



Fish Community Monitoring at Pipestone National Monument: 2001 – 2008 Trend Report

Natural Resource Technical Report NPS/HTLN/NRTR—2010/366



ON THE COVER

Fish collection with a minnow seine at Pipestone National Monument.

Photograph by: The Heartland Inventory and Monitoring Network and Prairie Cluster Prototype Monitoring Program.

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Executive Summary

Pipestone National Monument (PIPE), located in southwestern Minnesota, was established to protect and interpret the cultural resources surrounding the pipestone quarries and to provide American Indian tribes access to these quarries. A goal at PIPE is to maintain and restore the historic prairie ecosystem that surrounds these pipestone quarries, and an important component of tallgrass systems is water quality/quantity and biotic integrity of prairie streams. Changes in land use have resulted in habitat loss and degradation, and poor water quality in many prairie streams. This has partially led to the decline of many native prairie fishes within their ranges, including the federally endangered Topeka Shiner (*Notropis topeka*). Although human disturbances within a watershed can alter a lotic system, PIPE may offer important habitat for conserving native species.

In 2001, an annual fish monitoring program was initiated at PIPE to determine the status and long-term trends in fish community composition, and to correlate this community data to water quality and habitat conditions. Fish community data were collected at two reaches from 2001 to 2008. One reach was sampled above the Winnemiss Falls, a 2.5 m waterfall, and a downstream reach was sampled near the west border of the park. Physical habitat and water quality were collected in conjunction with fish sampling.

The fish community in Pipestone Creek differed between the upstream-most reach (above falls) on the east side of the park and the downstream (lower) reach near the west boundary. The fish community above the falls consisted primarily of species tolerant to poor stream conditions with no Topeka Shiners collected at this reach during the eight year period. Richness, diversity, stream integrity and abundance were low, potentially due to daily fluctuations in dissolved oxygen (DO). Levels of DO fell below 5 mg/L at night, a lethal level for many fish species (USEPA 1988). In comparison, the lower reach had high richness, good stream integrity, and moderate to high diversity, indicating a healthy fish community. The fish community at this downstream reach consisted of species moderately tolerant to poor water quality which is typical of prairie streams (Pflieger 1997, Bramblett et al. 2005, Fischer and Paukert 2008). Of the four sites that have been historically sampled by the Heartland I&M Network (HTLN), the downstream reach contained 85% of the Topeka Shiner abundance in Pipestone Creek, further indicating a higher quality fish community than that found above the falls. Richness and diversity at this lower reach significantly increased over time, although this increase may be an artifact of annual variability in precipitation and the relative efficiency of sampling smaller sites. Individual species catch fluctuated within acceptable limits of variability during the eight year sampling period, relative to baselines established from the first three years of data. However, when sample area was taken into account, deviations from baseline conditions were found for species catch per area at the lower reach, suggesting that size of the site may introduce variability in the samples.

Although a small portion (1 km) of Pipestone Creek flows through the park, PIPE appears to provide some protection for native prairie fishes as evidenced by the higher quality fish community and presence of Topeka Shiners at the downstream reach. Additional study would be useful in determining mechanisms behind differences in fish communities of Pipestone Creek as

it enters the park from agricultural land use and the communities found downstream where the prairie system is intact.

Acknowledgments

We would like to thank current and former staff at Pipestone National Monument, particularly Gia Wagner, Kristin Legg, April Deming, and Seth Hendricks for assistance with field sampling. We would also like to acknowledge the help of the Minnesota Conservation Corp.

Introduction

Pipestone National Monument (PIPE), located in southwestern Minnesota, is approximately 1.2 km² in size, of which 80% is native or restored tallgrass prairie. A goal at PIPE is to maintain and restore the historic prairie ecosystem that surrounds the Pipestone quarries. An integral part of tallgrass systems is water quality/quantity and biotic integrity of prairie streams. A severe threat to prairie systems has been the conversion of large portions of grasslands to cropland or livestock pasture (Knopf and Samson 1997) during the last century. In addition, other anthropogenic factors, such as dams, have also caused direct habitat loss and fragmentation (Mammoliti 2002). These disturbances have increased sedimentation, nutrient loading, and other chemical pollution, and has altered the water quality and habitat of prairie streams. Many native fish populations have been adversely impacted throughout their ranges by a number of factors associated with land use changes. As a result of habitat changes and decline of water quality conditions in Midwestern streams, the Topeka Shiner (*Notropis topeka*), a native prairie stream fish found at PIPE, was listed as federally endangered in 1998 under the Endangered Species Act of 1973 (63 FR 69008). Currently, the Topeka shiner inhabits less than 10% of its historic range (Tabor 1998). In addition to this federally protected species, several other Midwestern stream fishes are imperiled, making it necessary to protect prairie streams on publicly owned lands in order to offer refuge for native species.

Native fish communities are an important component of prairie stream systems. Changes or shifts in stream habitat complexity and water quality often determine biotic communities, including fish (Lazorchak *et al.* 1998). Therefore, monitoring trends in fish community composition and associated habitat conditions serves as a strong basis for measuring stream integrity. Many fish species are considered intolerant of habitat alterations and monitoring their assemblages can serve as a useful tool to assess changes in water and habitat quality (Karr 1981; Robison and Buchanan 1988; Pflieger 1997; Barbour *et al.* 1999; Peitz 2005). Accordingly, trends in the composition and abundance of fish populations historically have been used to assess the biological integrity of streams (Karr 1981; Barbour *et al.* 1999; Moulton *et al.* 2002). Moreover, the intrinsic value of fish to the public as environmental indicators and as a recreational opportunity makes the status of fish diversity a valuable interpretive topic for park visitors, as well as an informative tool for preserving and conserving aquatic resources at PIPE and for supporting management decisions.

Objectives

The specific objectives for fish community monitoring at PIPE are: (1) to determine the status and long term trends in fish richness, diversity, abundance, and community composition and (2) to correlate the long-term community data to overall water quality and habitat condition.

Methods

Details on methods of site selection, fish sampling, and habitat and water quality data collection not listed in this report can be found in the Protocol for Monitoring Fish Communities in Small Streams in the Heartland Inventory and Monitoring Network (Dodd *et al.* 2008).

Study Area and Reach Selection

Approximately 1 km of Pipestone Creek flows through PIPE. The stream was stratified into four reaches based on natural breaks in the stream (such as large pools or a waterfall; Figure 1). A sample reach is a section of stream that encompasses all channel units (riffles, runs, pools, glides) within the stream, resulting in a representative fish sample. Reach length was based on the ability to find areas of the stream with adequate water to collect fish from five sample sites within the reach or the ability to find areas where seining would be effective (large deep pools were excluded). During 2001-2006, four reaches (above falls, upper, middle, lower) were sampled annually at Pipestone Creek (Figure 1). The upstream-most reach was located above the Winnewissa Falls, a 2.5 m waterfall. The remaining three reaches were located downstream of the waterfall. Beginning in 2007, only two reaches were retained for sampling (reaches in yellow, Figure 1). The lower most reach was retained with the rationale that sampling the downstream most reach gives a more representative sample of the overall watershed. The reach above the waterfall was retained due to the differences in water quality and habitat composition at this reach compared to reaches below the falls. To reduce potential variability resulting from site differences, only the two retained reaches that are currently being sampled and will be sampled in the future are analyzed in this report.

Fish Collection

Fish communities were sampled in August-September from 2001 to 2008. Fish were collected using a common sense seine (also referred to as a minnow seine) of 1.8 m depth and a mesh size of 6.44 mm. Every year fish were collected from three to five sites (channel units) within the reach. In pool or run channel units, a two-person crew dragged the seine across the bottom, trapping fish against a bank or shallow water area until the seine could be raised out of the water. Block seines were deployed if flow between pools was present, in an attempt to isolate fish in the selected pool. In riffle channel units, kick seining was used with one or two people disturbing the substrate in a downstream direction, dislodging fish into the seine. Fish were retained in the net in water or in an aerated bucket of water until they could be examined. All fish were identified to species, if possible, and counted. Topeka Shiners were measured, weighed, sexed, and aged (juvenile vs. adult). Beginning in 2006, a subsample of 30 individuals per species at each reach were also measured and weighed, and any diseases or anomalies were recorded. Fish that were too small or that were difficult to identify in the field were preserved for laboratory identification. All other fish were released back into the sample reach.

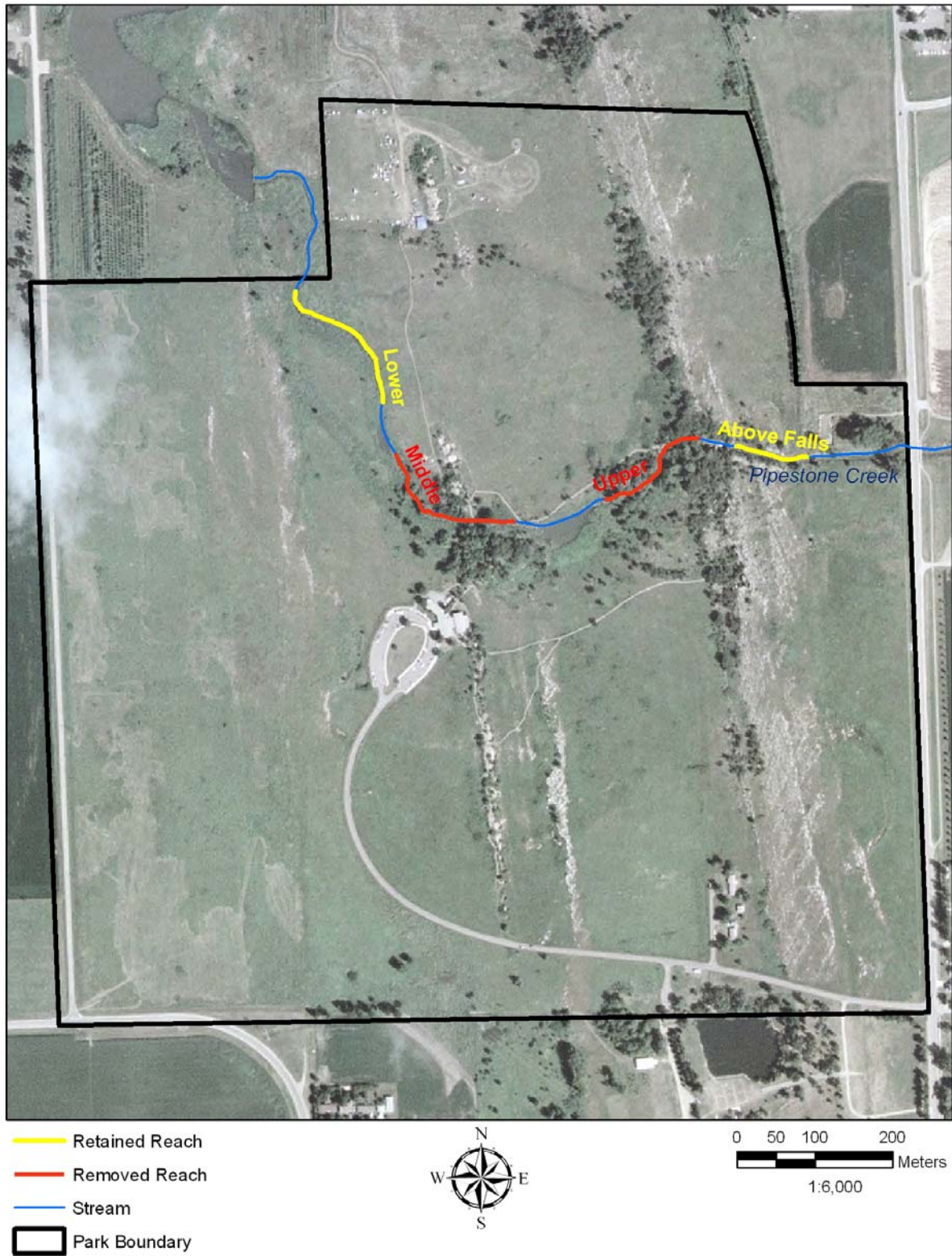


Figure 1. Location of reaches sampled annually in 2001-2006 and those retained in 2007-2008.

Habitat and Water Quality

Physical habitat and water quality were collected in conjunction with fish sampling during 2001-2008. In-stream habitat (width, depth, length, substrate, *etc.*), streambank erosion, and riparian vegetation were collected at each site within the reach (see Dodd *et al.* 2008 for a list of all habitat parameters collected). Prior to fish collection, discrete water quality measurements (temperature, dissolved oxygen, pH, and conductivity) were collected at each site within the reach during 2001-2006 using hand-held YSI© meters. In 2006, continuous water quality sampling was added, and in 2007-2008 continuous sampling replaced discrete water quality sampling at the retained reaches. YSI© data loggers were deployed at reaches to obtain hourly temperature, dissolved oxygen, pH, specific conductance, and turbidity data (CORE 5) for a minimum of 24 hours.

Data Analysis

Fish Metrics

Five biological metrics were calculated for the two retained reaches (above falls and lower reach) sampled during 2001-2008. These metrics reflect fish community diversity (species richness and diversity), abundance (catch and catch per area), and overall stream integrity (Index of Biotic Integrity). Community diversity was assessed using Simpson's Diversity Index, which indicates the probability that two individuals picked at random from the reach are the same species. This index has an inverse relationship with diversity; the index decreases as diversity increases. Because it is more intuitive that an increasing index score correspond to increasing diversity, the inverse of the Simpson's Index (1-SI) was used in analyses. Therefore, a diversity value (1-SI) of 1 corresponds to a completely diverse community while a value of 0 indicates no diversity. In this report, 'catch' refers to the total number of fish caught, and 'catch per area' to this number divided by the cumulative surface area of all sites sampled within that reach. The Index of Biotic Integrity (IBI) developed by Karr (1981) and used in Midwest streams by Fausch *et al.* (1984) was used to assess overall stream health and includes 12 metrics: 1) total number of fish species; 2) number and identity of darter species; 3) number and identity of sunfish species; 4) number and identity of sucker species; 5) number and identity of species intolerant to poor water quality and habitat conditions; 6) proportion of individuals as green sunfish; 7) proportion of individuals as omnivores; 8) proportion of individuals as insectivorous cyprinids; 9) proportion of individuals as top carnivores; 10) number of individuals in sample; 11) proportion of individuals as hybrids; 12) proportion with an anomaly (disease, eroded fins, lesions, or tumors). Each of the 12 raw metric values was scored as 1 (worst), 3, or 5 (best). The metric scores were added to calculate an IBI score that ranges from 0 to 60. Based on this IBI score, the overall integrity of the stream is classified from very poor to excellent: very poor = 0-20; poor = 21-30; fair = 31-40; good = 41-50; excellent (reference condition) = 51-60. More detailed methods on calculating biological metrics used in this report can be found in Karr (1981), Fausch *et al.* (1984), and Dodd *et al.* (2008).

Analysis of Metrics: Species richness, species diversity (1-SI), IBI, catch, and catch per area (CPA) were calculated for each year from 2001-2008 for the reach above the falls and the lower reach. Regression analyses were used to evaluate trends in fish metrics across time. Because the reach above the falls is different in water quality (dissolved oxygen) and in-stream habitat

composition (substrate type and site dimensions), reaches were analyzed separately (see Table 5 in Peitz 2005). Those metrics that demonstrated a significant temporal trend were used in analyses with habitat and water quality parameters to determine relationships between abiotic factors and fish communities.

Multivariate Control charts

Control charts indicate when a system may be going ‘out of control’ by plotting through time some measure of a stochastic process with reference to its expected value. The expected value is often a baseline that represents the averages of empirical measurements, and serves as a reference point for establishment of control limits. Control limits specify thresholds beyond which variability in the indicator of interest indicates a process is going out of control (Morrison 2008). Using relative abundances of all species simultaneously, trends in overall fish assemblages were evaluated by multivariate control charts with both reaches analyzed separately. Two metrics were used to describe the species abundance relationships: species catch and species CPA. In this multivariate case, species catch considered the number of individuals of each species summed over all sites in each reach. Species CPA was calculated by dividing the total catch for each species in each reach by the cumulative surface area of all sites sampled within that reach. Multivariate control charts are derived from a distance-based ordination approach. These charts consider the relative abundance relationships of all species in a community and compute the distance of the community at any point in time from a baseline centroid (that represents the normal community state) in multivariate p -space. This distance is then plotted over time, and a bootstrapping technique is used to generate percentiles that serve as control limits (Anderson and Thompson 2004). We used the program *control chart.exe* to construct the multivariate control charts (Anderson 2008), inputting catch or CPA for each species in each year at a reach. We considered the first three years as a baseline period, and evaluated the divergence from this period in future years. CY dissimilarity, which modifies zero values by adding a constant before logarithmic transformations, was used as the distance measure. The 95th percentile of the distribution of deviations across all sites was used as a control limit.

Habitat Metrics

Physical habitat and water quality parameters were summarized using means and standard errors (SE) for each retained reach from 2001 to 2008. Because continuous water quality sampling replaced discrete measurements in 2007 and 2008, a combination of discrete and continuous data was used in analyses. For data collected from 2001-2006, averages (across sites in a reach) of discrete water quality measurements were used in analyses. For 2007 and 2008, continuous measurements were used, but only those measurements taken during fish sampling (i.e., the 2-3 hour time period fish were collected in that reach) were used for analyses. Not all water quality parameters were collected every year at both reaches. Therefore, sample sizes vary ($n = 5$ to 8) depending on the reach and water quality variable sampled.

Regression analyses were used to evaluate relationships between fish communities and habitat (width, depth, length, area) and water quality (water temperature, turbidity, dissolved oxygen, pH, conductivity, specific conductance) variables. Only fish metrics showing a significant temporal trend at a reach (i.e., richness and diversity at the lower reach) were used in regression analyses. In addition to physical habitat and water chemistry data, annual total precipitation prior

to fish sampling (i.e., total precipitation from January to August each year) was also analyzed using regressions.

Results

Fish Community

A total of 25 species were collected at all reaches sampled in 2001-2008, with 24 species collected in the two retained reaches (above falls and lower) during the eight year sampling period (Appendix 1). Both retained reaches revealed considerable variability over time, particularly in richness and diversity. Richness at the above falls reach was typically less than that of the lower reach and ranged from 2 to 8 species, while the lower reach ranged from 7 to 15 species (Figure 2). At the above falls reach, diversity ranged from 0.31 to 0.70, whereas diversity at the lower reach ranged from 0.46 to 0.87 (Figure 3). Both species richness and diversity revealed significant positive linear trends at the lower reach (richness: $F = 10.08$, $P = 0.019$, Figure 2; diversity: $F = 6.448$, $P = 0.044$, Figure 3). There were no significant linear trends ($P > 0.05$) in richness or diversity above the falls. However, years with higher richness typically had lower diversity due to dominance by one species above the falls. Fathead Minnow (*Pimephales promelas*) dominated in 2002, 2007, and 2008, and Creek Chub (*Semotilus atromaculatus*), were common in 2001 at the above falls reach (see Appendix 1).

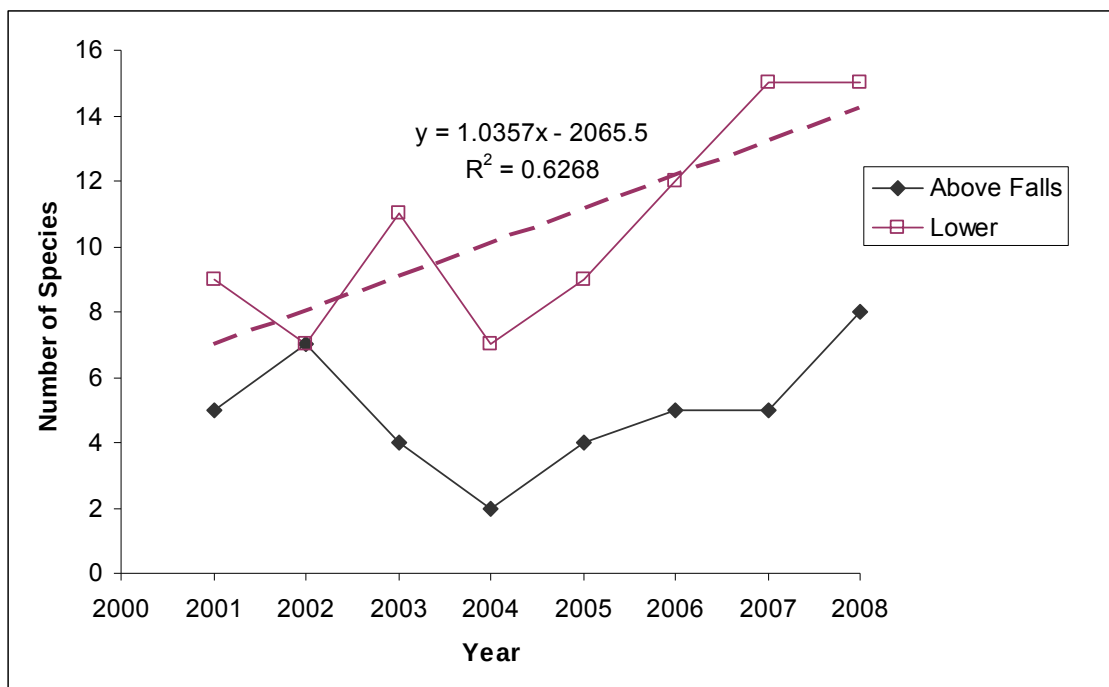


Figure 2. Species richness for the above falls (solid diamonds) and lower (open squares) reaches sampled in 2001-2008. Significant regression line (dashed line), linear equation, and R^2 value are given for the lower reach.

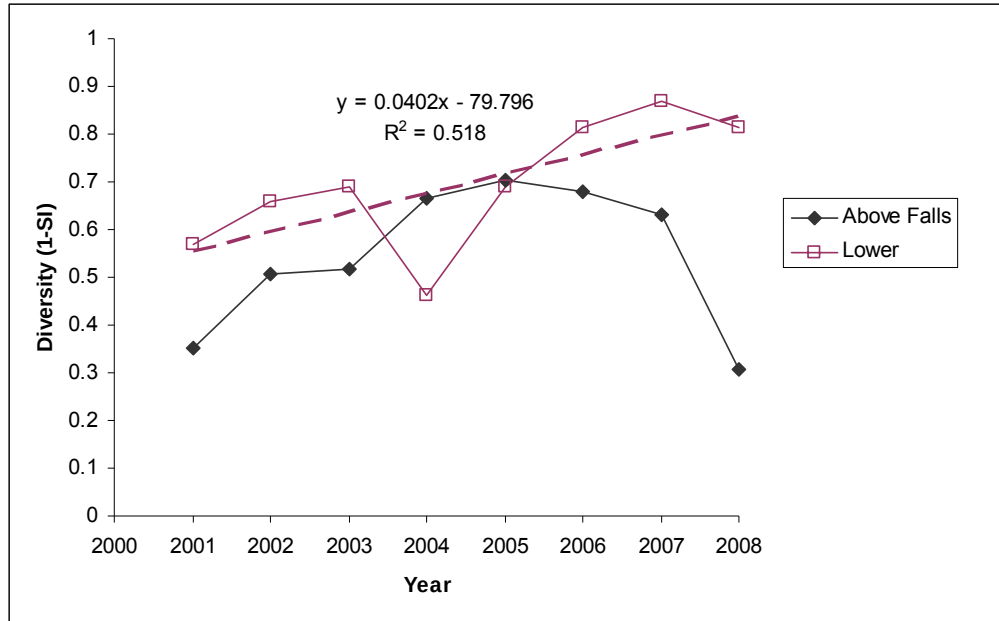


Figure 3. Diversity for the above falls (solid diamonds) and lower (open squares) reaches sampled in 2001-2008. Significant regression line (dashed line), linear equation, and R^2 value are given for the lower reach.

Stream integrity was rated as poor to fair for the above falls reach, ranging in IBI scores from 26 to 34. The lower reach rated as having good stream integrity for most years (scores ranged from 42 to 50) with the exception of 2006 where the IBI score fell on the boundary between fair and good (IBI = 40). There were no significant linear trends ($P > 0.05$) in IBI at either reach.

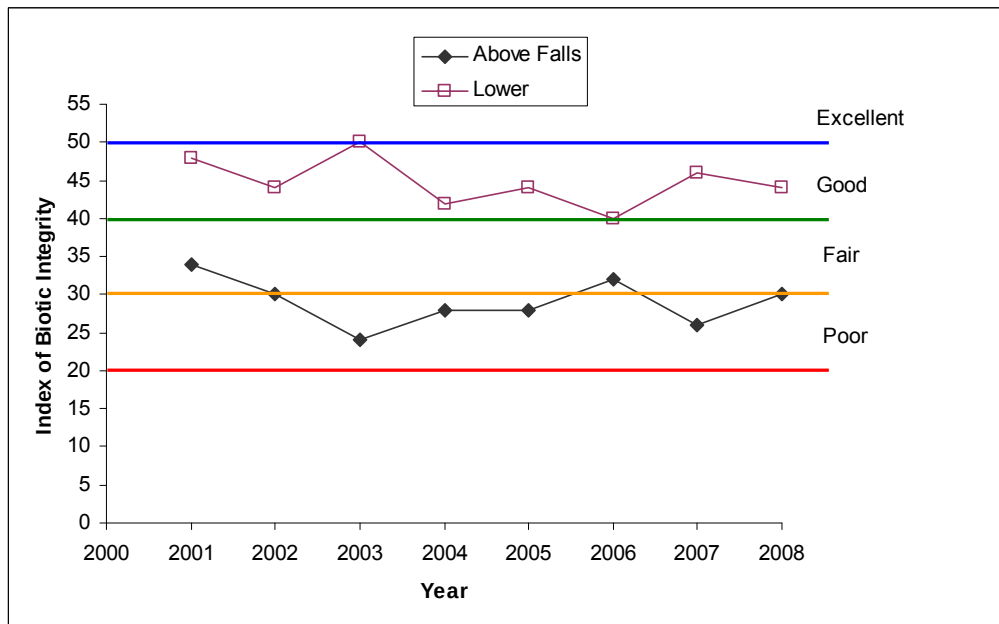


Figure 4. Index of Biotic Integrity (IBI) for the above falls (solid diamonds) and lower (open squares) reaches sampled in 2001-2008. Horizontal lines represent boundaries between IBI rating categories.

In most years, fewer fish were collected above the falls compared to the lower reach, with the exception of 2008 when a large number of Fathead Minnows were collected above the falls (Figure 5 top panel, Appendix 1). At the above falls reach, catch ranged from 4 fish in 2004 to 589 fish in 2008, and CPA ranged from 0.02 to 5.16 fish/m² (Figure 5). Catch and CPA ranged from 103 to 665 fish and 0.39 to 2.65 fish/m² (Figure 5), respectively, in the lower reach with a spike in abundance occurring in 2003 due to large numbers of Common Shiner (*Luxilus cornutus*) and Fathead Minnow (Appendix 1). No significant linear trends ($P > 0.05$) were found at either reach for catch or CPA.

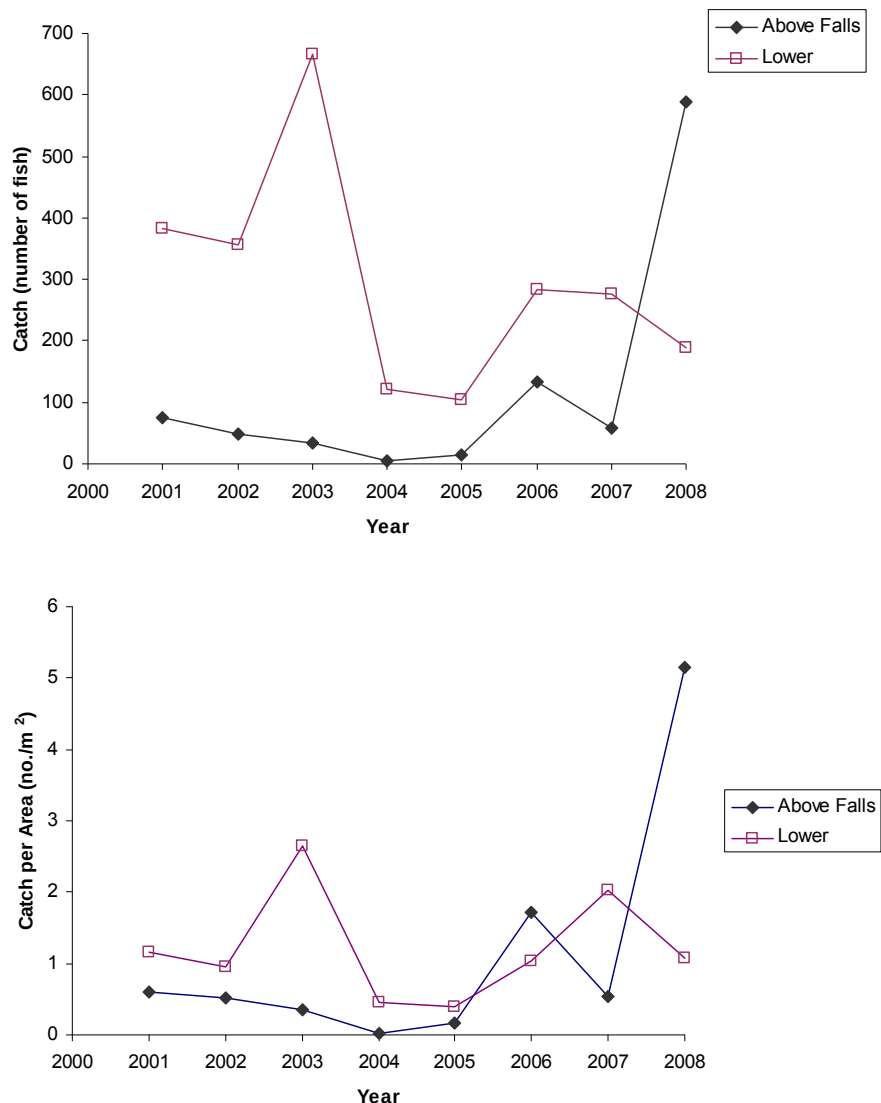


Figure 5. Catch (top panel) and catch per area (bottom panel) for the above falls (solid diamonds) and lower (open squares) reaches sampled in 2001-2008.

From 2001-2008, species catch and CPA were dominated by Fathead Minnow (~66%) and Creek Chub (~ 17%) at the above falls reach (Appendix 1). In the lower reach, abundant species included Common Shiner (~35%), Fathead Minnow (~13%), Bigmouth Shiner (*Notropis dorsalis*, ~13%), and Central Stoneroller (*Campostoma anomalum*, ~12%), which made up approximately 74% of the total abundance from 2001 to 2008. Topeka Shiners were found in three of the four reaches sampled from 2001-2008. A total of 131 Topeka Shiners were collected, with the lower reach accounting for 85% of the abundance (Table 1). There was no linear trend ($P > 0.05$) in Topeka Shiner abundance at this lower reach. Additional information on numbers of fish collected for each species at each reach can be found in Appendix 1.

Table 1. Numbers of Topeka Shiners collected at reaches sampled from 2001-2008. Reaches in bold type are those reaches retained for long-term monitoring. NS indicates the reach was not sampled in that year.

Reach	2001	2002	2003	2004	2005	2006	2007	2008	Total
Above falls	0	0	0	0	0	0	0	0	0
Upper	0	0	0	0	0	13	NS	NS	13
Middle	1	0	2	0	0	4	NS	NS	7
Lower	0	0	19	0	13	33	36	10	111

Individual species catch remained at or below the control limit (solid and dashed horizontal lines; Figure 6) for both reaches, with the exception of the above falls reach in 2008 which is likely due to the high number of Fathead Minnows collected in that year. Species catch comes close to the control limit (dashed horizontal line) at the lower reach in 2005, but fell well below the limit in 2006-2008. When sample area was taken into account, species abundance (CPA) was above the control limits for both reaches in 2004, but comes back ‘in control’ at the above falls reach during 2005-2008 (Figure 7). Species CPA at the lower reach continues to fluctuate around the control limit from 2005-2008 with species CPA falling above the limit in 2006 and 2007.

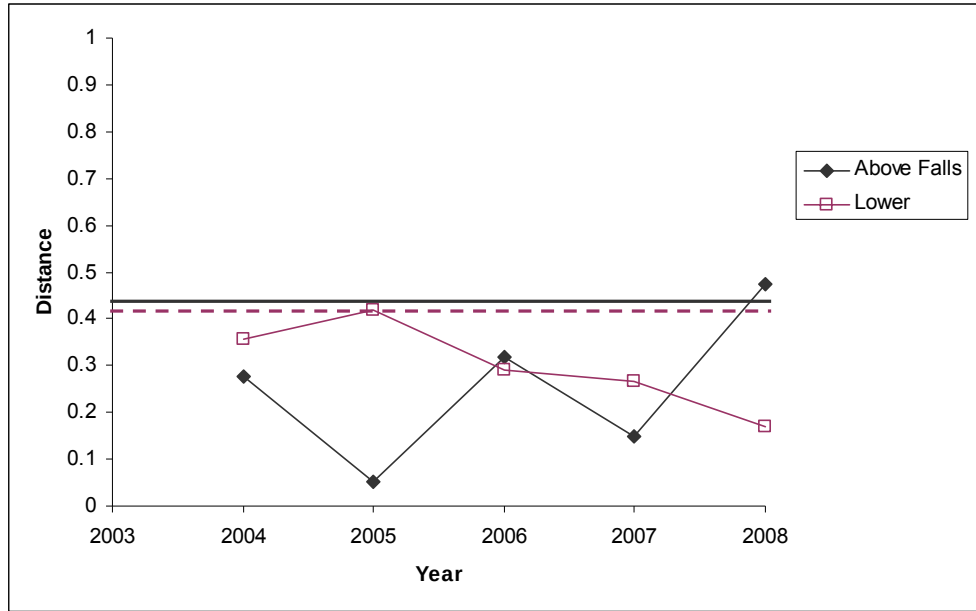


Figure 6. Multivariate control chart for individual species catch at the above falls (solid diamonds) and lower (open squares) reaches. The solid horizontal line is the 95% control limit for the above falls reach. The dashed horizontal line is the 95% control limit for the lower reach. The first three years of data were used as a baseline and, therefore, are not shown. Distance on the y-axis indicates the distance to a baseline centroid ($b = 3$).

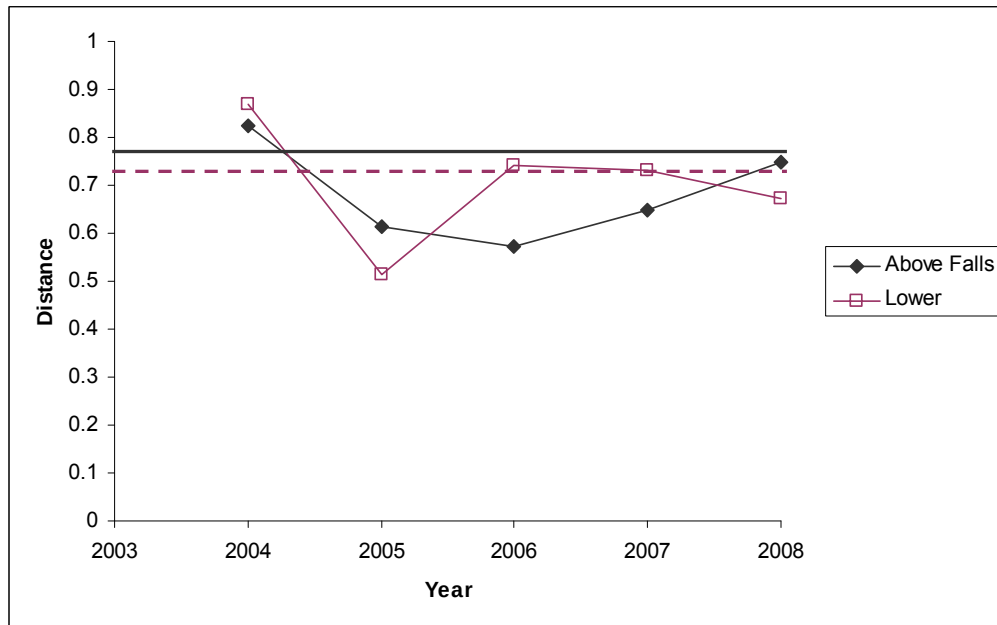


Figure 7. Multivariate control chart for individual species catch per area at the above falls (solid diamonds) and lower (open squares) reaches. The solid horizontal line is the 95% control limit for the above falls reach. The dashed horizontal line is the 95% control limit for the lower reach. The first three years of data were used as a baseline and, therefore, are not shown. Distance on the y-axis indicates the distance to a baseline centroid ($b = 3$).

Habitat and Water Quality Relationships

Species richness and community diversity at the lower reach were the only two metrics found to have significant trends over time; therefore, relationships between these two metrics and environmental variables were analyzed with simple linear regressions. Species richness at the lower reach had significant negative relationships with mean depth, mean length, and area (all $P < 0.05$), and a marginally significant ($0.05 < P < 0.10$) relationship with mean width (Table 2; Figure 8 top panel), indicating that years in which this reach was smaller (e.g., 2007 and 2008), more species were collected. A marginally significant relationship was also found between diversity and mean depth, mean length, and area (Table 2; Figure 8 bottom panel). Diversity was also significantly positively correlated with mean turbidity at the lower reach (Table 2).

Both species richness and diversity at the lower reach revealed significant positive relationships with mean water temperature (Table 2; Figure 9) and significant negative relationships with total precipitation from January to August (Table 2; Figure 10), suggesting that years in which precipitation was low (2006-2008) and water temperatures were high (2007), more species and higher diversity was found at the lower reach.

Table 2. Results of simple linear regressions between environmental variables and fish metrics (species richness and community diversity) at the lower reach from 2001-2008. Those values in bold are significant at $\alpha = 0.05$. Those values in plain text are marginally significant at $\alpha = 0.10$. Symbols in parentheses indicate direction of relationship. Precipitation data was obtained from the National Oceanic and Atmospheric Administration's National Weather Service (NWSLI Station ID = PIPM5).

Environmental Variables	Species Richness (# species)	Diversity (1-SI)
Mean Depth (cm)	F=14.97, P=0.008, n=8 (-)	F=4.22, P=0.086, n=8 (-)
Mean Length (m)	F=16.34, P=0.007, n=8 (-)	F=4.42, P=0.080, n=8 (-)
Area (m ²)	F=16.48, P=0.007, n=8 (-)	F=3.80, P=0.099, n=8 (-)
Mean Width (m)	F=4.00, P=0.092, n=8 (-)	
Mean Water Temperature (C)	F=9.34, P=0.022, n=8 (+)	F=14.31, P=0.009, n=8 (+)
Mean Turbidity (cm)		F=9.94, P=0.034, n=6 (+)
Total Precipitation Jan.-Aug.(in.)	F=20.66, P=0.004, n=8 (-)	F=14.28, P=0.009, n=8 (-)

Considering the six environmental variables (depth, length, area, water temperature, turbidity, and precipitation) that showed a significant relationship ($P < 0.05$) with richness or diversity, simple linear regression analyses were used to evaluate relationships between these abiotic parameters. Mean depth and mean length were marginally positively correlated with total precipitation from January to August (depth: $F = 5.45$, $P = 0.058$, $n = 8$; length: $F = 5.91$, $P = 0.051$, $n = 8$), indicating that the reach was larger in years with higher precipitation. Mean length was found to be significantly negatively correlated with mean water temperature ($F = 6.10$, $P = 0.049$, $n = 8$), and area was marginally negatively correlated with mean water temperature ($F = 4.64$, $P = 0.075$, $n = 8$), indicating that water temperatures were higher when the reach was smaller. Based on the results of these regression analyses, years with higher precipitation had larger site dimensions with lower water temperatures and lower species richness and diversity.

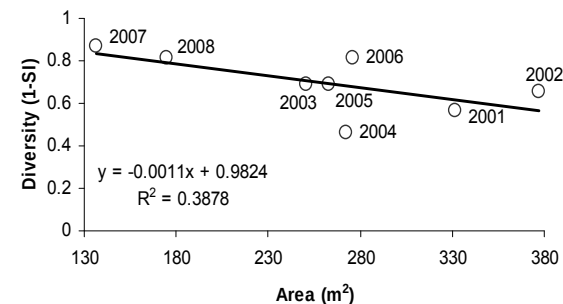
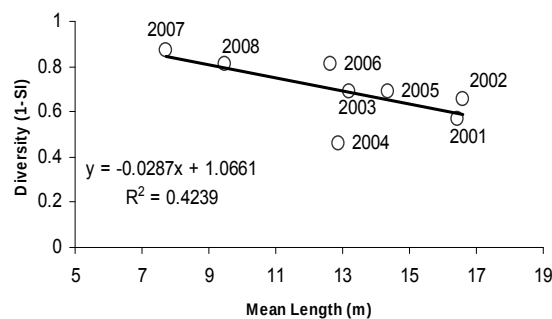
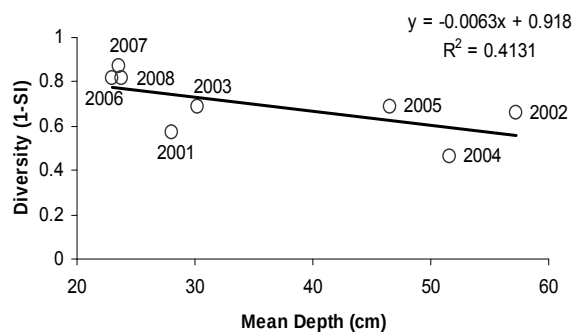
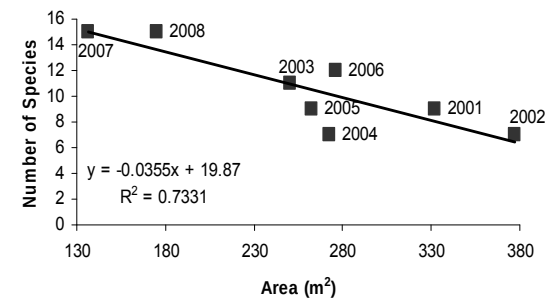
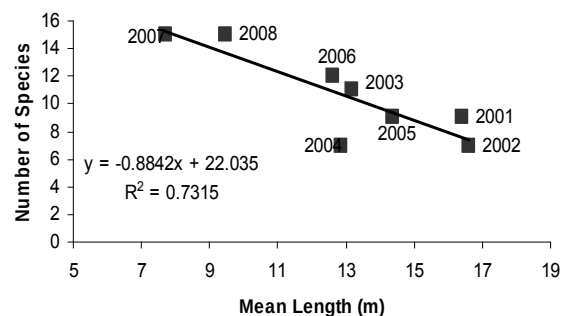
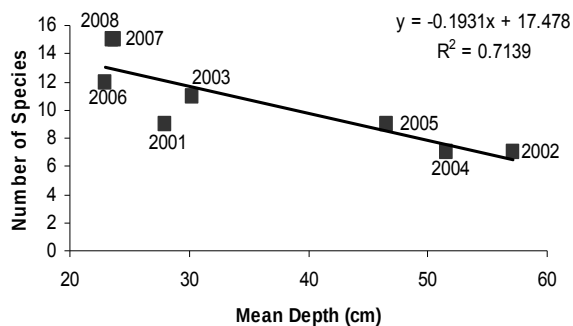


Figure 8. Regressions of species richness (top panel; solid squares) and diversity (bottom panel; open circles) with mean depth, mean length, and area at the lower reach for 2001-2008. Linear equation and R^2 value are given in each graph.

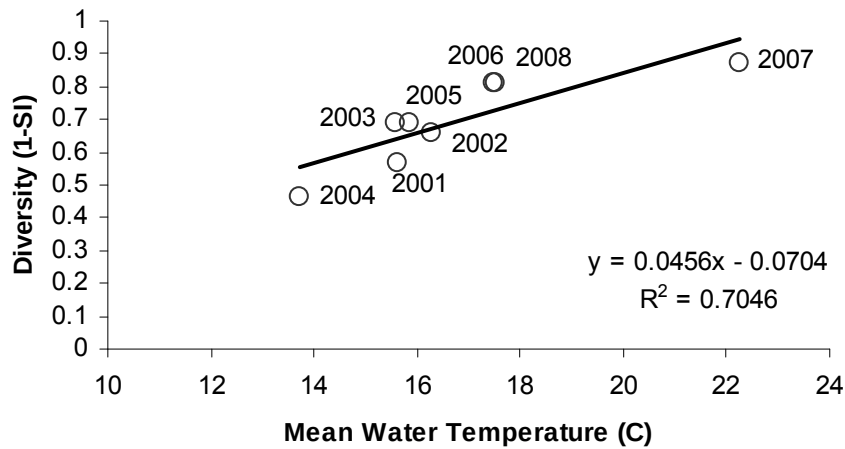
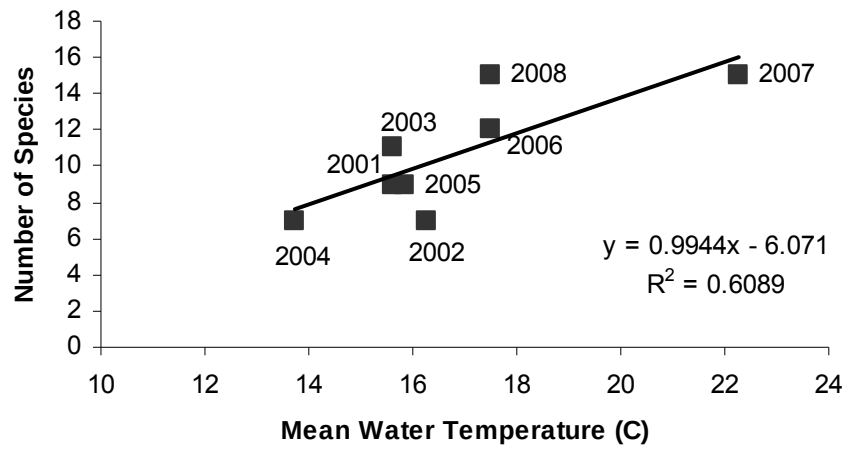


Figure 9. Regressions of species richness (top panel; solid squares) and diversity (bottom panel; open circles) with mean water temperature at the lower reach for 2001-2008. Linear equation and R^2 value are given in each graph.

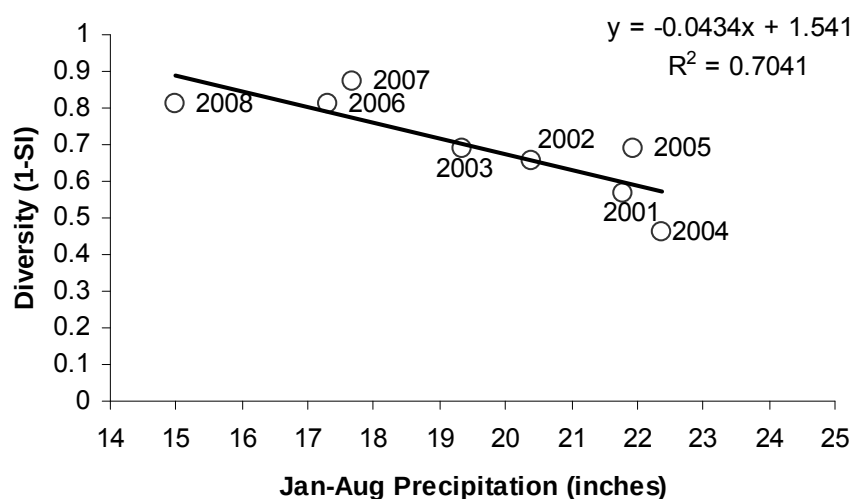
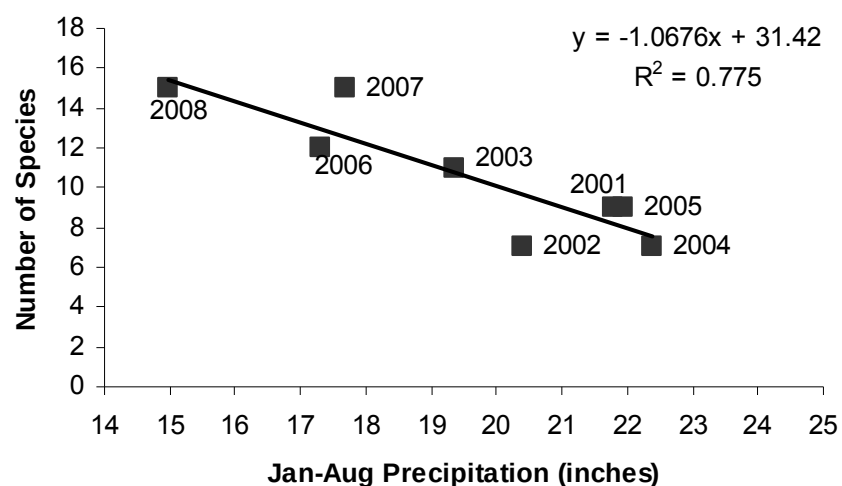


Figure 10. Regressions of species richness (top panel; solid squares) and diversity (bottom panel; open circles) with total precipitation prior to sampling (January – August) each year from 2001-2008 at the lower reach. Linear equation and R^2 value are given in each graph.

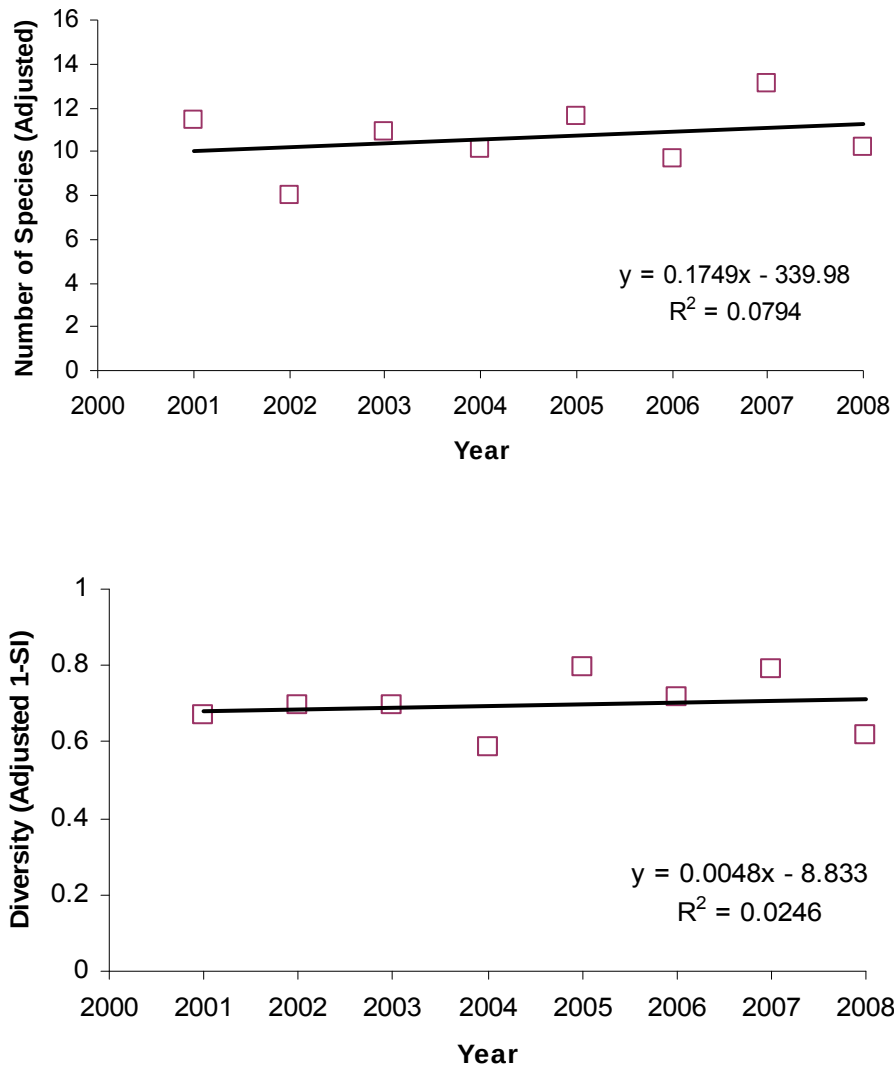


Figure 11. Species richness and diversity (1-SI) at the lower reach adjusted for total annual precipitation prior to sampling (precipitation from January – August each year). Regression line, linear equation, and R^2 value are given for the lower reach.

Potential Sampling Bias

The significant increase in species richness and diversity over time at the lower reach, along with the significant negative relationship of both variables with precipitation, may be interpreted to suggest that the fish community in the lower reach has changed and that precipitation (or intercorrelated variables of site dimensions) is driving these changes. Variability in precipitation accounted for 70% of the variability in diversity, and almost 80% of the variability in species richness.

There is an alternate interpretation of these results, however. If increased precipitation, which is positively associated with longer and deeper reaches, decreases the relative efficiency of sampling, this could explain the negative relationship of species richness and diversity with precipitation. In other words, more rain results in longer and deeper reaches, which makes seining methods less efficient. If we assume this is the case, it is possible to adjust the fish metrics based on the regression models in Figure 10. We did this by taking the difference of the values of richness (or diversity) for each year along the regression line from overall mean richness (or diversity), and adding or subtracting this difference to the actual value of richness (or diversity) to adjust for annual variation in precipitation. Once adjustments were calculated, there was no significant trend in richness ($F = 0.52$, $P = 0.499$, $n = 8$) or diversity ($F = 0.16$, $P = 0.711$, $n = 8$) across time (Figure 11).

Discussion

The fish community in Pipestone Creek differed between the upstream-most reach (above falls) located near the east side of the park boundary and the downstream (lower) reach near the west boundary. At the above falls reach, richness, diversity, stream integrity (IBI) and abundance were low compared to the lower reach, probably due to the differences in water quality and habitat conditions (Appendix 3 and 4). Large diel fluctuations in dissolved oxygen (DO) were recorded above the falls, where levels dropped below 5 mg/L at night (see Appendix 4), a lethal level for many fish species (USEPA 1988). Physical habitat is uniform above the falls with a narrow and shallow channel (Appendix 3) that consists largely of bedrock (see Table 5 in Peitz 2005). The shallow conditions and bedrock substrate in addition to the open canopy and inputs of nutrients from agricultural land use upstream allow attached algae (periphyton) to flourish, creating high DO concentrations during the day via photosynthesis and causing low DO levels at night through respiration. These fluctuations in DO levels are the likely the driving mechanism behind the poor quality of the fish community above the falls. Although no significant temporal trends were found in fish communities above the falls, years with higher richness typically had lower diversity due to dominance by one species, either the Fathead Minnow or the Creek Chub. Both of these species are tolerant of poor water quality conditions.

In contrast, the lower reach was characterized by high richness, good stream integrity, and moderate to high diversity. The overall trend of increasing richness and diversity at this reach over time may be attributable to annual variability in precipitation and a relative inefficiency of sampling larger channel units during wet years. In years with higher precipitation, sample sites (depth, length) were larger and associated with lower richness and diversity, potentially due to lower sampling efficiency in larger sites. Once richness and diversity were adjusted to account for differences in precipitation among years, no trend in these fish community metrics was evident. The relationship between precipitation and richness or diversity was used to make this adjustment because the coefficients of determination were fairly strong for both of these relationships. A number of the habitat and water quality variables were intercorrelated, however, and causal relationships are hypothesized rather than proven. Moreover, some of the significant or marginally significant relationships may be spurious due to the relatively large number of simultaneous comparisons. Sample sizes are too small for a multivariate model selection analysis.

Total catch and total CPA showed no directional trend at the lower reach, but total catch did vary considerably among years with large numbers of Common Shiner and Fathead Minnow present in 2003. In general, the fish community at this downstream reach consisted largely of species (Common Shiner, Bigmouth Shiner, and Central Stoneroller) moderately tolerant to poor water quality and contained 85% of the Topeka Shiner abundance in Pipestone Creek. Individual species catch did not vary significantly from baseline conditions (first three years of data) at the lower site, but deviations from baseline conditions were found for CPA. Because only CPA revealed such deviations and not catch, the CPA results could be due to the variability in site dimensions (resulting from variation in precipitation) over time and the potential efficiencies or inefficiencies in sampling varying sizes of sites within the lower reach.

Further study and data collection will be helpful in determining the true mechanisms behind differences in fish communities in Pipestone Creek. Collection of additional water quality data, particularly DO and temperature, for several weeks seasonally (especially during summer low flows) would be useful at the reach above the falls, where water quality is suspected to have a large impact on the fish community. The sampling methodology should be evaluated for relative efficiencies and biases due to different size channel units and larger substrates (see Table 5 in Peitz 2005) in reaches downstream of the waterfall. Comparison of the seining method with other methods may also help elucidate potential biases and sources of error. Dauble and Gray (1980) found that backpack electrofishing gear was more effective in nearshore areas of rivers that had irregular substrate and faster flows, while seines were better in more uniform substrate (such as that found above the falls). Ultimately, the most appropriate interpretation of the species richness and diversity data at the lower reach will remain in question until sampling efficiencies and potential biases of the methodology can be examined. However, no negative trends in fish communities were observed or inferred, and the park appears to play some role in protecting native prairie fishes as evidenced by the higher quality fish community and presence of Topeka Shiners at the downstream reach.

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Appendix 1. Species and numbers collected at the reach sampled above the falls during 2001-2008.

Family	Common Name	Genus	Species	2001	2002	2003	2004	2005	2006	2007	2008
Cyprinidae	Bigmouth Shiner	<i>Notropis</i>	<i>dorsalis</i>	0	2	0	0	0	0	0	0
Ictaluridae	Black Bullhead	<i>Ameiurus</i>	<i>melas</i>	0	0	0	0	0	0	0	0
Cyprinidae	Blacknose Dace	<i>Rhinichthys</i>	<i>atratus</i>	0	1	0	0	0	0	6	9
Percidae	Blackside Darter	<i>Percina</i>	<i>maculata</i>	0	0	0	0	0	0	0	0
Cyprinidae	Bluntnose Minnow	<i>Pimephales</i>	<i>notatus</i>	0	1	4	0	0	0	0	0
Cyprinidae	Brassy Minnow	<i>Hybognathus</i>	<i>hankinsoni</i>	2	3	0	0	0	0	0	0
Gasterosteidae	Brook Stickleback	<i>Culaea</i>	<i>inconstans</i>	0	0	0	0	0	3	1	1
Cyprinidae	Central Stoneroller	<i>Campostoma</i>	<i>anomalum</i>	0	0	2	0	1	17	0	0
Cyprinidae	Common Shiner	<i>Luxilus</i>	<i>cornutus</i>	0	0	0	0	0	0	0	0
Cyprinidae	Creek Chub	<i>Semotilus</i>	<i>atromaculatus</i>	60	3	5	2	6	55	12	18
Cyprinidae	Fathead Minnow	<i>Pimephales</i>	<i>promelas</i>	2	34	23	0	6	49	33	488
Centrarchidae	Green Sunfish	<i>Lepomis</i>	<i>cyanellus</i>	0	0	0	0	0	0	0	0
Percidae	Johnny Darter	<i>Etheostoma</i>	<i>nigrum</i>	0	0	0	0	0	0	0	0
Cyprinidae	Luxilus spp.	<i>Luxilus</i>	<i>spp.</i>	0	0	0	0	0	0	0	0
Cyprinidae	Non-carp minnow spp.	<i>Cyprinidae</i>	<i>spp.</i>	0	0	0	0	0	0	0	16
Esocidae	Northern Pike	<i>Esox</i>	<i>lucius</i>	0	0	0	0	0	0	0	0
Cyprinidae	Notropis spp.	<i>Notropis</i>	<i>spp.</i>	0	0	0	0	0	0	0	1
Centrarchidae	Orangespotted Sunfish	<i>Lepomis</i>	<i>humilis</i>	0	0	0	0	0	0	0	0
Cyprinidae	Red Shiner	<i>Cyprinella</i>	<i>lutensis</i>	0	0	0	0	0	0	0	0
Cyprinidae	Sand Shiner	<i>Notropis</i>	<i>stramineus</i>	3	0	0	0	0	0	0	37
Ictaluridae	Stonecat	<i>Noturus</i>	<i>flavus</i>	0	0	0	0	0	0	0	0
Cyprinidae	Topeka Shiner	<i>Notropis</i>	<i>topeka</i>	0	0	0	0	0	0	0	0
Ictaluridae	Unknown madtom	<i>Noturus</i>	<i>spp.</i>	0	0	0	0	0	0	0	0
Catostomidae	White Sucker	<i>Catostomus</i>	<i>commersoni</i>	8	5	0	2	2	10	7	19
Ictaluridae	Yellow Bullhead	<i>Ameiurus</i>	<i>natalis</i>	0	0	0	0	0	0	0	0
TOTAL				75	49	34	4	15	134	59	589

Appendix 2. Species and numbers collected at the lower reach sampled during 2001-2008.

Family	Common Name	Genus	Species	2001	2002	2003	2004	2005	2006	2007	2008
Cyprinidae	Bigmouth Shiner	<i>Notropis</i>	<i>dorsalis</i>	242	70	0	0	0	0	0	0
Ictaluridae	Black Bullhead	<i>Ameiurus</i>	<i>melas</i>	0	0	1	0	0	0	0	0
Cyprinidae	Blacknose Dace	<i>Rhinichthys</i>	<i>atratus</i>	0	0	0	0	1	17	8	6
Percidae	Blackside Darter	<i>Percina</i>	<i>maculata</i>	0	0	0	0	0	0	0	1
Cyprinidae	Bluntnose Minnow	<i>Pimephales</i>	<i>notatus</i>	0	62	0	15	29	21	18	3
Cyprinidae	Brassy Minnow	<i>Hybognathus</i>	<i>hankinsoni</i>	0	0	0	0	0	0	0	0
Gasterosteidae	Brook Stickleback	<i>Culaea</i>	<i>inconstans</i>	0	0	0	0	0	0	39	7
Cyprinidae	Central Stoneroller	<i>Campostoma</i>	<i>anomalum</i>	16	33	88	6	3	42	36	64
Cyprinidae	Common Shiner	<i>Luxilus</i>	<i>cornutus</i>	19	183	302	88	48	102	64	35
Cyprinidae	Creek Chub	<i>Semotilus</i>	<i>atromaculatus</i>	2	3	15	0	1	1	20	20
Cyprinidae	Fathead Minnow	<i>Pimephales</i>	<i>promelas</i>	44	0	193	0	0	17	33	28
Centrarchidae	Green Sunfish	<i>Lepomis</i>	<i>cyanellus</i>	0	0	1	0	0	0	0	1
Percidae	Johnny Darter	<i>Etheostoma</i>	<i>nigrum</i>	1	0	7	1	2	9	5	3
Cyprinidae	Luxilus spp.	<i>Luxilus</i>	<i>spp.</i>	0	0	0	0	0	0	1	0
Cyprinidae	Non-carp minnow spp.	<i>Cyprinidae</i>	<i>spp.</i>	0	0	0	0	0	0	0	3
Esocidae	Northern Pike	<i>Esox</i>	<i>lucius</i>	0	0	0	0	0	0	0	0
Cyprinidae	Notropis spp.	<i>Notropis</i>	<i>spp.</i>	0	0	0	0	0	0	2	0
Centrarchidae	Orangespotted Sunfish	<i>Lepomis</i>	<i>humilis</i>	3	1	1	0	1	0	0	1
Cyprinidae	Red Shiner	<i>Cyprinella</i>	<i>lutrensis</i>	0	0	0	0	0	1	1	0
Cyprinidae	Sand Shiner	<i>Notropis</i>	<i>stramineus</i>	43	0	24	2	0	16	11	3
Ictaluridae	Stonecat	<i>Noturus</i>	<i>flavus</i>	0	0	0	2	0	0	0	0
Cyprinidae	Topeka Shiner	<i>Notropis</i>	<i>topeka</i>	0	0	19	0	13	33	36	10
Ictaluridae	Unknown madtom	<i>Noturus</i>	<i>spp.</i>	0	0	0	0	0	0	1	0
Catostomidae	White Sucker	<i>Catostomus</i>	<i>commersoni</i>	12	3	14	8	5	23	2	3
Ictaluridae	Yellow Bullhead	<i>Ameiurus</i>	<i>natalis</i>	0	0	0	0	0	1	0	0
TOTAL				382	355	665	122	103	283	277	188

Appendix 3. Average in-stream habitat and water quality data for retained reaches from 2001 to 2008. Blanks indicated that a parameter was not collected for that reach during that year.

Reach	2001	2002	2003	2004	2005	2006	2007 ^A	2008 ^A
Width (m)								
Above Falls	3.6	3.8	3.6	4.5	3.5	3.6	3.6	3.4
Lower	4.0	4.5	3.8	4.2	3.7	4.4	3.5	3.7
Length (m)								
Above Falls	7.0	4.9	5.3	7.7	5.4	4.4	6.1	6.7
Lower	16.4	16.6	13.2	12.9	14.4	12.6	7.7	9.5
Area (m²)								
Above Falls	123.9	93.5	96.1	173.4	95.4	78.3	109.1	114.1
Lower	331.7	376.8	250.6	272.5	262.8	275.9	136.5	175.0
Depth (cm)								
Above Falls	25.4	32.2	20.6	43.2	33.8	20.2	20.5	20.3
Lower	28.0	57.2	30.2	51.6	46.6	22.9	23.5	23.8
Velocity (m/s)								
Above Falls						0.23	0.17	0.07
Lower						0.15	0.17	0.10
Water Temperature(°C)								
Above Falls	15.0	20.0	20.9	15.1	19.0	14.2		19.7
Lower	15.6	16.3	15.6	13.7	15.8	17.5	22.3	17.5
Air Temperature(°C)								
Above Falls	17.0	26.6	28.6	22.2	33.4	18.8		
Lower	20.1	23.2	21.2	12.8	23.3	20.4		
Dissolved Oxygen (mg/L)								
Above Falls	5.94	16.56	13.66	7.68	13.45	4.98		9.50
Lower	8.22	8.76	7.56	9.25	9.22	7.58	8.20	8.61
pH								
Above Falls		8.40	8.28	7.75	8.10	6.92		7.86
Lower		8.30	8.24	8.15	8.30	7.72	8.17	8.16
Specific Conductance (uS/cm)								
Above Falls			692.2	731.4	584.2	495.0		710.5
Lower			645.6	704.2	570.8	472.6	714.5	686.0
Turbidity (cm)								
Above Falls	56.6	69.6	75.6	26.8		78.2		B
Lower	60.1	91.0	59.2	20.2	87.2	91.6	B	B

^A In 2007 and 2008, water quality data was collected hourly using dataloggers. Average water quality parameters for these two years include only data collected during the hours of fish sampling.

^BIn 2007 and 2008, turbidity was collected using a probe that records data in nephelometric turbidity units (NTU) rather than cm of visibility. See Appendix 4 for averages.

Appendix 4. Average and range (in parentheses) for water quality variables collected during a 24 hour period in 2007 and 2008 using dataloggers. Data at the above falls reach was not collected in 2007.

	Above Falls	Lower	
	2008	2007	2008
Water Temperature(°C)	18.6 (15.2 - 22.0)	22.3 (18.5 - 25.9)	19.4 (17.0 - 22.2)
Dissolved Oxygen (mg/L)	8.00 (4.40 - 12.89)	7.95 (6.87 - 10.05)	8.03 (6.79 - 10.72)
pH	7.82 (7.56 - 8.12)	8.21 (8.12 - 8.39)	8.20 (8.05 - 8.38)
Specific Conductance (uS/cm)	696.6 (679 - 711)	713.0 (690 - 731)	682.9 (671 - 690)
Turbidity (NTU)	8.8 (1.9 - 23.4)	23.7 (22.8 - 26.3)	2.0 (0 - 12.2)

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