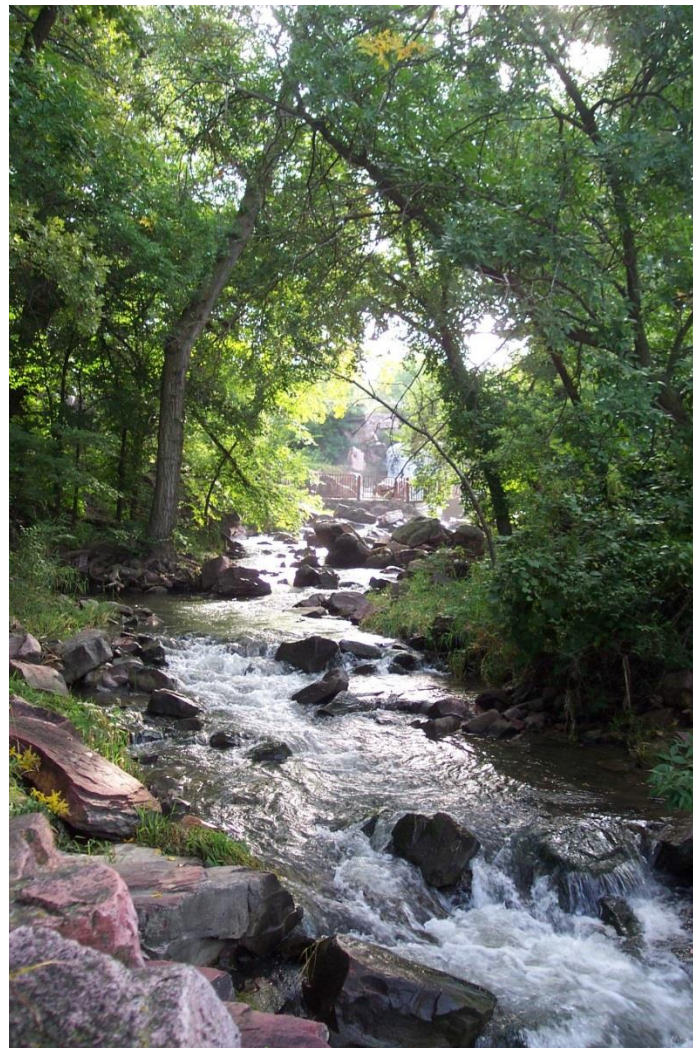




Aquatic Invertebrate Monitoring at Pipestone National Monument

1989-2010 Status and Trend Report

Natural Resource Technical Report NPS/HTLN/NRTR—2013/824



ON THE COVER

Pipestone Creek, Pipestone National Monument

Photo from the Heartland Inventory and Monitoring Network

Aquatic Invertebrate Monitoring at Pipestone National Monument

1989-2010 Status and Trend Report

Natural Resource Technical Report NPS/HTLN/NRTR—2013/824

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Abstract

In the late 1980's, the National Park Service (NPS) began monitoring water quality and invertebrate community structure in Pipestone Creek at Pipestone National Monument, Minnesota (PIPE). Preliminary monitoring was conducted at PIPE in 1989. Following this baseline year, monitoring was not conducted again until 1996, but it was conducted annually until 2007 and every three years thereafter. The objectives of this monitoring are: 1) determine the status and trends of invertebrate species diversity, abundance, and community metrics, and 2) relate the invertebrate community to overall water quality through quantification of metrics related to species richness, abundance, diversity, and region-specific multi-metric indices as indicators of stream condition and habitat condition.

Aquatic invertebrates were collected using a Surber stream bottom sampler (500 μm mesh, 0.09 m^2). Samples were collected at three successive riffles, with three benthic invertebrate samples collected per riffle. Diversity and community metrics calculated from the invertebrate data include family richness, taxa richness, Ephemeroptera, Trichoptera, Plecoptera (EPT) richness, the ratio of EPT/(EPT+Chironomidae), Shannon's diversity index, Shannon's evenness index, and the Hilsenhoff Biotic Index (HBI). Control charts and the Mann-Kendall trend test were used to further evaluate change over time in the benthic invertebrate communities. Water quality and habitat data were collected in conjunction with the benthic samples.

Based on the invertebrate community metrics reported here, the water quality of Pipestone Creek within PIPE has not diminished beyond that reported in earlier studies and stream condition is generally good. Pipestone Creek is impacted from a combination of agricultural practices and urbanization and is listed as a 303d stream by the Minnesota Pollution Control Agency due to elevated turbidity and fecal coliform levels. Because impacts to water quality in Pipestone Creek occur outside the monument boundaries, there are few available options to monument management for mitigating this situation. Maintaining riparian buffer zones along Pipestone Creek above the monument will aid in protecting aquatic life in Pipestone Creek as well as in-stream habitat from local chemical runoff and sedimentation. The long history and continuing efforts of aquatic invertebrate monitoring at Pipestone National Monument provides a sound tool to recognize both deterioration and chronic decline of water quality of Pipestone Creek.

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Introduction

Pipestone Creek, a tributary of the Big Sioux River, meanders from east to west about 100 km through southwestern Minnesota. The creek originates 19.3 km northeast of Pipestone National Monument (PIPE) as a drainage ditch near Holland, Minnesota (Harris et al. 1991). The city of Pipestone, Minnesota lies on the south side of the creek and borders the monument on the south end. Pipestone Creek flows through the center of the monument and widens twice within its boundaries to form Lake Hiawatha and an unnamed pond. A recreational lake on Pipestone Creek borders the Monument on the west side. Natural vegetation of the area is native and restored bluestem prairie (Kuchler 1964, Stubbendieck and Willson 1986), but agriculture (e.g., row crops) is the primary land use in the watershed. A natural waterfall within the monument was lowered 2.5 to 3.0 m in the early 1900's (Harris et al. 1991). Upstream of the waterfall, Pipestone Creek is channelized, essentially without meanders, and with a largely bedrock substrate.

Water quality data represent only a snap-shot of the broad temporal range of chemical and physical conditions, and should be cautiously interpreted. Due to the limitations of using water periodically obtained quality data, aquatic invertebrate communities often are used as a surrogate of the long-term water quality condition. Aquatic invertebrates are exposed to the chemical and physical conditions of the stream over the long term, and, as such, they can serve as an important tool for understanding and detecting changes in stream integrity over time. They are also sedentary, relatively easy to identify, and are sensitive to changes in environmental conditions (Barbour et al. 1999). Various metrics calculated from species richness, abundance, diversity, tolerance to disturbance, and region-specific multi-metric indices can provide clues to the overall water quality conditions for biological support in the stream.

Water pollution within the watershed is primarily agricultural in origin, but the city of Pipestone, Minnesota releases effluent into Pipestone Creek below the monument boundary. The National Park Service (NPS), Water Resources Division, conducted an extensive review of historic water quality data for an area 4.8 kilometers upstream and 1.6 kilometers downstream of the monument (NPS Water Resources Division 1999). This report noted that since 1974 dissolved oxygen, pH, cadmium, copper, lead, and zinc have periodically exceeded their respective EPA criteria for freshwater aquatic life use. Additionally, concentrations of nitrate, nitrite plus nitrate, chloride, cadmium, lead and methylene chloride have exceeded EPA drinking water criteria during monitoring events since 1974 (Water Resources Division 1999). In addition, Pipestone Creek is listed by the state of Minnesota as a 303d waterway due to exceeding limits of fecal coliform contamination and turbidity for freshwater bathing and aquatic life uses, respectively (Minnesota Pollution Control Agency 2007).

The various anthropogenic disturbances described above have a significant potential for disrupting the ecological integrity and functioning of the Pipestone Creek ecosystem. To assess these potential threats, the NPS began monitoring the aquatic invertebrates of Pipestone Creek within PIPE beginning in 1989 (Harris et al. 1991). From 1992-1995, the NPS Midwest Regional Office funded additional aquatic invertebrate sampling efforts within the creek. However, sampling was sporadic and mostly outside the collection season of interest (summer) for this report. Concerted monitoring

efforts began in 1996-1997. Peitz and Cribbs (2005) reported on status and trends of the aquatic invertebrate community at PIPE from inception of monitoring through 2004, and Bowles (2009) reported on the trend in the resource from 2005 to 2007. The purpose of this report is to summarize aquatic invertebrate monitoring data collected since 1989 and assess that data with respect to trend.

Methods

Methods and procedures used in this report follow Bowles et al. (2008), Monitoring Protocol for Aquatic Invertebrates of Small Streams in the Heartland Inventory & Monitoring Network. Samples were collected from Pipestone Creek (Figure 1) during a summer index period.

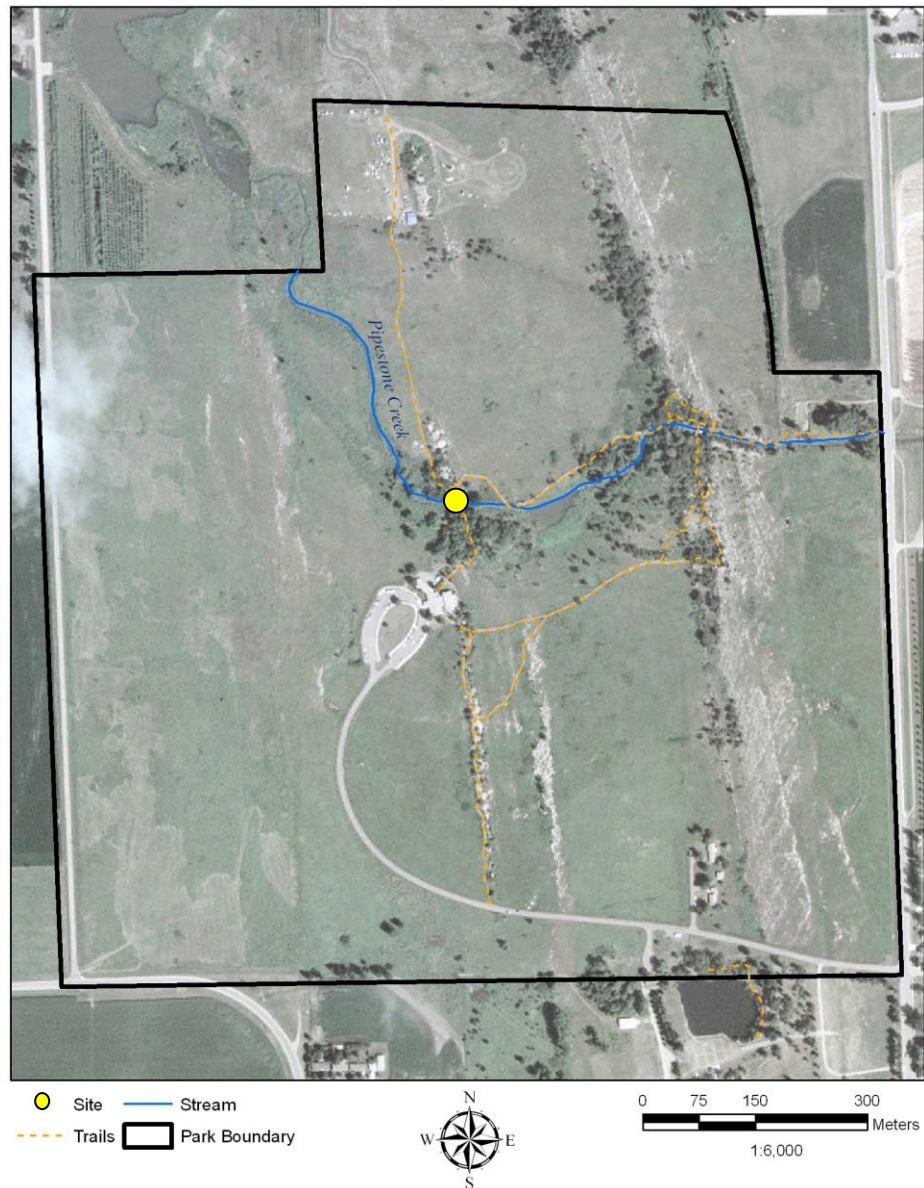


Figure 1. Map of Pipestone National Monument, Minnesota showing the lower boundary of the invertebrate monitoring site (yellow dot) on Pipestone Creek.

Sample Collection

Aquatic invertebrates were collected from three successive riffles with three benthic invertebrate samples collected per riffle, resulting in nine samples. A Surber stream bottom sampler (500 μm mesh, 0.09 m^2) was used to collect the samples. Samples were sorted in the laboratory following a subsampling routine described in Bowles et al. (2008). Taxa were identified to the lowest practical taxonomic level (usually genus) and counted.

For each sample, current velocity (m/sec) and depth (cm) were recorded immediately in front of the sampler. Beginning in 2006, qualitative habitat variables (embeddedness, periphyton, filamentous algae, aquatic vegetation, deposition, and organic material) were visually estimated within the sampling net frame as percentage categories (0, <10, 10-40, 40-75, >75). Habitat data were analyzed as midpoints of each category. Dominant substrate size from the area within the sampling net frame was visually assessed using the Wentworth scale (Wentworth 1922). Stream discharge was measured immediately upstream of the sampling site (Bowles et al. 2008). Discharge measurements serve to illustrate the general flow characteristics for Pipestone Creek in a given sampling year and are not intended to be exact measurements. Discharge was not measured in 2010.

Water quality data for 2005 represent static readings taken from each sampled riffle with calibrated hand-held meters. In comparison, water quality readings since 2006 were recorded hourly at least 24 hours prior to sampling for each stream using calibrated data loggers or sondes. Due to equipment failure, no data for dissolved oxygen and pH were collected at some sites in 2007. The water quality data presented in this report are only intended to describe the prevailing conditions for the 24 hours prior to sampling.

Data Analysis

The data addressed in this report are only those collected during the summer index period (July-September) from the general sampling reach described in Bowles et al. (2008). Univariate control charts were established for Pipestone Creek to illustrate the general trend of invertebrate community metrics and provide a visual tool for managers to determine which variables may require more in-depth analyses or management action in the future (Morrison 2008). Data from 1996-2004 serve as a baseline for constructing thresholds based on standard deviations of the mean of these data points. This period was chosen because the methods used were most similar to those used in Peterson et al. (1999) and the current protocol. Data collected from 2005-2010 were evaluated against this baseline period.

Control charts plot a characteristic through time with reference to its expected value. Expected values were developed by determining the natural variability within the baseline data, and setting a range of values based on that baseline. For example, upper or lower thresholds specify amounts of variability beyond what would normally be expected and indicate when a system is going “out of control” (Morrison 2008). Control charts, as used here, contain a control limit (mean $\pm$ 1.86 standard deviations) for those community metrics that respectively decrease or increase due to stressors. The

threshold indicated in the control chart serves to suggest biologically important change may be occurring when thresholds are exceeded (Morrison 2008). Setting a control chart threshold equal to 1.86 standard deviations is analogous to significance tests at a critical value of 0.05 for one-tailed tests. The student's t-distribution ($df = 8$) was used to determine the one-tailed area because of the relatively small sample size. A critical value of 0.05 is widely accepted as the 'standard' in significance testing approaches.

A trend analysis of invertebrate metrics data from Pipestone Creek across years (1988-2010) was conducted using a non-parametric Mann-Kendall trend test ($\alpha=0.05$) (Time Trends software, version 3.0, NIWA 2010). The non-parametric Mann-Kendall test is directly analogous to linear regression, but it does not assume any particular distributional form and it tests whether Y values tend to increase or decrease with time (Esterby 1993, Helsel and Hirsch 2002, Stark and Fowles 2006). The Mann-Kendall test has been recommended over other trend tests for the evaluation of stream invertebrate samples (Stark and Fowles 2006). This test complements, rather than provides an alternative to, the control chart approach. Control charts, as constructed with a single control limit, guard against the indicators declining, but do not provide any thresholds for meaningful changes in the opposite (i.e., improving) direction. The Mann-Kendall test can detect either a positive or a negative trend. Mann-Kendall tests, as employed, evaluate changes over the entire data series, whereas control charts can call attention to a more abrupt change that does not equate with a significant long-term trend.

Results

Invertebrate Community Metrics

Summary data from 1989 to 2010 for invertebrate community metrics, including family and genus richness, Ephemeroptera, Plecoptera, Trichoptera (EPT) richness, ETP/Chironomidae ratio, Shannon Index, Shannon Evenness Index, and Hilsenhoff Biotic Index (HBI) are shown in Appendix A, Table A-1. Benthic samples generally contained an assemblage of invertebrates commonly associated with stream communities, including mayflies (Ephemeroptera, primarily *Baetis*, *Caenis*, and *Stenacron*), caddisflies (Trichoptera, primarily *Cheumatopsyche*, *Hydropsyche*, *Helicopsyche*, and *Hydroptila*), dragonflies and damselflies (Odonata), midges (Chironomidae), black flies (*Simulium*) riffle beetles (*Stenelmis*), crayfish (Decapoda), and snails (Gastropoda). Mean family and taxa richnesses across years were 6.9 (range = 3.3 to 15.3) and 10.7 (range = 4.2 to 16.2), respectively. EPT richness for Pipestone Creek was relatively low (range = 1.23 to 6.2). EPT ratios ranged from 0.23 to 0.77 and were highly variable among years. Lower values of EPT ratio were due to increased numbers of pollution tolerant Chironomidae relative to the EPT taxa. Shannon's diversity index scores reported here did not exceed 1.87, reflecting low species richness and communities dominated by one or a few taxa. For biological data, values of Shannon's diversity index range generally from 1.5 (low species richness and evenness) to 3.5 (high species evenness and richness). A similar pattern was observed for Shannon's evenness index values that ranged from 0.47 to 0.79 across years. Mean HBI scores across years ranged from good to fair (4.13 to 6.6) (Figure 8). For HBI, lower values are desired. Control charts for Pipestone Creek showed that few of the annual means for invertebrate metrics met or exceeded their respective control limits (Figures 2-8). Exceptions included taxa richness, EPT richness, and Shannon's diversity index in 1998.

Mann-Kendall trend analysis showed that all metrics did not have a significant trend across years (Figures 2-8). Although none of the P-values were less than 0.05, those for family richness and Shannon diversity index ($P=0.05$ and 0.08 , respectively) were close to that limit, and could be considered "marginally significant". Although not shown to be statistically significant, family and taxa richness and HBI appear to have steadily increased since 2005.

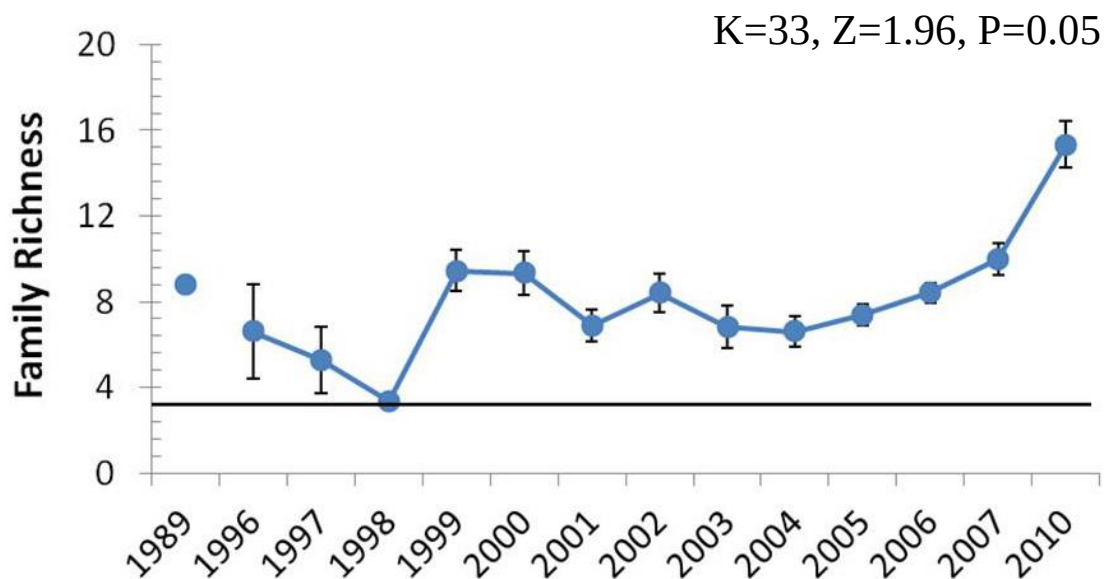


Figure 2. Control chart for family richness for Pipestone Creek, Pipestone National Monument. Points are means for a given year, and the vertical bars are standard errors ($n=3$). The horizontal line represents the control limit corresponding to the Type I error rate of 0.05. K= Mann-Kendall statistic, Z= normalized test statistic, P=probability value ($\alpha=0.05$).

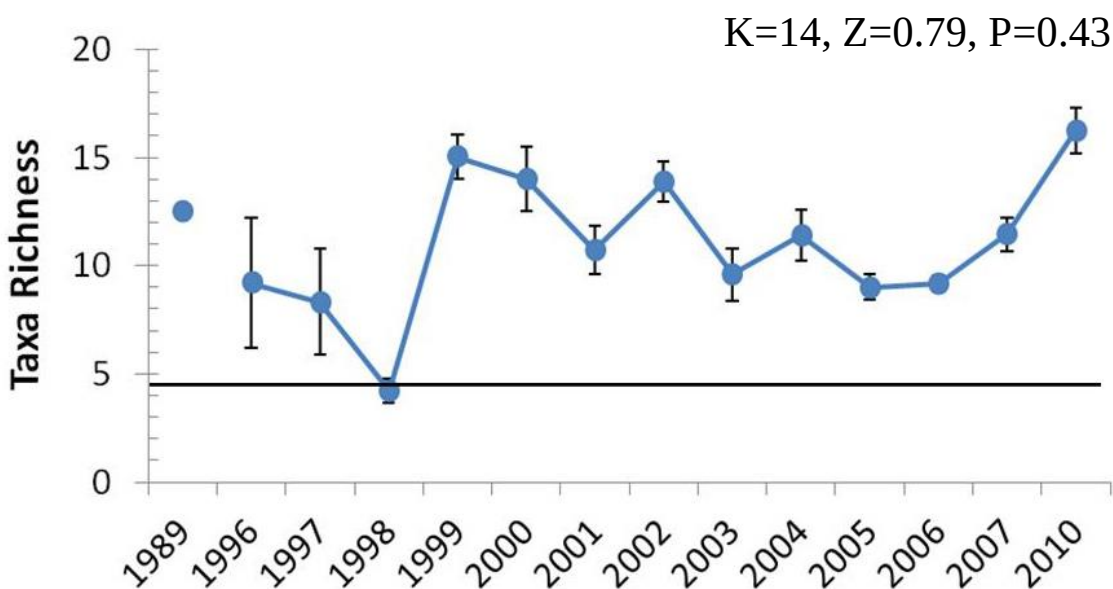


Figure 3. Control chart for taxa richness for Pipestone Creek, Pipestone National Monument. Points are means for a given year, and the vertical bars are standard errors ($n=3$). The horizontal line represents the control limit corresponding to the Type I error rate of 0.05. K= Mann-Kendall statistic, Z= normalized test statistic, P=probability value ($\alpha=0.05$).

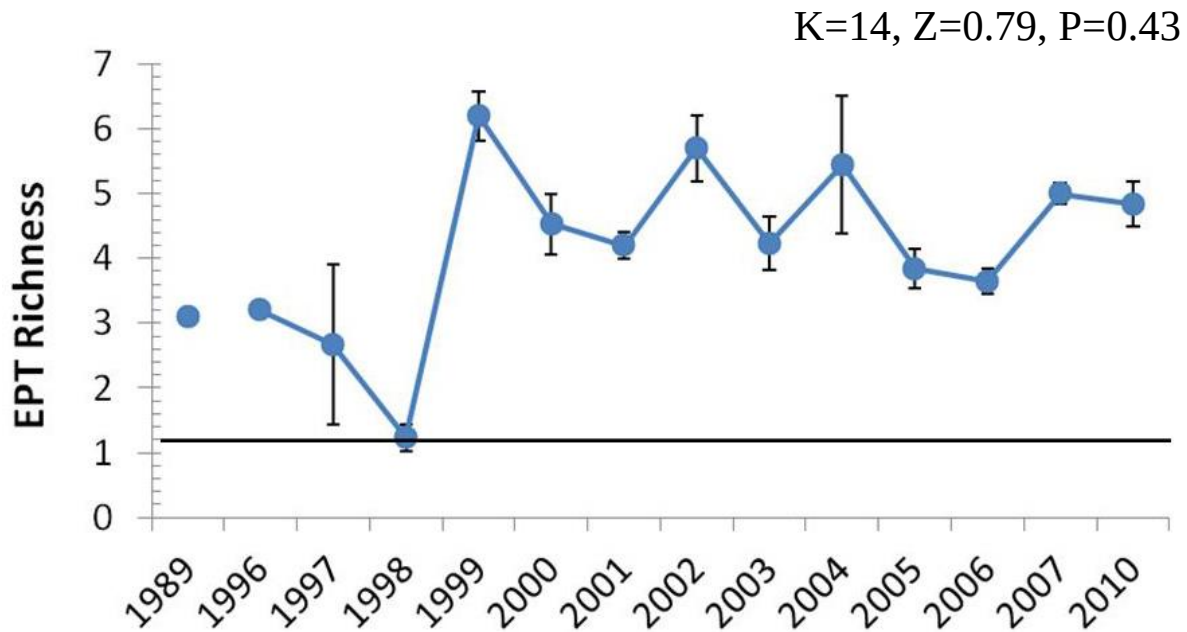


Figure 4. Control chart for Ephemeroptera, Plecoptera, Trichoptera (EPT) richness for Pipestone Creek, Pipestone National Monument. Points are means for a given year, and the vertical bars are standard errors ($n=3$). The horizontal line represents the control limit corresponding to the Type I error rate of 0.05. K= Mann-Kendall statistic, Z= normalized test statistic, P=probability value ($\alpha=0.05$).

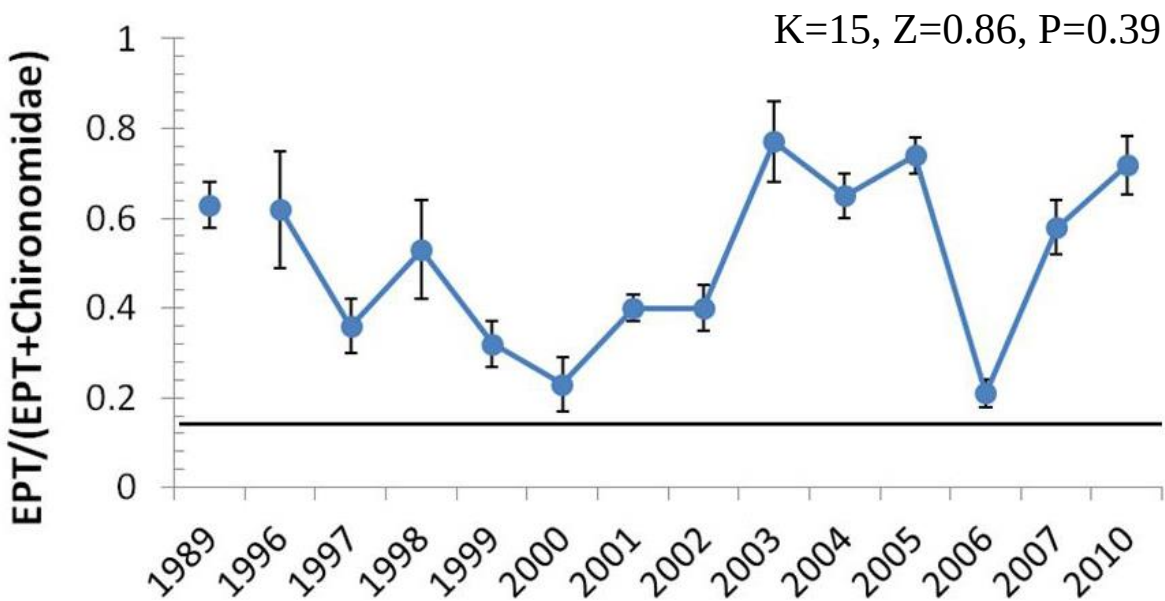


Figure 5. Control chart for Ephemeroptera, Plecoptera, Trichoptera (EPT)/Chironomidae ratio for Pipestone Creek, Pipestone National Monument. Points are means for a given year, and the vertical bars are standard errors ($n=3$). The horizontal line represents the control limit corresponding to the Type I error rate of 0.05. K= Mann-Kendall statistic, Z= normalized test statistic, P=probability value ($\alpha=0.05$).

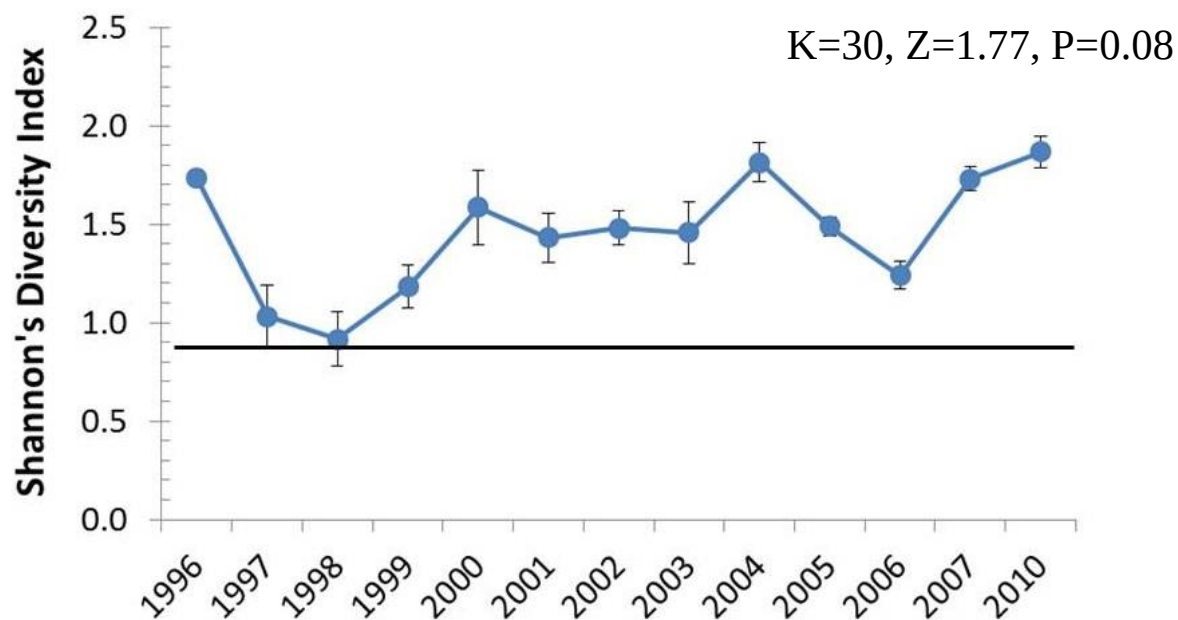


Figure 6. Control chart for Shannon's Diversity Index for invertebrate taxa for Pipestone Creek, Pipestone National Monument. Points are site means for a given year, and the vertical bars are standard errors (n=3). The horizontal line represents the control limit corresponding to the Type I error rate of 0.05. K= Mann-Kendall statistic, Z= normalized test statistic, P=probability value ($\alpha=0.05$).

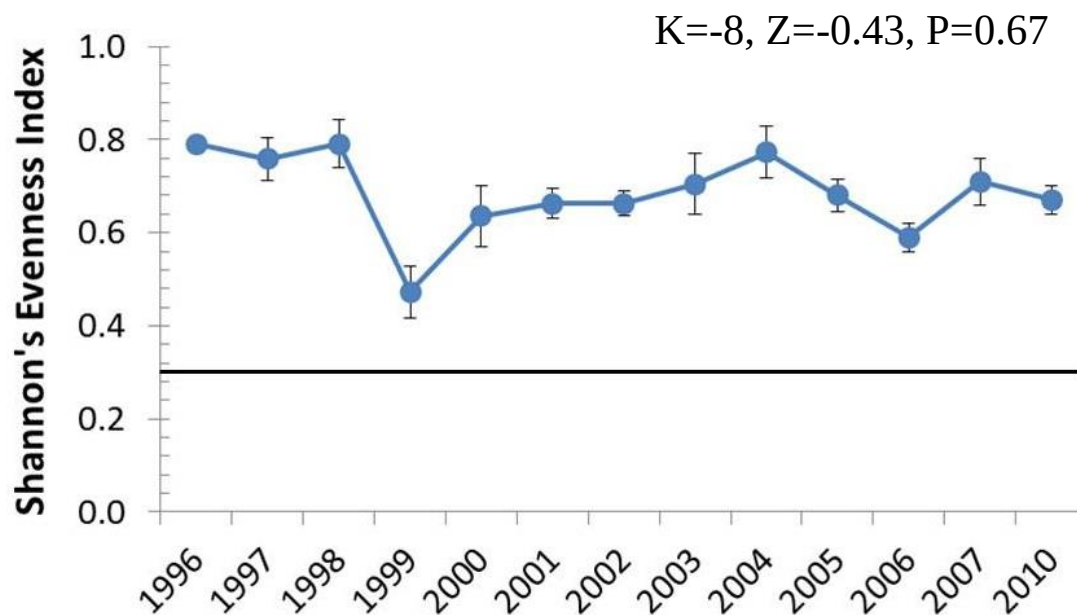


Figure 7. Control chart for Shannon's Evenness Index for invertebrate taxa for Pipestone Creek, Pipestone National Monument. Points are site means for a given sampling date, and the vertical bars are standard errors (n=3). The horizontal line represents the control limit corresponding to the Type I error rate of 0.05. K= Mann-Kendall statistic, Z= normalized test statistic, P=probability value ($\alpha=0.05$).

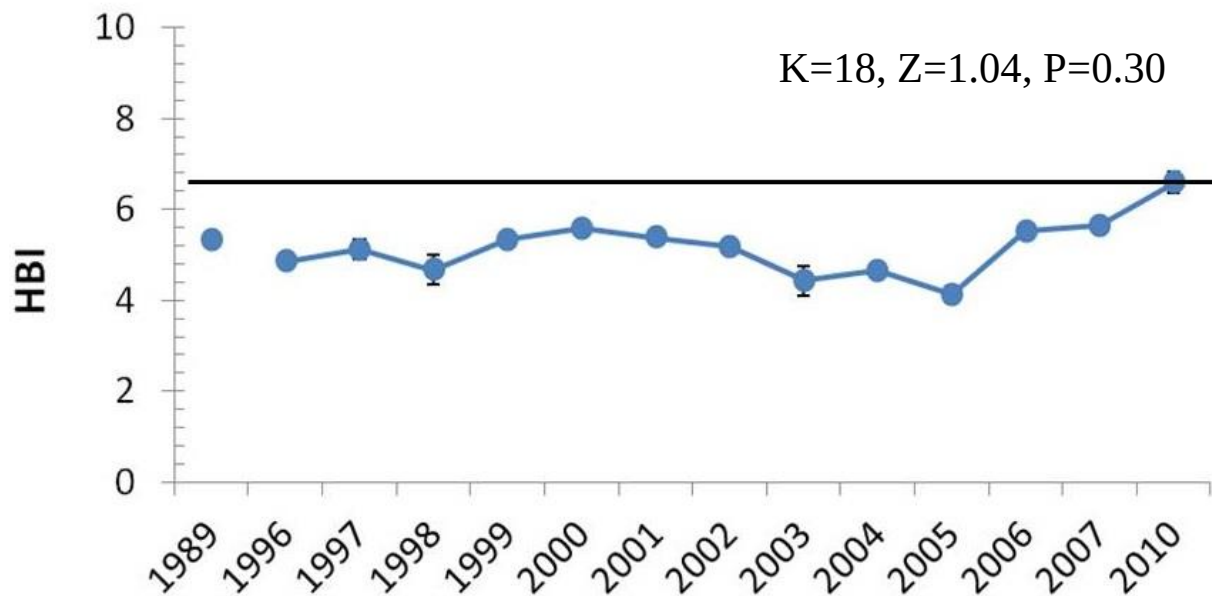


Figure 8. Control chart for Hilsenhoff Biotic Index for Pipestone Creek, Pipestone National Monument, Minnesota. Points are site means for a given year, and the vertical bars are standard errors (n=3). The horizontal line represents the control limit corresponding to the Type I error rate of 0.05. K= Mann-Kendall statistic, Z= normalized test statistic, P=probability value ($\alpha=0.05$).

Water quality and Habitat

Water quality data for Pipestone Creek from 2005 to 2010 are shown in Appendix Table A-2. The water quality data reported here, exclusive of turbidity and dissolved oxygen in 2010, generally fell within acceptable ranges for Minnesota streams (Appendix Table A-3). Turbidity was often substantially higher than the acceptable range of 25 NTU or less.

Habitat data are presently insufficient for statistical analysis, but they are useful for qualitative characterizations (Appendix A, Table A-4). From the two sampling events where habitat variables were measured, mean embeddedness in samples ranged from 20.56 to 39.44% while mean periphyton ranged from 20.56 to 25%. Percent aquatic vegetation ranged from 17.78 to 66.94% consisting entirely of mosses. Percent filamentous algae was low (<4%). Mean dominant substrate ranged in size from Wentworth Sizes 13 to 16 (22.6-90 mm), which corresponds to small pebble to small cobble substrate. Mean depth among samples in 2007 and 2010 were 12.44 cm and 29.44, respectively. Current velocity in 2007 was 0.19 m/sec compared to 0.72 m/sec in 2010. Discharge for Pipestone Creek in 2007 was 0.05 m³/sec.

Discussion

Based on the invertebrate community metrics reported here, the water quality of Pipestone Creek within PIPE has not diminished beyond that reported in earlier studies (Harris *et al.* 1991, Harris *et al.* 1999, Peitz and Cribbs 2005, Bowles 2009). Invertebrate community metrics, when viewed across years, offer a mixed message on water quality condition. While family and taxa richness and EPT ratio appear to have gradually increased over time, so did HBI. This indicates that while more taxa now inhabit the community and Chironomidae have become less abundant, the taxa present in the stream appear to be becoming more tolerant of disturbance since 2006. The range of HBI values reported here are similar to the mean HBI reported from least disturbed streams in Minnesota (Genet and Chirhart 2004) so the slight increase in values for Pipestone Creek may not be biologically significant. The HBI was developed primarily to assess organic pollution (i.e., wastewater effects) (Hilsenhoff 1988), so the observed trends may be a response to the documented issues with fecal coliform bacteria pollution in Pipestone Creek. Indeed, the number of EPT taxa collected from Pipestone Creek across years is substantially less than that reported from riffle/run habitats in least disturbed streams in Minnesota (i.e., 5.4 versus 17) (Genet and Chirhart 2004). Additionally, those EPT taxa collected from Pipestone Creek were moderately tolerant of disturbance (tolerance value >5). The reasons for the low metric scores in 1998 are not known, but, because streams are highly variable ecosystems, observed differences in sampling metrics among years may not be biologically significant.

Given the known anthropogenic disturbances in Pipestone Creek upstream of the monument, it is likely that the aquatic invertebrate community within PIPE is not fully biologically supporting. Many small, perennial streams of the Great Plains region, such as Pipestone Creek, historically had seasonally turbid flows, but agricultural practices over the past 150 years have degraded them into frequently turbid streams to the detriment of the fauna inhabiting them (Rabeni 1996). Pipestone Creek is listed as a 303d impaired waterway by the state of Minnesota (Minnesota Pollution Control Agency 2007) based on elevated turbidity and fecal coliform bacteria concentrations exceeding recommended levels for aquatic consumption/aquatic recreation. Agricultural practices including row crops and livestock operations upstream of PIPE and runoff from impervious surfaces within the City of Pipestone are two of the main threats to water quality in Pipestone Creek (Minnesota Pollution Control Agency 2007). The Minnesota Pollution Control Agency (2007) estimated that the overall magnitude of reduction needed to meet water quality standards for these impairments is approximately 77% and 26% for current fecal coliform bacteria and turbidity levels, respectively. Although the water quality of Pipestone Creek has experienced disturbances, the results reported here for water quality and invertebrate community structure are generally consistent with studies of other streams in the region (MacFarlane 1983, Whiles *et al.* 2000, Hall *et al.* 2003, Kosnicki and Sites 2007, Poulton *et al.* 2007, Bowles 2009b, Bowles and Clark 2012, Bowles, et al. 2010, 2010b).

There are few available options to management for mitigating this situation largely because the impacts to this invertebrate community and water quality originate upstream of the monument boundaries. Maintaining riparian buffer zones along Pipestone Creek above the monument will aid in protecting aquatic life in Pipestone Creek as well as in-stream habitat from local chemical runoff and sedimentation. Improved buffer zones will also reduce bank erosion within the monument by reducing stream velocity and the amount of water entering Pipestone Creek from riparian sources. The long history and continuing efforts of aquatic invertebrate monitoring in Pipestone Creek provide a sound tool to recognize both deterioration and chronic decline of water quality.

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Appendix A. Water quality, habitat and invertebrate metrics for Pipestone Creek.

Table A-1. Mean and standard error (in parentheses) of invertebrate metrics collected from Pipestone Creek, Pipestone National Monument, 1989, 1996-2007, and 2010. N= number of samples collected. Hilsenhoff Biotic Index was based on family-level scores prior to 2005.

Year	1989	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2010
N	10	10	30	30	30	30	30	30	30	20	19	17	9	9
Family Richness	8.8 (0)	6.6 (2.2)	5.27 (1.57)	3.33 (0.27)	9.43 (0.96)	9.33 (1.02)	6.87 (0.74)	8.4 (0.88)	6.83 (1)	6.6 (0.73)	7.37 (0.50)	8.41 (0.45)	10 (0.73)	15.33 (1.07)
Taxa Richness	12.5 (0.3)	9.2 (3)	8.33 (2.45)	4.22 (0.53)	15.03 (1)	14 (1.49)	10.73 (1.09)	13.87 (0.94)	9.6 (1.2)	11.4 (1.19)	9 (0.59)	9.18 (0.36)	11.44 (0.78)	16.22 (1.06)
EPT Richness	3.1 (0.1)	3.2 (0)	2.67 (1.23)	1.23 (0.2)	6.2 (0.38)	4.53 (0.47)	4.2 (0.21)	5.7 (0.51)	4.23 (0.42)	5.45 (1.07)	3.84 (0.31)	3.65 (0.19)	5 0.17	4.83 (0.35)
EPT Ratio	0.63 (0.05)	0.62 (0.13)	0.36 (0.06)	0.53 (0.11)	0.32 (0.05)	0.23 (0.06)	0.4 (0.03)	0.4 (0.05)	0.77 (0.09)	0.65 (0.05)	0.74 (0.04)	0.21 (0.03)	0.58 (0.06)	0.72 (0.06)
Shannon's Diversity Index	n/a	1.73 (0.16)	1.03 (0.14)	0.92 (0.11)	1.18 (0.19)	1.59 (0.12)	1.43 (0.09)	1.48 (0.16)	1.4 (0.10)	1.82 (0.05)	1.49 (0.07)	1.24 (0.06)	1.73 (0.08)	1.87 (0.04)
Shannon's Evenness Index	n/a	0.79 (0.05)	0.76 (0.05)	0.79 (0.06)	0.47 (0.07)	0.64 (0.03)	0.66 (0.03)	0.66 (0.07)	0.70 (0.06)	0.77 (0.03)	0.68 (0.03)	0.59 (0.05)	0.71 (0.03)	0.67 (0.02)
Hilsenhoff Biotic Index	5.32 (0.14)	4.85 (0.14)	5.12 (0.21)	4.67 (0.33)	5.34 (0.12)	5.59 (0.11)	5.38 (0.1)	5.17 (0.07)	4.43 (0.32)	4.65 (0.13)	4.13 (0.18)	5.52 (0.08)	5.64 (0.16)	6.58 (0.23)

Table A-2. Water quality characteristics for Pipestone Creek, Pipestone National Monument, 2005-2010. Data in 2005 were collected with hand-held instruments, and data for 2006-2010 were collected continuously with a data logger. Values are mean, standard deviation, and range.

Year	N	Statistic	Temperature (°C)	Specific Conductance (µm/cm)	Dissolved Oxygen (mg/liter)	pH	Turbidity (NTU)
2005	10	Mean	20.32	653.8	7.78	7.84	n/a
		Standard Deviation	0.09	1.95	0.11	0.02	n/a
		Range	20-20.9	647-661	7.3-8.2	7.66-7.89	n/a
2006	10	Mean	20.32	653.80	7.78	7.84	n/a
		Standard Deviation	0.29	6.18	0.33	0.07	n/a
		Range	20.0-20.9	647-661	7.3-8.2	7.66-7.89	n/a
2007 (upstream)	40	Mean	17.05	783.2	9.44	7.98	180.27
		Standard Deviation	2.23	39.74	0.54	0.11	410.73
		Range	14.03-21.18	710-839	8.30-10.29	7.82-8.19	5.4-1411.30
2007 (downstream)	35	Mean	21.54	710.64	7.72	8.09	8.84
		Standard Deviation	2.38	26.12	0.49	0.10	3.90
		Range	17.09-26.82	632-742	6.72-8.69	7.9-8.36	3.0-18.30
2010 (upstream)	36	Mean	21.01	585.97	6.16	7.69	20.69
		Standard Deviation	1.58	132.48	1.066	0.13	18.99
		Range	17.38-23.94	203-797	4.12-9.22	7.55-8.03	0-77.70
2010 (downstream)	36	Mean	21.54	617.14	6.95	7.95	13.32
		Standard Deviation	1.67	145.26	0.68	0.05	10.99
		Range	17.81-24.54	189-784	5.09-7.64	7.81-8.02	0-41.40

Table A-3. Acceptable ranges for water quality parameters in Minnesota streams. Adapted from Minnesota Administrative Rules (2009).

Water Quality Parameter	Acceptable Range
Temperature	<30 °C
Dissolved Oxygen	24 hr minimum of 7 mg/liter
Specific Conductance	<1,000 µS/cm
pH	6.5-8.5
Turbidity	25 NTU

Table A-4. Means and standard errors (n = 3) for habitat variables recorded for Pipestone Creek, Pipestone National Monument, 2007 and 2010.

Year	Depth (cm)	Current Velocity (m/sec)	% Vegetation	% Filamentous Green Algae	% Periphyton	% Embeddedness	Substrate Size (Wentworth Categories)
2007	12.44 (2.44)	0.19 (0.05)	17.78 (4.34)	3.89 (3.89)	25 (0)	39.44 (9.55)	13.2 (1.07)
2010	29.44 (0.94)	0.72 (0.05)	66.94 (15.82)	0 (0)	20.56 (2.22)	20.56 (2.22)	16.0 (0.51)

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