Fourche River at Devils Tower National Monument.

Parameter	Units	Site 1	Site 2	Site 3
Northing		44.5818	44.5832	44.5933
Easting		-104.7161	-104.7063	-104.7003
Datum		NAD83	NAD83	NAD83
Water Temperature	˚C	17.4	14.9	16.1
Dissolved oxygen	% saturation	107	90	101
Dissolved oxygen	mg/L	9.0	7.9	8.7
Specific Conductivity	µS/cm	2190	2184	2187
pH		8.0	8.0	8.0
Oxidation-reduction potential	mV	90	57	68
Secchi disk depth	cm	Bottom	Bottom	Bottom

I identified at least 31 taxa of invertebrates in the Belle Fourche River at Devils Tower National Monument. Total invertebrate density in the Belle Fourche River was 3760 ind/m^2, and insects (3610 ind/m^2) were far more abundant than non-insects (150 ind/m^2). Additionally, most of the taxa were insects (23 taxa) from 7 orders. Coleoptera (1119 ind/m^2) was the most abundant insect order followed by Diptera (1055 ind/m^2), Trichoptera (771 ind/m^2), and Ephemeroptera (568 ind/m^2; Figure 2). I collected fewer non-insect taxa (8 taxa from 5 phyla), and Crustacea (88 ind/m^2) were the most abundant followed by Annelida (36 ind/m^2), and Mollusca (22 ind/m^2).

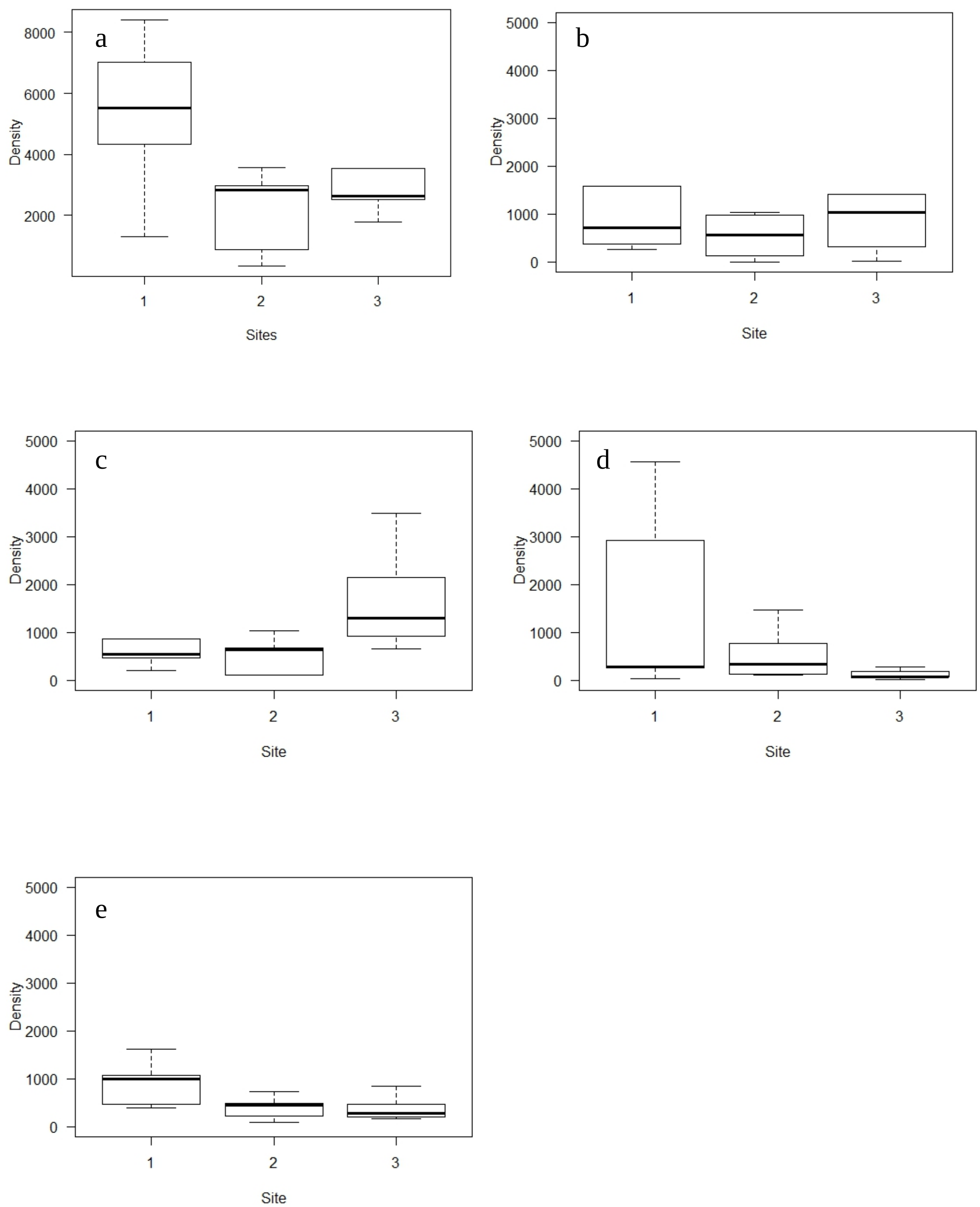

Figure 2. Total invertebrate density (a) at each site in the Belle Fourche River at Devils Tower National Monument. Coleoptera (b) were the most abundant invertebrates, followed by Diptera (c), Trichoptera (d), and Ephemeroptera (e). Bold lines are median values, the lower and upper edges of the box represent the 25th and 75th percentiles, and whiskers are the upper and lower limits of the data.

I collected the most invertebrates at site #1 (5320 ind/m^2) and the fewest invertebrates at site #2 (2110 ind/m^2) (Tables 3 and 4), but densities were not different among sites (F = 0.79, df = 1, P = 0.39). Coleoptera (F= 0.001, df = 1, P = 0.98; Figure 2b) and Diptera (F= 1.6, df = 1, P = 0.23; Figure 2c) densities were similar among sites. However, Trichoptera (F= 3.9, df = 1, P = 0.069; Figure 2d) and Ephemeroptera (F = 4.9, df = 1, P = 0.045; Figure 2e) densities were lowest at site #3, but individual sites were not significantly different using multiple comparison tests. *Tricorythodes*, *Cinygmula*, and *Paracloeodes* were the most abundant (>150 ind/m^2) Ephemeroptera in the river. *Cheumatopsyche* and *Ceratopsyche* (Figure 3a) dominated the Trichoptera. *Dubiraphia* (mostly larvae; Figure 3b) were the most abundant Coleoptera. Finally, non-Tanypodinae Chironomidae and *Culicoides* were the most abundant Diptera in the Belle Fourche River. I collected other insect orders at lower abundances (<150 ind/m^2; Table 3). *Hyallela* (Amphipoda) were by far the most abundant non-insect invertebrates collected and were most abundant at site #1.

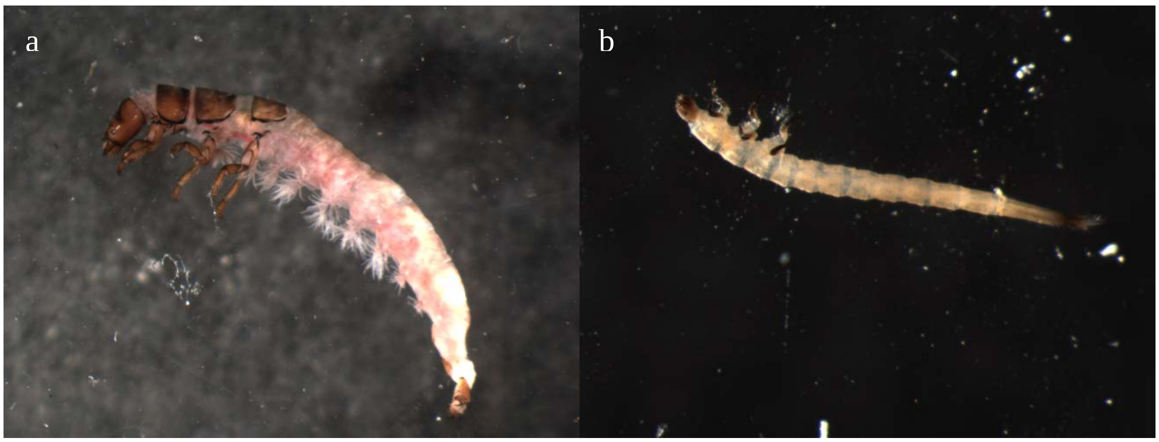

Figure 3. Photos of *Ceratopsyche* (Trichoptera; a) and larval *Dubiraphia* (Coleoptera; b) from the Belle Fourche River. Photos by Cody Bish.

Collector-gatherers (2600 ind/m^2) and collector-filterers (760 ind/m^2) were the most common functional feeding group of invertebrates in the Belle Fourche River at Devils Tower National Monument (Figure 4). I also collected scrapers (200 ind/m^2), predators (190 ind/m^2), shredders (2 ind/m^2), and parasites (1 ind/m^2) at much lower abundances. The dominant gatherers in the Belle Fourche River were *Tricorythodes*, *Dubiraphia*, non-Tanypodinae Chironomidae, *Hyalella*, and Oligochaetes. The dominant filterers in the river were hydropsychid caddisflies, Sphaeriidae, and *Simulium*. Scraper (400 ind/m^2; F = 4.6, df = 1, P = 0.05) and filterer (1630 ind/m^2; F = 4.1, df = 1, P = 0.06) densities were highest at site #1, but values were not different among sites (Bonferroni corrected, P > 0.18 and P > 0.21, respectively) (Figure 4). Gatherer, shredder, predator, and parasite densities were not different among sites (ANOVA, P >0.1).

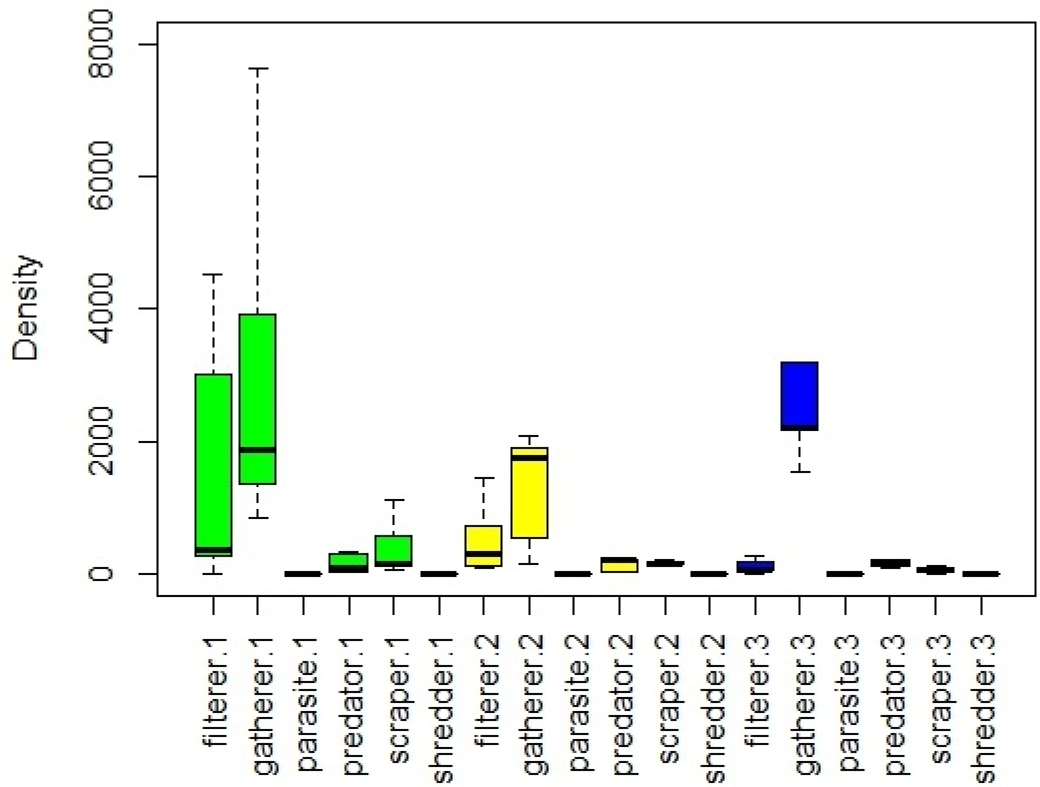

Figure 4. Density (ind/m2) of invertebrate functional feeding groups at site #1 (green), site #2 (yellow), and site #3 (blue) in the Belle Fourche River at Devils Tower National Monument. Bold lines are median values, lower and upper limits of the boxes are the 25th and 75th percentiles, and whiskers are limits of the data.

Clingers (1930 ind/m^2) were the dominant habit of insects in the Belle Fourche River and were mainly composed of hydropsychid caddisflies and the beetle *Dubiraphia*. Burrowers were also abundant (1110 ind/m^2) in the river and were primarily composed of Chironomidae. Sprawlers (470 ind/m^2) and swimmers (160 ind/m^2) had lower abundances. Sprawlers were primarily composed of the mayfly *Tricorythodes* and the amphipod *Hyallela*, and swimmers were dominated by the mayfly *Paracloeodes*. I also collected a small number of plankton (cyclopoid copepods) at site #1. Clinger, burrower, climber, and swimmer densities were not different among sites (ANOVA, $P > 0.05$); however, I collected more sprawlers at site #1 compared to the other sites ($F = 5.1$, df = 1, $P = 0.04$; Bonferroni corrected, $P = 0.03$; Figure 5).

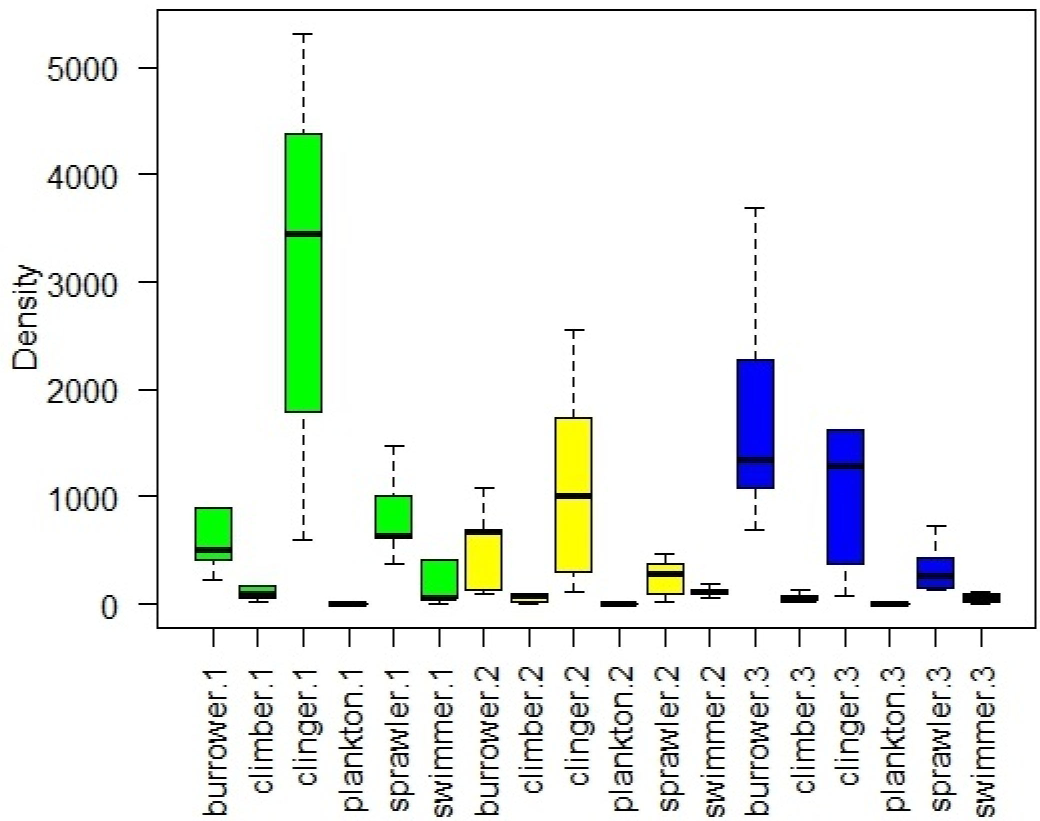

Figure 5. Density (ind/m2) of invertebrate habits at site #1 (green), site #2 (yellow), and site #3 (blue) in the Belle Fourche River at Devils Tower National Monument. Bold lines are median values, lower and upper limits of the boxes are the 25th and 75th percentiles, and whiskers are the lower and upper limits of the data.

Table 3. Density (ind/m^2) of insects at each site along the Belle Fourche River at Devils Tower National Monument. Variance is standard error.

Taxa	Site #1	Site #2	Site #3
Ephemeroptera	912±130	400±53	391±70
Cinygmula	9±4	5±3	0±0
Leucrocuta	0±0	7±7	2±2
Neochoroterpes	9±7	16±11	2±2
Paracloeodes	293±183	119±22	49±20
Tricorythodes	600±106	249±84	337±111
Odonata	49±20	23±5	70±17
Argia	0±0	7±5	14±11
Coenagrion/Enallagma	47±32	7±7	28±20
Dromogomphus	2±2	9±4	28±20
Hemiptera	33±13	33±12	26±14
Ambrysus	33±15	33±13	19±19
Corixidae (early instar)	0±0	0±0	7±7
Lepidoptera (*Petrophila*)	37±20	7±7	7±3
Trichoptera	1614±366	570±135	130±30
Cheumatopsyche	614±424	470±224	109±48
Ceratopsyche	949±547	51±26	0±0
Hydroptila	30±9	9±7	2±2
Oecetis	21±13	40±11	19±8
Coleoptera	1395±360	544±126	1418±431
Berosus	7±5	0±0	2±2
Dubiraphia	1337±696	481±185	1393±748

Taxa	**Site #1**	**Site #2**	**Site #3**
Microcylloepus	51±17	63±34	23±15
Diptera	946±184	517±93	1702±280
Chironomidae	867±411	496±171	1546±430
Non-Tanypodinae	830±381	470±167	1518±424
Tanypodinae	26±26	23±13	12±7
Culicoides	28±20	19±8	154±87
Simulium	42±18	2±2	2±2
Tipula	7±7	0±0	0±0
Total Insects	4987±231	2094±90	3745±225

Table 4. Density (ind/m2) of non-insect invertebrates at each site along the Belle Fourche River at Devils Tower National Monument. Variance is standard error.

Taxa	**Site #1**	**Site #2**	**Site #3**
Crustacea	249±108	0±0	14±5
Copepoda (Cyclopoida)	14±14	0±0	0±0
Hyalella	226±214	0±0	5±5
Ostracoda	9±9	0±0	9±9
Mollusca	51±11	14±4	0±0
Physidae	30±19	0±0	0±0
Sphaeriidae	21±9	14±7	0±0
Annelida	30±30	0±0	77±24
Oligochaeta	30±30	0±0	77±24
Nematomorpha	2±2	0±0	0±0
Hydracarina	0±0	2±2	5±5
Total Non-Insects	333±66	16±3	95±12

In general, bioassessment metrics calculated using aquatic invertebrates indicated that the Belle Fourche River at Devils Tower National Monument had good ecosystem quality (Table 5). Additionally, 60% of metrics did not differ significantly among sites (ANOVA, P >0.05). Hilsenhoff's Biotic Index (HBI) values suggested that the average pollution tolerance of an invertebrate in the river was similar among sites and moderate in value. The % intolerant (>40%) and the % Ephemeroptera, Plecoptera, and Trichoptera (EPT; ~50%) were high at sites #1 and #2. Similarly, approximately 6 EPT taxa were collected at sites #1 and #2. Conversely, the % tolerant taxa (≥8 tolerance value) and % tolerant were fairly low at all sites (<24%). According to the metrics, site #3 had lower ecosystem quality compared to the other sites. Site #3 had lower % clinger taxa (F = 17, df = 1, P = 0.005), % EPT (F = 14, df = 1, P = 0.002), % filterers (F = 5.0, df = 1, P = 0.0043), % intolerant (F = 5.4, df = 1, P = 0.037), EPT/Chironomidae ratio (F = 6.7, df = 1, P = 0.023), and taxa diversity (Shannon's diversity; F = 11.6, df = 1, P = 0.001), but only % clinger taxa (Bonferroni corrected, P = <0.0049) and taxa diversity (Bonferroni corrected, P = <0.0012) were significant after multiple comparisons tests. Additionally,% Chironomidae (F = 12.8, df = 1, P = 0.003; Bonferroni corrected, P = 0.013) and % tolerant (6-7; F = 12.4, df = 1, P = 0.004; Bonferroni corrected, P = 0.015) were highest at site #3. Despite differences in the % Chironomidae among sites, these insects composed a relatively small portion of the assemblage (<8%).

Table 5. Invertebrate bioassessment metrics at each site along the Belle Fourche River at Devils Tower National Monument. Variance is standard error. Metrics with significant site effects (ANOVA; P<0.05) were marked with an asterisk and significant differences among sites (multiple comparison tests) are shown in the differences column.

Metric	Site #1	Site #2	Site #3	Differences Among Sites
% Chironomidae*	2.9%±0.7	4.4%±0.7	7.6%±1.3	#1 vs. #3
% clingers	56%±6.1	47%±7.5	36%±11.9	
% clingers taxa*	49%±6.3	46%±2.6	26%±1.5	#1 vs. #3 #2 vs. #3
% EPT*	49%±16	52%±5.7	17%±3.5	
% EPT taxa	39%±7.4	50%±4.9	35%±5.6	
% filterers*	30%±13	24%±5.2	4.4%±1.9	
% gatherers	59%±15	58%±5.5	87%±1.4	
% intolerant (0-5)*	45%±13	43%±4.0	18%±3.2	
% intolerant taxa (0-5)	41%±7.4	44%±2.9	39%±2.8	
% non-insects	7.3%±5.1	0.55%±0.28	2.9%±0.79	
% predators	3.0%±1.1	6.9%±1.3	6.7%±1.5	
% predator taxa*	20%±3.7	31%±3.8	33%±3.5	
% tolerant (6.0-7.0)*	17%±4.6	28%±4.8	46%±7.9	#1 vs. #3
% tolerant (≥7)	13%±12	46%±5.0	76%±3.5	
% tolerant taxa (≥7)	24%±4.5	23%±5.2	28%±3.1	
% tolerant (≥8)	13%±4.4	11%±2.7	5.6%±1.4	
% tolerant taxa (≥8)	23%±4.0	18%±3.2	23%±4.2	
EPT richness	5.8±1.0	6.4±0.40	3.8±0.20	
EPT/Chironomidae*	5.9±2.6	2.6±0.68	0.40±0.77	
HBI	5.05±0.35	5.46±0.09	5.68±0.07	
Taxa diversity*	1.79±0.064	1.89±0.038	1.38±0.084	#1 vs. #3 #2 vs. #3

Metric	Site #1	Site #2	Site #3	Differences Among Sites
Taxa evenness	0.67±0.041	0.75±0.035	0.57±0.029	
Taxa richness	15±2.0	13±1.8	12±1.5	
Total abundance	5320±200	2110±77	3841±192	

Discussion

The Belle Fourche River at Devils Tower National Monument appeared to support a healthy assemblage of invertebrates. I collected a diverse assemblage of aquatic invertebrates that varied in taxonomy, pollution tolerance, functional feeding group, and habit. Total invertebrate density and diversity indicated that many individuals and taxa lived in the river. Trichoptera and Ephemeroptera were the 3rd and 4th most abundant order of insects in the river and these orders are both known to be sensitive to degradation. Healthy rivers are predicted to have a high % gathering, % filtering, and % clinging invertebrates, all of which dominated the assemblage in the Belle Fourche River. The average pollution tolerance of an invertebrate in the river was moderate (5.4 on a scale from 0 to 10), and I collected approximately13 taxa per sample.

Relatively little information has been published on the Belle Fourche River. Two studies investigated geologic processes of the Belle Fourche River, including sediment storage (Marron 1992) and sinuosity (Gomez and Marron 1991). Others have investigated the fish in the Belle Fourche River (Hayer et al. 2008), including Keyhole Reservoir (Mueller 1981). However, no studies have investigated the aquatic invertebrates of the Belle Fourche River except for Rust (2006).

Rust (2006) assessed the water and ecosystem quality of the Belle Fourche River at Devils Tower National Monument. She found that the average tolerance value of an invertebrate in the Belle Fourche River was 5.27 which is similar to what I measured (5.40). Additionally, Rust (2006) collected a similar number of taxa (13 taxa),% Chironomidae (3.4%), % EPT (40%), and % clingers (45%) to the current study (15 taxa, 5.0%, 39% and 46%, respectively). Rust (2006) did not define tolerant and intolerant taxa, but the % taxa with tolerance values $\geq$7 in the current study (25%) were similar to Rust's (2006) % tolerant taxa (20%). Conversely, I collected a higher % intolerant taxa (41%) and EPT taxa (5.3 taxa) compared to Rust (2006, 25% and 4, respectively). The differences in the data may be due to different sampling strategies (dip net vs. Hess sampler), date of collection, and the areas sampled.

In the current study, I collected aquatic invertebrates from three sites along the Belle Fourche River at Devils Tower National Monument. Sites #1 and #2 generally had similar bioassessment metrics, but the values at site #3 were typically considered more impacted by comparison. For example, the % Chironomidae and % tolerant (6-7) individuals were highest at site #3, and the % clinger taxa, % EPT, % filterers, % intolerant, EPT/Chironomidae, and taxa diversity were lowest at site #3. Site #3 was the most downstream reach of the Belle Fourche River I sampled and was located where the river flows out of the park. The reason that site #3 showed lower quality compared to the other sites is unknown, but may be due to differences in substrate or human impact. The substrate at sites #1 and #2 were primarily cobble (site #1), and gravel and cobble (site #2), whereas site #3 may have had more fines in the substrate. In general, finer substrate generally supports fewer aquatic invertebrates (Williams and Mundie 1978, Bourassa and Morin 1995, Yamamuro and Lamberti 2007). Additionally, the soil type is different at site #3 compared to the other sites. The red Spearfish Formation seen in the cover photo is the oldest formation at Devils Tower and is composed of sandstone and siltstone. Perhaps the eroding Spearfish Formation increased the fines at site #3 over time compared to the other sites. Alternatively, human activities immediately outside the park may affect site #3. A large private campground sits just outside Devils Tower National Monument and the Belle Fourche River flows around that area (Figure 1). The campground has 56 recreational vehicle sites with full-hookups and an additional 16 ha camping area along the river. Devils Tower National Monument also has a campground without hookups, but I did not observe elevated metrics at site #2. Substrate or anthropogenic activities by site #3 may at least partially be responsible for lower bioassessment metrics at site #3.

Table 6. Selected invertebrate bioassessment metrics in the Belle Fourche River at Devils Tower National Monument compared to other rivers in parks within the Northern Great Plains Network region. The Laramie River flows through Fort Laramie National Historic Site, the Knife River flows through Knife River Indian Villages National Historic Site, and the Little Missouri River flows through Theodore Roosevelt National Park.

Metric	Predicted response to impact	Belle Fourche River	Laramie River	Knife River	Little Missouri River
% Chironomidae	Increase	5.0%	6.3%	49%	58%
% clingers	Decrease	46%	40%	4.3%	22%
% gatherers	Decrease	68%	58%	61%	61%
% intolerant (0-5)	Decrease	35%	64%	7.3%	12%
% tolerant (≥8)	Increase	9.9%	0.15%	64%	2.4%
EPT richness	Decrease	5.3	11	2.7	2.3
EPT/Chironomidae	Decrease	3.0	2.6	0.23	1.8
HBI	Increase	5.40	4.82	6.08	5.90
Taxa diversity	Decrease	1.69	1.79	1.49	0.90
Taxa richness	Decrease	13	21	11	5
Total density (ind/m^2)	Decrease	3,757	21,478	3,224	720

Compared to other rivers flowing through parks in the Northern Great Plains Network region, the Belle Fourche River had good ecosystem quality. The Belle Fourche River had the lowest % Chironomidae, and the highest % clingers, % gatherers, and EPT/Chironomidae ratio compared to the Laramie River (Tronstad 2013c), the Knife River (Tronstad 2013a), and the Little Missouri River (Tronstad 2013b; Table 6). The Laramie River at Fort Laramie National Historic Site showed better responses than the Belle Fourche River for several metrics, but values were generally similar (Table 6). However, the Laramie River was much more diverse than the other rivers, had an exceptionally low % tolerant taxa, and a very high % intolerant taxa. The bioassessment metrics for rivers in North Dakota parks (the Knife and Little Missouri Rivers) generally had values that showed greater impact. The rivers in North Dakota are functionally different ecosystems compared to the Belle Fourche and Laramie Rivers. For example, the rivers in North Dakota are much larger, contained much finer substrate, and flowed through a different landscape (e.g., geology, land use, etc.). Therefore, the rivers in North Dakota parks are not necessarily more impacted, but their baseline values and potential for such metrics are different. The Belle Fourche and Laramie Rivers are much more comparable because they are located in a similar area, with similar land use and substrate.

Compared to other streams in northeastern Wyoming, the Belle Fourche River at Devils Tower National Monument appeared to be in good condition. I compared individual metrics used in the Wyoming Stream Integrity Index (Hargett 2011) to values measured from the Belle Fourche River at Devils Tower National Monument. The Belle Fourche River was located in the northeastern plains bioregion of Wyoming and the multimetric index developed for this area used number of mayfly taxa, number of taxa with univoltine life cycles (live at least 1 year), and HBI. All sites and metrics were within the least disturbed category (Table 7) indicating that the Belle Fourche River supported its designated uses (Hargett 2011).

Table 7. Metrics included in the Wyoming Stream Integrity Index for the northeastern plains, the expected trend in relation to stream impairment, the threshold values for least disturbed sites, and metrics calculated for three sites along the Belle Fourche River at Devils Tower National Monument. Metrics from the Belle Fourche River were electronically composited to simulate field composite samples used to develop the metrics.

Metric	**Trend**	**Threshold**	**Site 1**	**Site 2**	**Site 3**
Number of Ephemeroptera	-	>3	4	5	4
Number of univoltine taxa	-	>10	17	18	19
HBI	+	<6.8	5.05	5.46	5.68

Fecal coliform concentrations in the Belle Fourche River at Devils Tower National Monument are known to exceed the water quality criteria for recreation. I did not measure the concentration of fecal coliform in the river when I collected samples or how concentrations varied over the previous year, but fecal coliform may affect the aquatic invertebrate assemblage. Studies have measured fecal coliform concentrations and aquatic invertebrates in streams, and found that all invertebrates used the fecal bacteria and total invertebrate densities increased (del Rosario et al. 2002, Kaller and Kelso 2006). Fecal coliform in the Belle Fourche River may come from livestock using the river upstream from Devils Tower National Monument. In the Belle Fourche River, the total density of invertebrates was highest at site #1 which was located in a pasture used by cattle. Others discovered that higher fecal coliform concentrations generally decreased the taxa richness and intolerant individuals along the Cuyahoga River in Ohio (Olive 1976). I did not observe differences in taxa richness among the sites, but the % of intolerant taxa was highest at site #1. Currently, not enough information is available to understand how fecal coliform concentrations vary along the Belle Fourche River and how these bacteria may impact the aquatic resources.

Conclusions

The Belle Fourche River flows through Devils Tower National Monument forming much of the southern boundary of the park. Because rivers are highly influenced by the surrounding landscape and what occurs upstream, the 3.6 km of river that flows through the park is tied to actions upstream. The land around Devils Tower National Monument is primarily used for livestock grazing and farming which may alter the river depending on how the land is managed. Elevated fecal coliform concentrations are probably the result of livestock using the river. Fecal coliform can also come from pets or septic treatment; however, the human population is rather sparse in this area. Another factor that changes the river at Devils Tower National Monument is Keyhole Reservoir. The dam is located upstream from the park and moderates the flow of the Belle Fourche River. Therefore, the river below the dam will not flood to the same degree as before the dam was built. Flooding is a natural event that is needed to maintain riparian vegetation (e.g., cottonwood trees) and flush the stream of fine sediment. Despite these disturbances, the invertebrates in the Belle Fourche River indicated that the ecosystem is generally in good condition. In general, the bioassessment metrics showed that sites #1 and #2 had higher quality than site #3. Future studies are needed to understand why site #3 differed from the other sites.

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