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Natural Resource Stewardship and Science

Aquatic Invertebrate Monitoring at Wilson's Creek National Battlefield

1996-2010 Status and Trend Report

Natural Resource Technical Report NPS/HTLN/NRTR—2013/754

ON THE COVER
Terrell Creek, Wilson's Creek National Battlefield, Missouri
Photo from The Heartland Inventory and Monitoring Network and Prairie Cluster Prototype Monitoring Program files

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June 2013

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

This report is available from http://science.nature.nps.gov/im/units/htln/ and the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/NRPM/).

Please cite this publication as:

Bowles D. E. 2013. Aquatic invertebrate monitoring at Wilson’s Creek National Battlefield: 1996-2010 status and trend report. Natural Resource Technical Report NPS/HTLN/NRTR—2013/754. National Park Service, Fort Collins, Colorado.

NPS 410/120911, June 2013

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Executive Summary

In the late 1980's, the National Park Service (NPS) began an program to monitor water quality and aquatic invertebrate community structure in prairie streams at several midwestern parks. Included in this baseline study were streams within Wilson's Creek National Battlefield (WICR). Preliminary monitoring was conducted at WICR from 1988 to 1990 at Wilson's Creek and a tributary, Skegg's Branch. Following theses baseline years, monitoring was not conducted again until 1996, from which date it was conducted annually through 2007. Since 2007, monitoring was conducted every 3 years. An additional tributary, Terrell Creek, was included for monitoring beginning in 2006. Since 2006, monitoring at WICR has been based on a monitoring protocol developed by the Heartland Inventory and Monitoring Network using revised methodology from previous protocols. The objectives of current monitoring are to: 1) determine the status and trends of invertebrate species diversity, abundance, and community metrics, and 2) relate invertebrate community composition, as quantified by metrics related to species richness, abundance, diversity, and region-specific multimetric indices that function as indicators of water quality and habitat condition, to overall water quality within the study area.

For each stream, a Surber stream bottom sampler (500 μm mesh, 0.09 m^2) was used to sample three successive riffles, with three benthic invertebrate samples collected per riffle. Water quality and habitat data were collected in conjunction with the benthic samples. The Stream Condition Index (SCI) was calculated for each stream and sampling year using the mean values of four metrics: (1) taxa richness, (2) Ephemeroptera, Trichoptera, Plecoptera (EPT) richness, (3) Shannon's diversity index, and (4) the Hilsenhoff biotic index (HBI). Control charts and the Mann-Kendall trend test were employed to further evaluate change over time in the benthic invertebrate communities.

Water quality, habitat, and aquatic invertebrate community metrics varied considerably among sampling years and streams sampled. Based on the invertebrate community metrics reported here, the water quality of Wilson's Creek within WICR is judged as impaired, while water quality of Skegg's Branch and Terrell Creek is judged to be not imparied. Wilson's Creek is impacted from a combination of nonpoint sources, increased runoff, urbanization, and treated effluent from a wastewater treatment plant. Based upon a 2012 assessment by the Missouri Department of Natural Resources, Wilson's Creek is listed as a 303d impaired stream due to nonpoint sources of *Escherichia coli*. Although Skegg's Branch historically has had high water quality, the effects of urbanization associated with the growth of Republic, Missouri where this stream originates potentially could contribute to the degradation of this resource. Because observed impairment, especially for Wilson's Creek, is attributed to activities in the watersheds outside the park boundaries, there are few available options to park management for mitigating this situation. The long history and continuing efforts of aquatic invertebrate monitoring at Wilson's Creek National Battlefield provides a sound tool to recognize both deterioration and chronic decline of water quality.

Acknowledgements

I thank David Peitz, Tyler Cribbs, Gary Sullivan, Carla Stark, Hope Dodd, Jake Waters, Angela Bandy, Jan Hinsey, Mike DeBacker, Greg Wallace, Jessica Luraas, Sherry Middlemis-Brown, and Lloyd Morrison for assisting with this project.

Introduction

Aquatic invertebrates are an important tool for understanding and detecting changes in ecosystem integrity over time. The monitoring objectives of this study (DeBacker et al. 2005) are 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 water quality and habitat condition. Peitz and Cribbs (2005) reported on status and trends of the aquatic invertebrate community at WICR from inception of monitoring through 2004. Bowles (2010) reported on the period from 2005 to 2007. The purpose of this report is to provide a status and trends report, using data from Bowles (2010) and aquatic invertebrate monitoring data collected in 2010.

Wilson's Creek is one of the largest tributary streams in the James River basin, draining most of the city of Springfield, Missouri. Due largely to this urban drainage, Wilson's Creek has experienced serious water quality degradation over the past few decades (Black 1997, Richards and Johnson 2002). The chronic pollution of Wilson's Creek arises from point sources such as a wastewater treatment plant and non-point sources such as stormwater run-off. Due to its urban origin, Wilson's Creek is also prone to flashiness following only moderate rainfall amounts (Richards and Johnson 2002). Historically, summer storms combined with wastewater effluent resulted in severe depletion of dissolved oxygen in Wilson's Creek (Emmett et al. 1978). The combined and synchronous effects of these stressors on aquatic life in Wilson's Creek are presently unknown.

Below where Rader Spring enters Wilson's Creek, downstream of the City of Springfield, most of the flow of Wilson's Creek consists of treated effluent from the Southwest Wastewater Treatment Plant (City of Springfield). Currently about 42.5 million gallons of treated sewage is released into Wilson's Creek daily. Although plant upgrades done in 1977 and 2001 aimed at partial removal of phosphorus from the wastewater, it continues to contribute this nutrient into Wilson's Creek (Missouri Department of Natural Resources 2007). Phosphorus-and nitrogen-related compounds remain relatively high in Wilson's Creek (Missouri Department of Natural Resources 2007) and at sufficient levels to stimulate algal growth (Mueller and Helsel 1996, Dodds et al. 2002). Nutrient enrichment in streams due to human induced land changes is problematic because it stimulates growth of periphyton and filamentous algae (Dodds et al. 2002; Dodds and Oakes 2006, 2008) and can lead to eutrophication and impairment of biological integrity in surface waters.

The treatment plant presently reduces average phosphorus discharge levels to 0.5 milligrams per liter (http://www.springfieldmo.gov/sanitary/phosphorus.html). The U.S. Environmental Protection Agency (Muller and Helsel 1996) recommends that total phosphorus should not exceed 0.05 mg/L in a stream at a point where it enters a lake or reservoir, and should not exceed 0.1 mg/L in streams that do not discharge directly into lakes or reservoirs. Muller and Helsel (1996) also noted that background nitrate concentrations in streams generally are less than 0.6 mg/L. However, Missouri Department of Natural Resources (2007) reported nitrate-nitrite and total nitrogen concentrations in Wilson's Creek as 1.73 mg/l and 1.93 mg/l, respectively. It is not entirely clear how much of this nutrient loading comes from the treatment plant in comparison to general urban run-off from the City of Springfield.

Upgrades to the wastewater treatment plant have improved the water quality in the creek in recent years, resulting in improved dissolved oxygen concentration (Berkas 1980, 1982). Concentrations of contaminants reported by Richards and Johnson (2002) are generally well below their respective state limits set for the protection of aquatic life, but densities of fecal indicator bacteria occasionally exceeded the state limit for whole-body-contact recreation during base-flow conditions and can be orders of magnitude greater than the state limit during storm events. Despite these known pollutants, there have been no serious actions to mitigate the water quality degradation produced by urban stormwater run-off into Wilson's Creek.

Skegg's Branch flows through a largely rural, landscape and its water quality and aquatic invertebrate community generally display good integrity. However, due to relatively recent expansive growth in the City of Republic, Missouri where this small stream originates, concern has been expressed about potential for urban runoff degrading this stream. Terrell Creek lies in a rural watershed and receives most of its flow from a spring source (Double Spring) located within the boundaries of WICR. Terrell Creek demonstrates high water quality and a robust biotic diversity.

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 quality data periodically obtained, invertebrate communities are used here as a surrogate of the long-term water quality condition of WICR streams. 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. Various metrics calculated from species richness, abundance, diversity, species tolerance to disturbance, and region-specific multi-metric indices can provide clues to the overall water quality conditions for biological support in the stream.

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 Wilson's Creek, Skegg's Branch, and Terrell Creek (Figure 1) during a late spring index period.

Sample Collection

For each sample, current velocity (m/sec) and depth (cm) were recorded immediately in front of the sampling net frame. 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 after invertebrate collections were completed. Discharge estimates illustrate the general flow characteristics for the respective streams for a given sampling year and are not intended to be exact measurements. Discharge was not measured in 2005, and the data for Wilson's Creek presented were obtained from the US Geological Survey Water Resources database (http://waterdata.usgs.gov/mo/nwis/uv?site_no=07052152).

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. These data may help explain variability between sampling periods, but they should not be used as an analytical tool in the strictest sense. Moreover, the water quality data represent only a snap-shot of the broad temporal range of conditions, and should be cautiously interpreted.

Due to the limitations of using water quality data periodically obtained with data loggers, invertebrate communities are used here as a surrogate of the long-term water quality condition of WICR streams. For each stream, three successive riffles were sampled with three benthic invertebrate samples collected per riffle, resulting in nine samples per stream. 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.

Invertebrate Metrics and Stream Condition Index (SCI)

Metrics calculated for the invertebrate communities included taxa richness, family richness, Ephemeroptera, Trichoptera, Plecoptera (EPT) richness, EPT ratio (= EPT/[EPT + Chironomidae]), Shannon's diversity index, Shannon's evenness index, and Hilsenhoff biotic index (HBI). These community metrics are described in Barbour et al. (1999) and Bowles et al. (2008). They are considered sufficiently sensitive to detect potential pollution problems in streams throughout the region. Mean metric values were established by averaging the values for each of three samples per riffle and then averaging the means for the three riffles to establish a site mean (n=3).

The Stream Condition Index (SCI) was calculated for each stream and sampling year using the mean values of four metrics (taxa richness, EPT richness, Shannon's diversity index, HBI) for a spring index period (Rabeni et al. 1997, Sarver et al. 2002). The SCI is a multimetric index founded on the reference site approach and is based on data collected from streams in the prairie region of Missouri (Rabeni et al. 1997). The SCI is recognized by the state of Missouri as a means of assessing stream integrity. The individual metrics comprising the SCI were chosen as sound measures of community structure and balance (Rabeni et al. 1997). The upper quartile value from the distribution for each metric in the SCI is used as the minimum value representative of reference conditions (Table 1).

The SCI scores produce three possible levels of stream condition: 1) fully biologically supporting (unimpaired, score 16-20), 2) partially biologically supporting (impaired, scores 10-14), and 3) non-biologically supporting (very impaired, scores 4-8). Unimpaired or reference thus infer a stream that is fully biological supporting. These streams have the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region. Impaired sites have stream reaches that are partially biologically supporting, with species composition, diversity and functional organization indicative of a disturbed system. Sites scored as very impaired lack conditions necessary for a sustainable, adaptable community. Both partially biologically supporting and non-biologically supporting categories indicate impaired streams that do not meet the beneficial use of protecting of aquatic life. See Rabeni et al. (1997) and Sarver et al. (2002) for further details on how these metrics and the SCI are calculated.

Table 1. Descriptive statistics and scores for the metrics for the spring index period based on single habitat coarse substrate (riffle) data (from Rabeni et al. 1997).

	Statistics					Scores		
Metrics	**1%**	**25%**	**50%**	**75%**	**99%**	**5**	**3**	**1**
Taxa Richness	10	15	18	20	29	>=15	14-8	<8
EPT Richness	3	4	5	7	11	>=4	3-2	<2
Biotic Index	5.6	5.8	6.3	6.6	7	<=6.6	6.7-8.3	>8.3
Shannon's Index	1.48	1.77	2.05	2.49	2.6	>=1.77	1.76-0.88	<0.88

Scoring: 16-20 not impaired, 10-14 impaired, 4-8 very impaired.

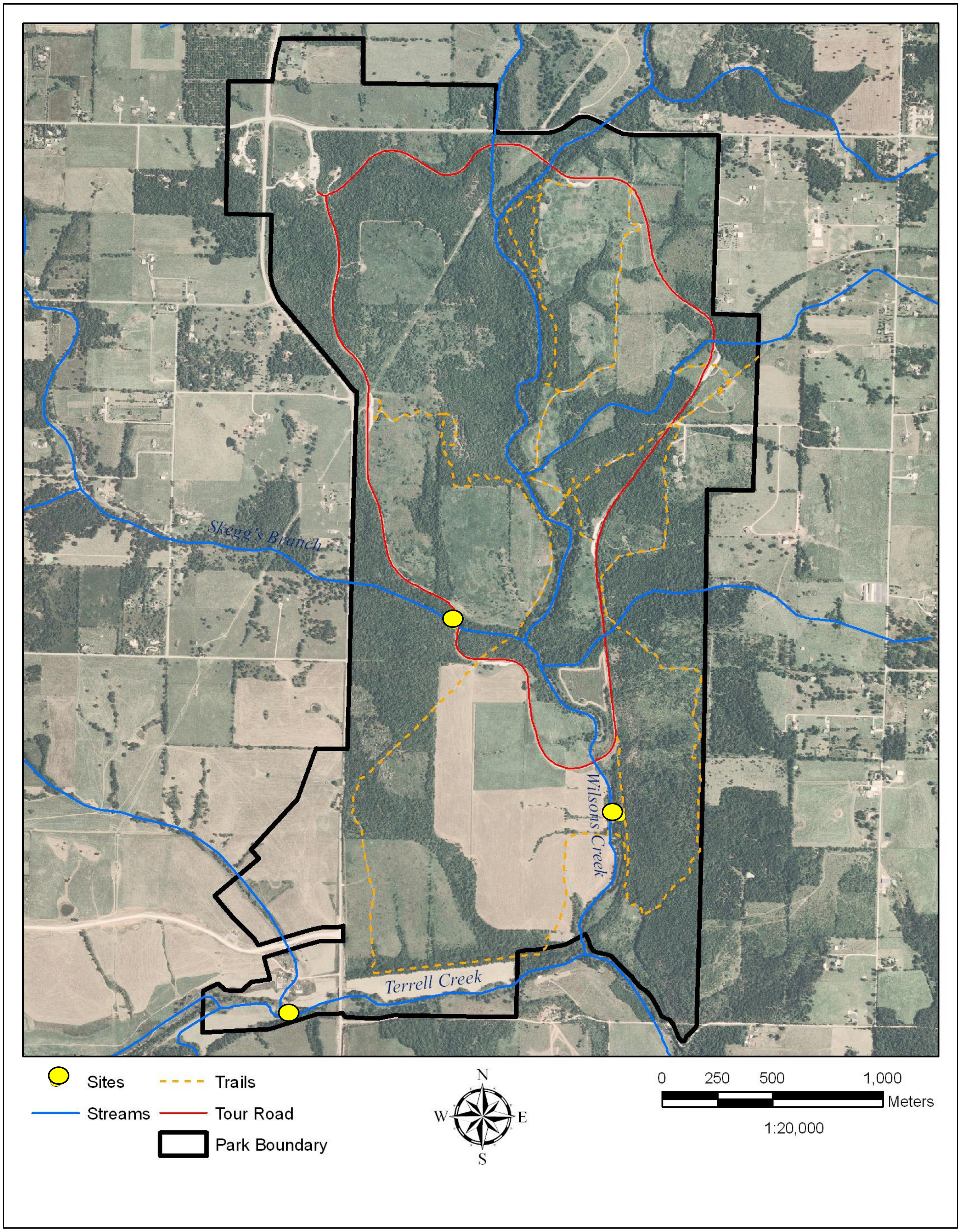

Figure 1. Aquatic invertebrate monitoring sites (yellow dots) at Wilson's Creek National Battlefield.

Data Analysis

The primary interest in the analysis and interpretation of the data presented in this report is the magnitude of change rather than change *per se* (Bowles et al. 2008), and whether it represents something biologically important. Null hypothesis significance testing in the strict sense may not be the best approach given these goals (Morrison 2007). Therefore, univariate control charts were established for Wilson's Creek and Skegg's Branch 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. There are presently insufficient data on which to establish a control chart for Terrell Creek. 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. The data addressed in this report are only those collected during the May-June index period from the general sampling reach described in Bowles et al. (2008). It does not include all historical data summarized in Peitz and Cribbs (2005). Thus, the primary purpose of sampling to date with respect to control chart construction has been to establish a baseline and evaluate natural variability. 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 determined using statistical procedures that determined natural variability within baseline data, setting a range of values that represent the 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 of (mean ± 1.86 standard deviations for Wilson's Creek and mean ± 2.02 standard deviations for Skegg's Branch) 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 and 2.02 standard deviations, respectively, is analogous to significance tests at a critical value of 0.05 for one-tailed tests. The student's *t*-distribution (df = 8 Wilson's Creek, df = 5 Skegg's Branch) 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 Wilson's Creek and Skegg's Branch across years (1988-2010) was conducted using a non-parametric Mann-Kendall trend test (α=0.05) (Time Trends software, version 3.0, NIWA 2010). Insufficient data exist to conduct a trend analysis for Terrell Creek. 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). Stark and Fowles (2006) recommended the Mann-Kendall test over other trend tests for the evaluation of stream invertebrate samples. The Mann-Kendall 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

Water Quality and Habitat

Core 5 water quality measurements varied considerably among streams and years sampled (Table 2). Observed differences among streams are likely due to natural variability over the term of deployment for water sampling equipment. For example, a longer deployment time of the dataloggers in 2006 resulted in substantially more readings, over a longer time, compared to other years. In general, Wilson's Creek had higher water temperatures and specific conductance in comparison to Skegg's Branch and Terrell Creek. The exception was in 2006 when mean specific conductance for Wilson's Creek was lower in comparison to Skegg's Branch. Values for specific conductance in Wilson's Creek were typically well above acceptable ranges for Missouri streams (Table 3). Mean turbidity recorded for Wilson's Creek in 2006 to 2010 was within the acceptable range for the region, but the data included values that were not within the acceptable range. In general, the observed readings at Wilson's Creek for temperature, specific conductance, and turbidity likely relate to the effects of urbanization in this watershed, and because most of the base flow for Wilson's Creek comes from the discharge of the Southwest Wastewater Treatment Plant in Springfield. The urbanized watershed of Wilson's Creek also produces a dynamic hydrograph (i.e., flashy flows) and the creek becomes very turbid following only a light rainfall (e.g., <2 cm). The water quality data for Skegg's Branch and Terrell Creek were generally typical for regional streams and do not suggest impairment based on the acceptable ranges.

Wilson's and Terrell creeks were similar in depth at riffles sampled (15-25 cm), but Skegg's Branch was generally shallower (5-20 cm) (Figure 2). Current velocities associated with samples taken in Wilson's Creek were variable, but were generally well below 0.9 m/sec (Figures 2-3). The variability and magnitude of depth and current velocity in these streams is reflected in their respective rates of discharge. Discharge (Table 4) for Wilson's Creek was substantially higher in 2007 (4.56 m^3/sec) compared to other years, and the lowest discharge of 0.93 m^3/sec was measured in 2006. In comparison, discharge for Skegg's Branch and Terrell Creek did not exceed 0.56 m^3/sec, and more often ranged from 0.10-0.30 m^3/sec.

Although habitat parameters were generally consistent between years for a given stream, there was considerable variation observed among the streams (Figures 4-9). Filamentous algae were poorly represented in riffles of all three streams (<20%) although we observed substantial algal growth in Wilson's Creek between riffles. Aquatic plants were poorly represented in Wilson's Creek (<45%) while Skegg's Branch and Terrell Creek both had much greater aquatic plant growth (40-60% Skegg's Branch, 5-50% Terrell Creek) (Figures 4-6). The vegetation in the latter two streams probably relates to their respective base flows supplied by springs and their watersheds being largely rural in location. The dominant aquatic vegetation in Skegg's Branch was mosses, while Terrell Creek generally had a diverse assemblage of mosses and hydrophytes. Periphyton consistently averaged about 25% in samples for all three streams (Figures 4-6). Mean substrate sizes among riffles and streams were similar and the overlap of standard error bars shows that substrate sizes overlapped broadly among the three streams (Figure 7-9). Mean dominant substrate size for all three streams generally ranged from Wentworth size classes 13 to 15 or small to large pebble (22.6-54.0 mm). Embeddedness, or the degree to which fine sediments surround coarse substrates on the surface of a streambed, averaged around 25 to 30%

for Wilson’s Creek (Figure 7) but typically exceeded 30% for Skegg’s Branch (Figure 8). Embeddedness was most variable for Terrell Creek ranging from around 25 to 45% (Figure 9).

Table 2. Water quality data for streams at Wilson's Creek National Battlefield, 2005-2010. Data in 2005 were collected with hand-held instruments. Data for 2006-2010 were collected continuously with calibrated data loggers. Values are mean, standard deviation, and range.

Year	Stream	N		Temperature (^oC)	Specific Conductance (µm/cm)	Dissolved Oxygen (mg/liter)	pH	Turbidity (NTU)
2005	Wilson's Creek	9	Mean	19.82	774.40	9.23	7.51	n/a
			Standard Deviation	0.26	4.16	0.12	0.08	n/a
			Range	19.5-20.1	770.00-781.00	9.11-9.41	7.44-7.64	n/a
	Skegg's Branch	9	Mean	16.42	399.00	9.254	7.434	n/a
			Standard Deviation	0.15	1.73	0.14	0.12	n/a
			Range	16.2-16.6	396.00-400.00	9.08-9.37	7.31-7.58	n/a
2006	Wilson's Creek	139	Mean	22.49	486.48	9.16	7.77	9.57
			Standard Deviation	1.49	51.61	1.42	0.17	28.20
			Range	18.96-25.13	348.00-563.00	7.45-12.13	7.43-8.11	0-300.5
	Skegg's Branch	139	Mean	18.68	495.83	8.82	7.92	0.69
			Standard Deviation	1.77	7.39	1.20	0.06	0.55
			Range	14.38-21.67	480.00-505.00	7.1-11.55	7.82-8.07	0-3.7
	Terrell Creek	90	Mean	16.25	471.68	8.98	7.38	2.70
			Standard Deviation	0.86	2.24	1.45	0.07	2.08
			Range	15.37-18.09	467.00-474.00	7.49-11.8	7.29-7.51	0-7.1
2007	Wilson's Creek	26	Mean	18.49	642.96	n/a	n/a	4.25
			Standard Deviation	1.33	14.02	n/a	n/a	0.64
			Range	17.05-20.89	624.00-665.00	n/a	n/a	3.1-5.1
	Skegg's Branch	90	Mean	15.27	489.51	n/a	n/a	2.07
			Standard Deviation	0.86	15.34	n/a	n/a	0.64
			Range	14.36-17.26	453.00-511.00	n/a	n/a	1.1-3.7
	Terrell Creek	25	Mean	14.70	477.64	6.45	n/a	0.76
			Standard Deviation	0.32	1.82	0.58	n/a	0.19
			Range	14.28-15.28	475.00-481.00	5.79-7.47	n/a	0.5-1.3
2010	Wilson's Creek	24	Mean	18.06	743.54	9.43	7.95	1.28
			Standard Deviation	0.26	4.13	0.37	0.03	0.21
			Range	16.64-20.38	726-796	5.56-7.52	7.78-8.27	0.9-1.7

Table 3. Water quality data for streams at Wilson's Creek National Battlefield, 2005-2010. Data in 2005 were collected with hand-held instruments. Data for 2006-2010 were collected continuously with calibrated data loggers. Values are mean, standard deviation, and range.

Year	Stream	N		Temperature (^oC)	Specific Conductance (µm/cm)	Dissolved Oxygen (mg/liter)	pH	Turbidity (NTU)
2010	Skegg's Branch	27	Mean	14.54	455.59	11.08	7.72	0.54
			Standard Deviation	0.24	0.47	0.17	0.01	0.28
			Range	12.87-16.56	453.00-460.00	9.94-12.58	7.65-7.82	0-1.2
	Terrell Creek	29	Mean	14.11	413.38	9.70	7.64	0.906897
			Standard Deviation	0.17	0.19	0.15	0.01	0.89
			Range	12.99-15.66	412.00-415.00	8.58-10.76	7.60-7.69	0.4-4.7

Table 4. Acceptable ranges for water quality parameters in southwestern Missouri streams. Adapted from Brown and Czarnezki (undated).

Water Quality Parameter	Acceptable Range
Temperature	0-34 ^oC
Dissolved Oxygen	5-15 mg/liter
Specific Conductance	100-400 µS/cm
pH	6.5-9.0
Turbidity	Variable, but generally <10 NTU dry weather

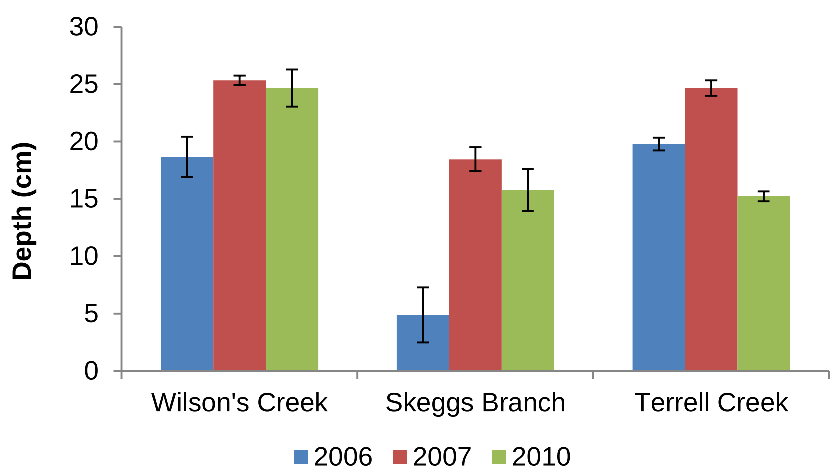

Figure 2. Mean depth (cm) and standard errors of riffles where benthic samples were collected.

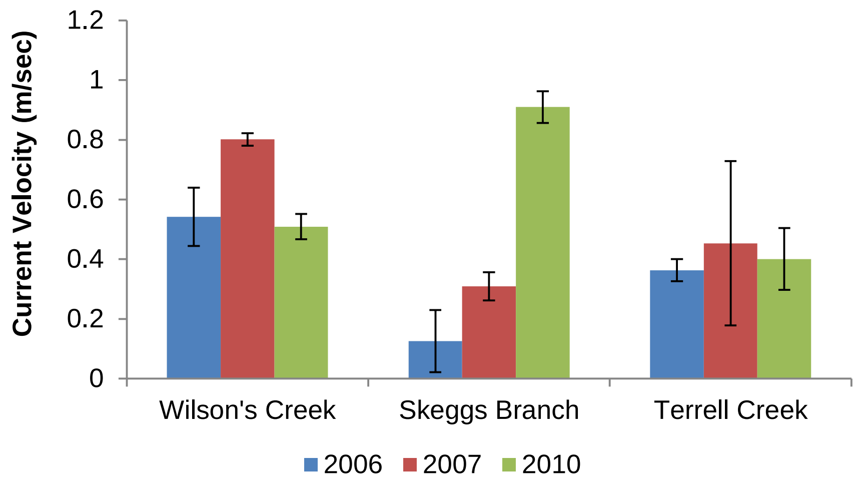

Figure 3. Mean current velocity (m/sec) and standard errors of riffles where benthic samples were collected.

Table 5. Discharge for streams at Wilson's Creek National Battlefield, 2005-2007, and 2010. Data from 2005 are from: http://waterdata.usgs.gov/nwis/

	Discharge (m^3/sec)			
Stream	**2005**	**2006**	**2007**	**2010**
Wilson's Creek	1.16	0.93	4.56	2.3
Skegg's Branch	n/a	0.01	0.14	0.10
Terrell Creek	n/a	0.10	0.56	0.33

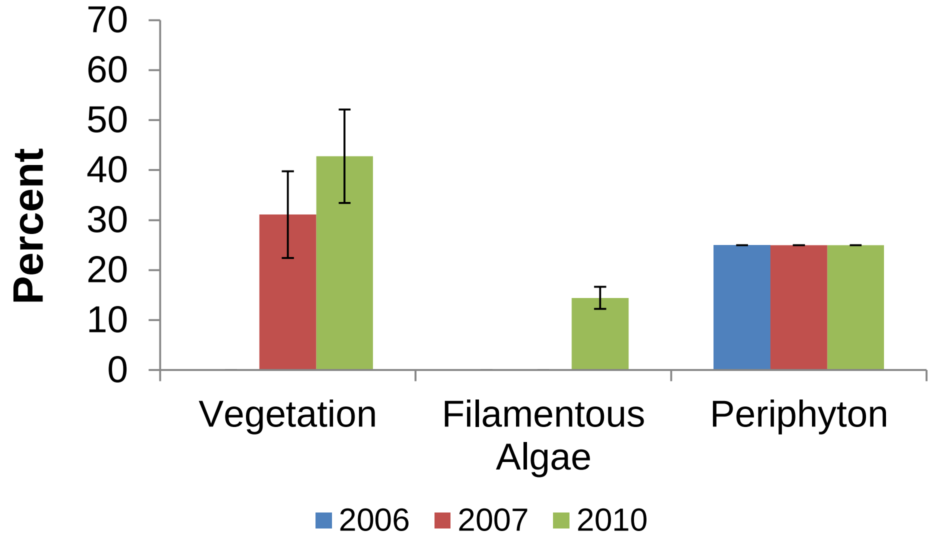

Figure 4. Mean percent and standard errors of habitat variables associated with benthic samples in Wilson's Creek, Wilson's Creek National Battlefield. Values are mid-point percentages.

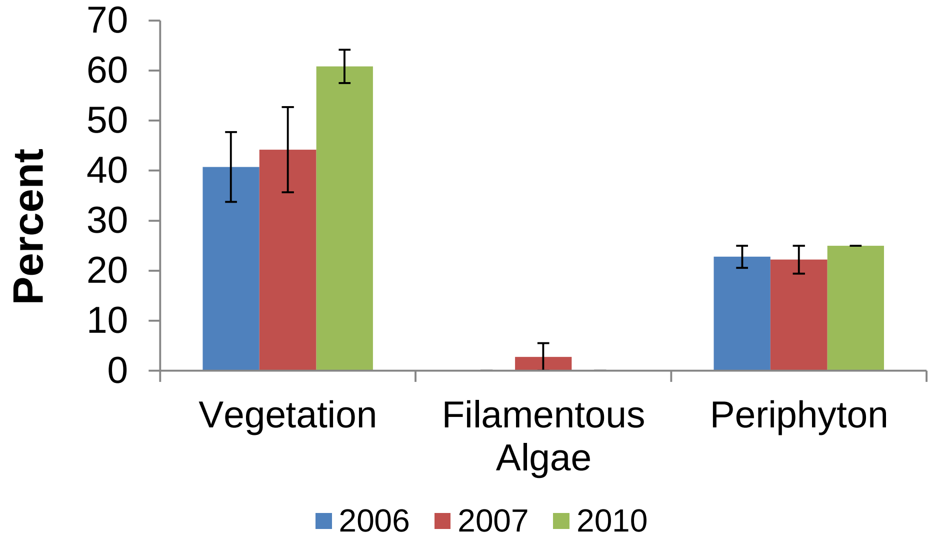

Figure 5. Mean percent and standard errors of habitat variables associated with benthic samples in Skegg's Branch, Wilson's Creek National Battlefield. Values are mid-point percentages.

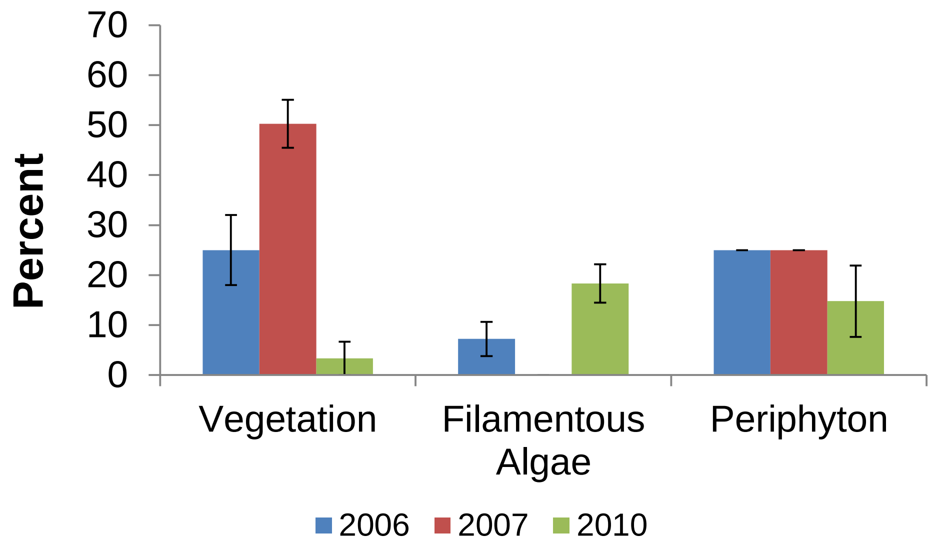

Figure 6. Mean percent and standard errors of habitat variables associated with benthic samples in Terrell Creek, Wilson's Creek National Battlefield. Values are mid-point percentages.

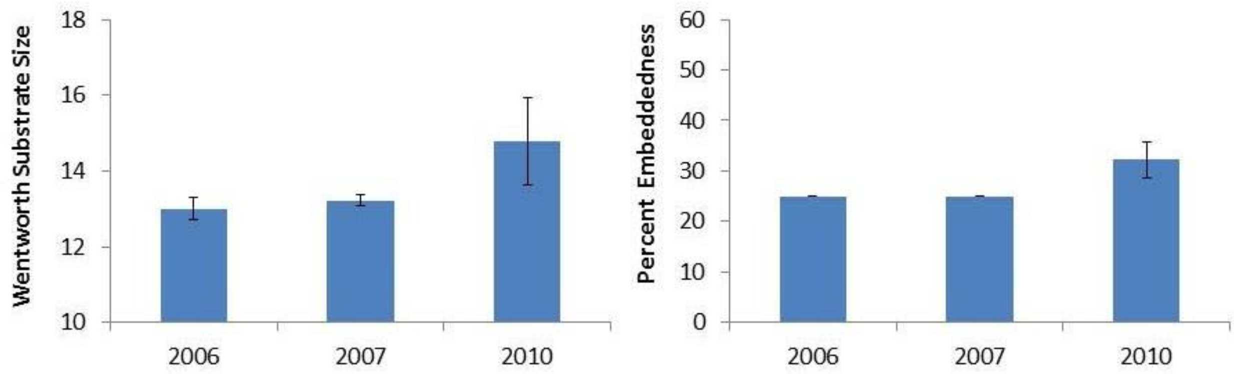

Figure 7. Mean substrate size and embeddedness with standard errors for stream riffles in Wilson's Creek Wilson's Creek National Battlefield.

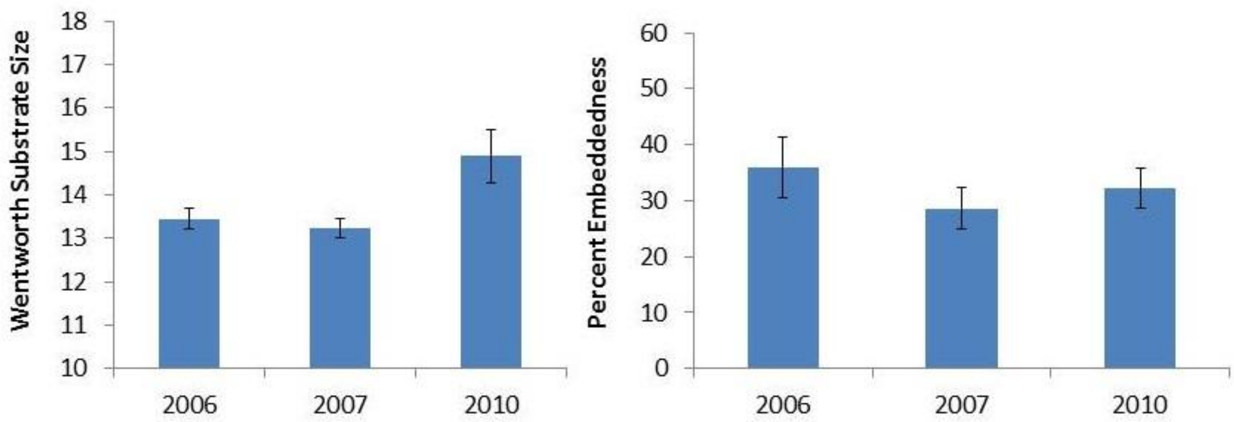

Figure 8. Mean substrate size and embeddedness with standard errors for stream in Skegg's Branch, Wilson's Creek National Battlefield.

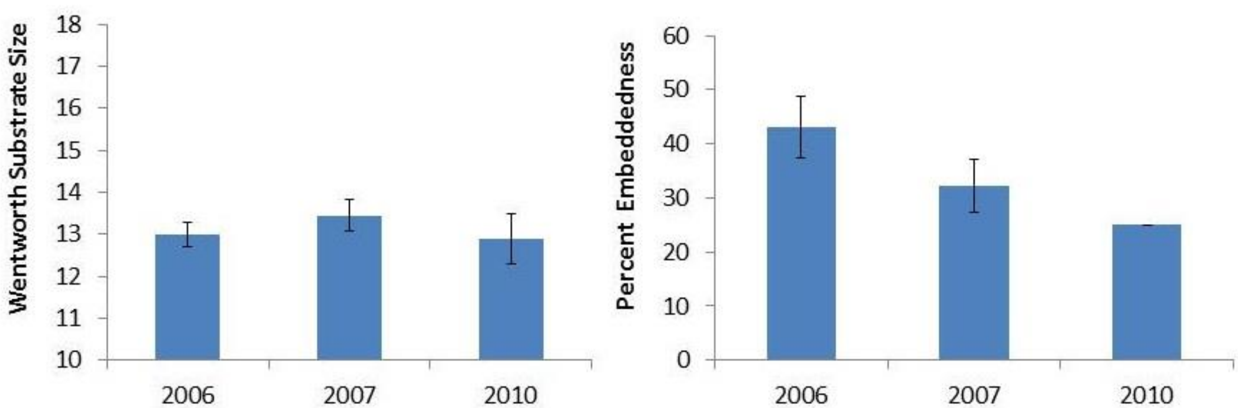

Figure 9. Mean substrate size and embeddedness with standard errors for stream riffles in Terrell Creek, Wilson's Creek National Battlefield.

Invertebrate Community Metrics

Invertebrate metrics were highly variable among streams and years sampled (Figures 10-30). Benthic samples generally contained a diverse assemblage of invertebrates commonly associated with stream communities, including mayflies (Ephemeroptera), caddisflies (Trichoptera), dragonflies and damselflies (Odonata), midges (Chironomidae), riffle beetles (Elmidae), crayfish (Decapoda), and snails (Gastropoda).

Control charts for Wilson's Creek showed that few of the invertebrate metrics exceeded their respective control limits (Figures 10-16). In 2007, the mean value for HBI exceeded the control limit although the range of data included values that did not exceed the limit (Figure 16). For HBI, lower values are desired. Metric values for Skegg's Branch were variable but in general did not exceed the control limit (Figures 17-23). Two exceptions for Skegg's Branch were EPT ratio in 2007 and 2010 (Figure 20), and Shannon evenness index in 2010 (Figure 22). Because streams are highly variable ecosystems, observed differences in sampling metrics among years likely is not biologically significant. Although Shannon index scores reported here for all streams are relatively low (≤ 2.69), they are similar to those reported for other regional systems (Jones *et al*. 1981, Bowles *et al*. 2008). Mean HBI scores were consistently around 5 or 6 for all three streams (Figures 16, 23, 30) indicating that taxa represented in samples were, on average, moderately tolerant of pollution. Mann-Kendall trend analysis showed that most metrics did not have a significant trend across years (Table 5). The exceptions were for Shannon diversity index and Shannon evenness index in Wilson's Creek, which significantly increasee across years (Figures 14-15), and EPT ratio and Shannon evenness index in Skegg's Branch, which significantly decreased across years (Figures 20 and 22). The notable decrease in EPT ratio for Skegg's Branch across years indicates more tolerant Chironomidae are becoming more prevalent (Figure 20). This suggests that overall conditions in Skegg's Branch may have declined since data were first collected in 1988-1989.

SCI scores for Wilson's Creek varied considerably across years with this stream being rated unimpaired in some years, but impaired in others (Table 6). The highly variable SCI scores are a direct reflection of the highly variable individual metrics that comprise them. Although this stream was judged as not impaired in some years, SCI scores across years generally indicated a tendency towards impairment. In comparison, the SCI scores for Skegg's Branch and Terrell Creek reflected unimpaired conditions for those streams.

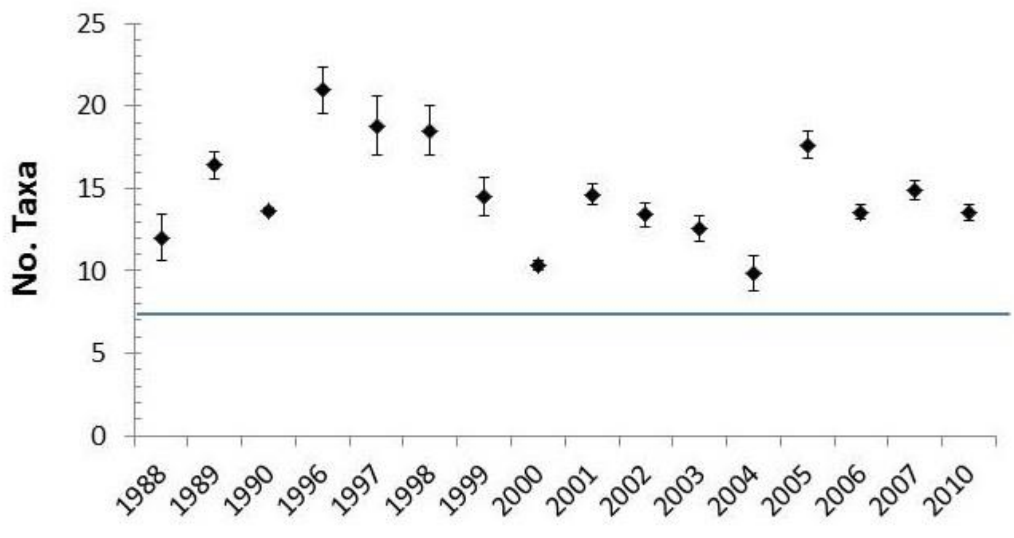

Figure 10. Control chart for taxa richness at Wilson's Creek, Wilson's Creek National Battlefield, 1988-2010. Points are means for a given sampling date, and the vertical bars are standard errors. The horizontal line represents the control limit corresponding to a 0.05 Type I error rate.

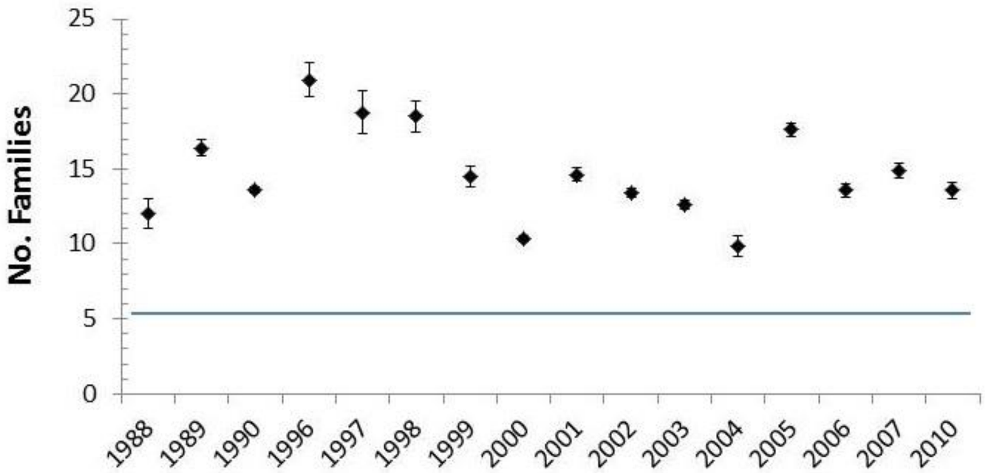

Figure 11. Control chart for family richness at Wilson's Creek, Wilson's Creek National Battlefield, 1988-2010. Points are means for a given sampling date, and the vertical bars are standard errors. The horizontal line represents the control limit corresponding to a 0.05 Type I error rate.

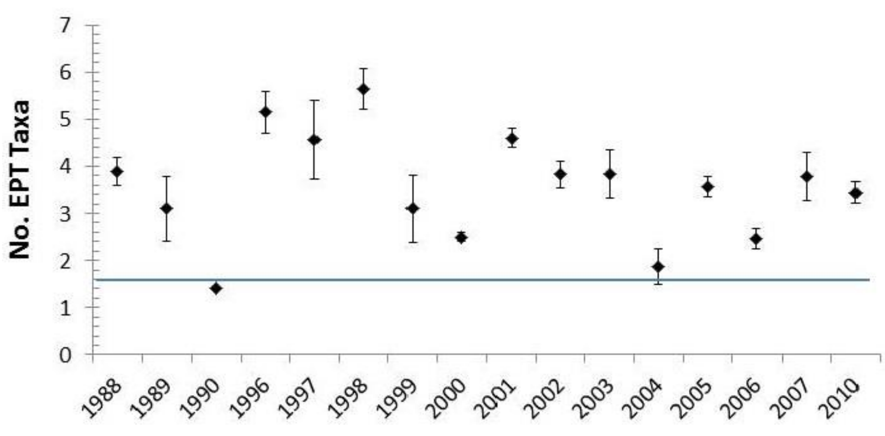

Figure 12. Control chart for Ephemeroptera, Plecoptera, and Trichoptera (EPT) at Wilson's Creek, Wilson's Creek National Battlefield, 1988-2010. Points are means for a given sampling date, and the vertical bars are standard errors. The horizontal line represents the control limit corresponding to a 0.05 Type I error rate.

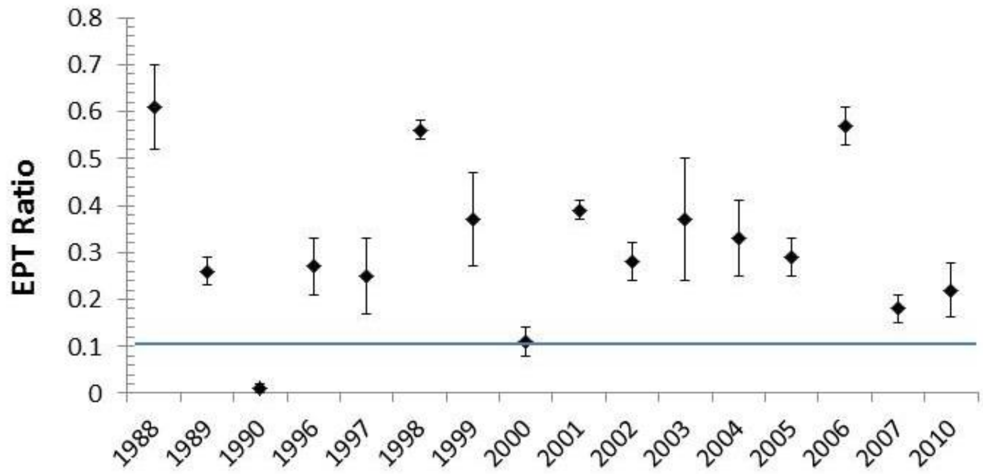

Figure 13. Control chart for EPT ratio at Wilson's Creek, Wilson's Creek National Battlefield, 1988-2010. Points are means for a given sampling date, and the vertical bars are standard errors. The horizontal line represents the control limit corresponding to a 0.05 Type I error rate.

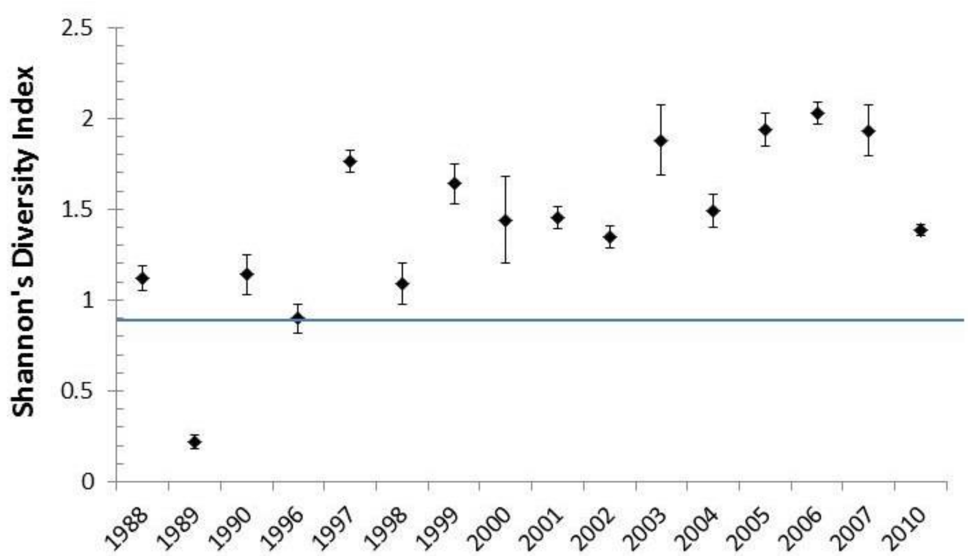

Figure 14. Control chart for Shannon's Diversity Index for genera at Wilson's Creek, Wilson's Creek National Battlefield, 1988-2010. Points are means for a given sampling date, and the vertical bars are standard errors. The horizontal line represents the control limit corresponding to a 0.05 Type I error rate.

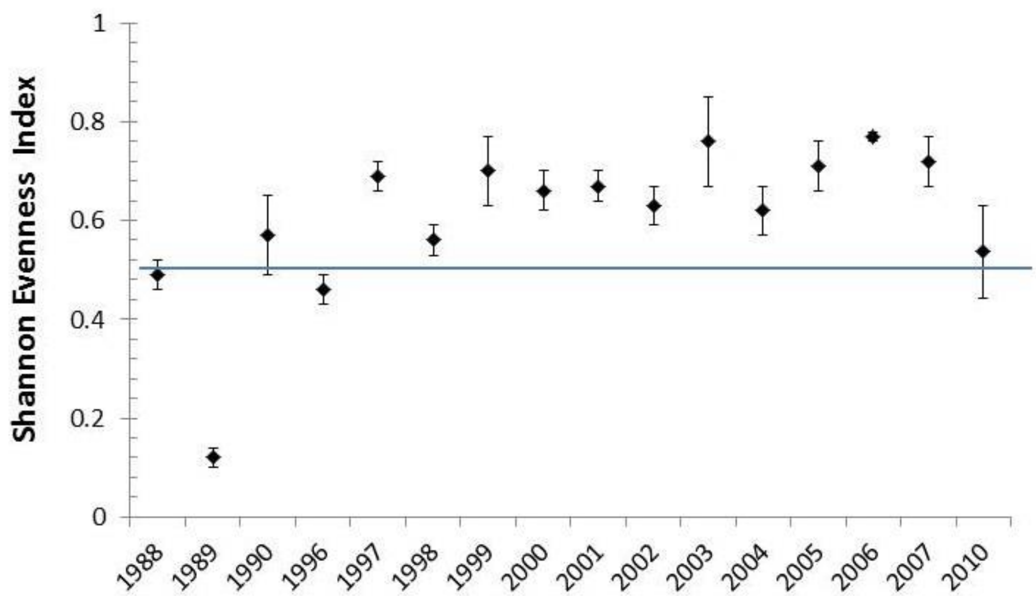

Figure 15. Control chart for Shannon Evenness Index at Wilson's Creek, Wilson's Creek National Battlefield, Missouri, 1988-2010. Points are means for a given sampling date, and the vertical bars are standard errors. The horizontal line represents the control limit corresponding to a 0.05 Type I error rate.

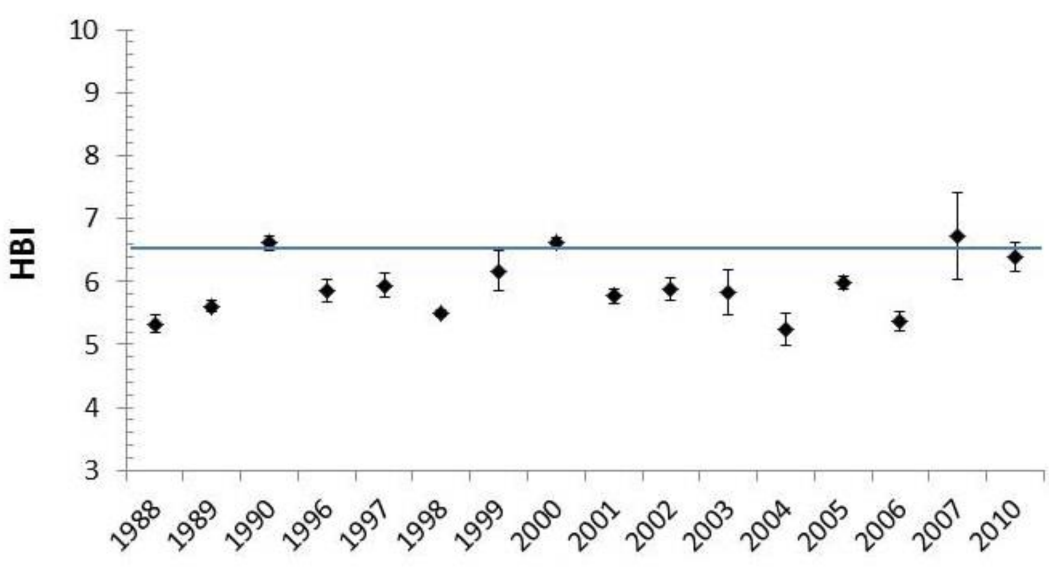

Figure 16. Control chart for Hilsenhoff Biotic Index at Wilson's Creek, Wilson's Creek National Battlefield, 1988-2010. Points are means for a given sampling date, and the vertical bars are standard errors. The horizontal line represents the control limit corresponding to a 0.05 Type I error rate. Hilsenhoff Biotic Index was based on family-level scores prior to 2005.

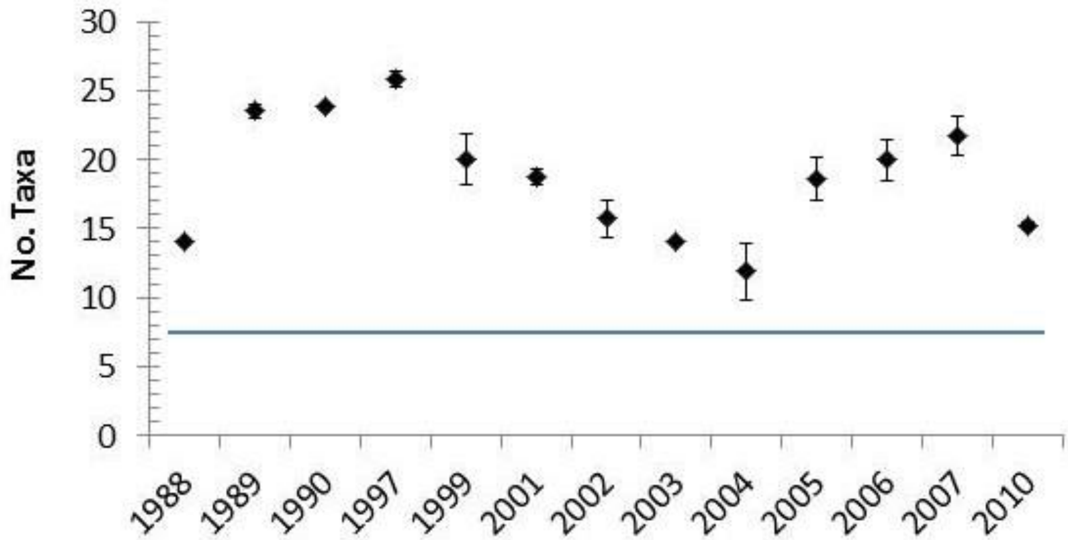

Figure 17. Control chart for taxa richness at Skegg's Branch, Wilson's Creek National Battlefield, 1988-2010. Points are means for a given sampling date, and the vertical bars are standard errors. The horizontal line represents the control limit corresponding to a 0.05 Type I error rate.

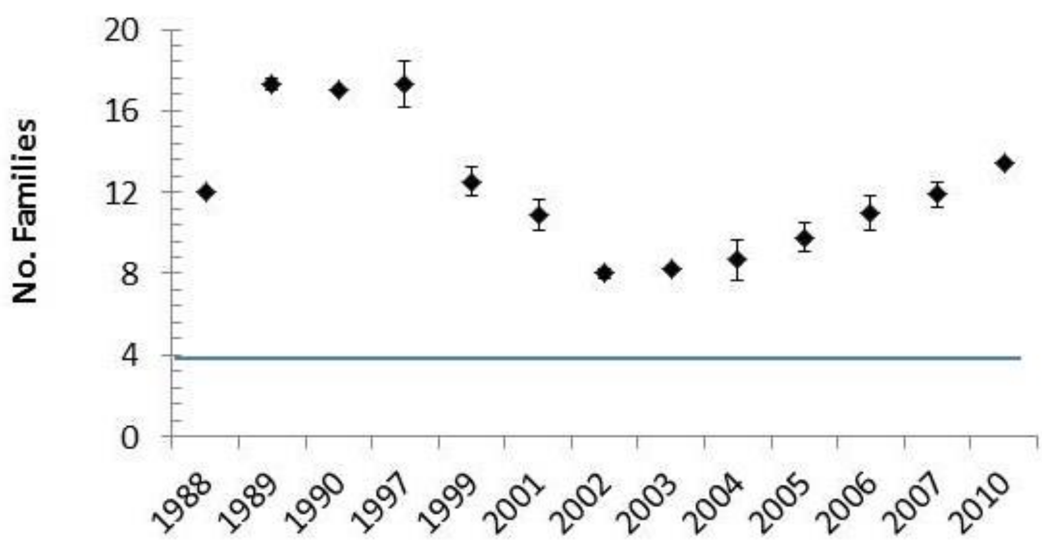

Figure 18. Control chart for family richness at Skegg's Branch, Wilson's Creek National Battlefield, 1988-2010. Points are means for a given sampling date, and the vertical bars are standard errors. The horizontal line represents the control limit corresponding to a 0.05 Type I error rate.

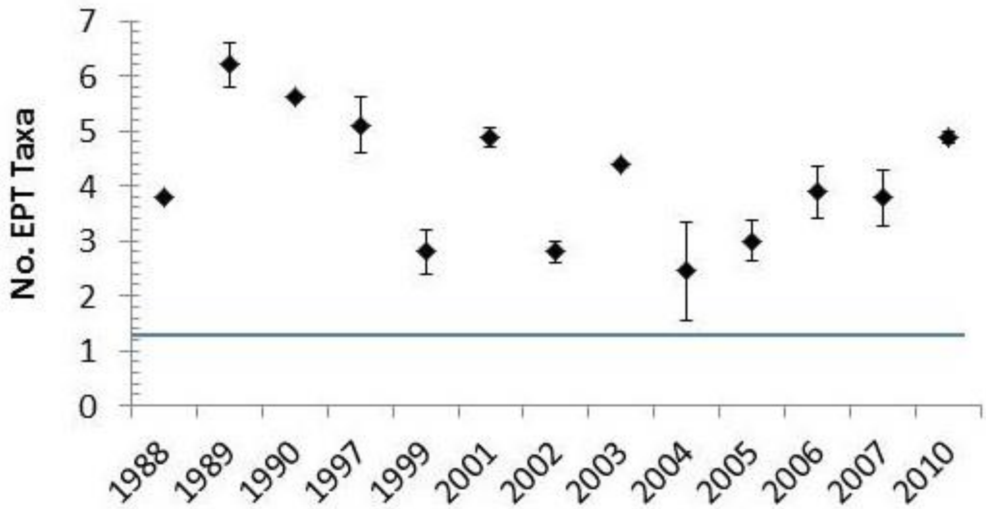

Figure 19. Control chart for Ephemeroptera, Plecoptera and Trichoptera (EPT) richness at Skegg's Branch, Wilson's Creek National Battlefield, 1988-2010. Points are means for a given sampling date, and the vertical bars are standard errors. The horizontal line represents the control limit corresponding to a 0.05 Type I error rate.

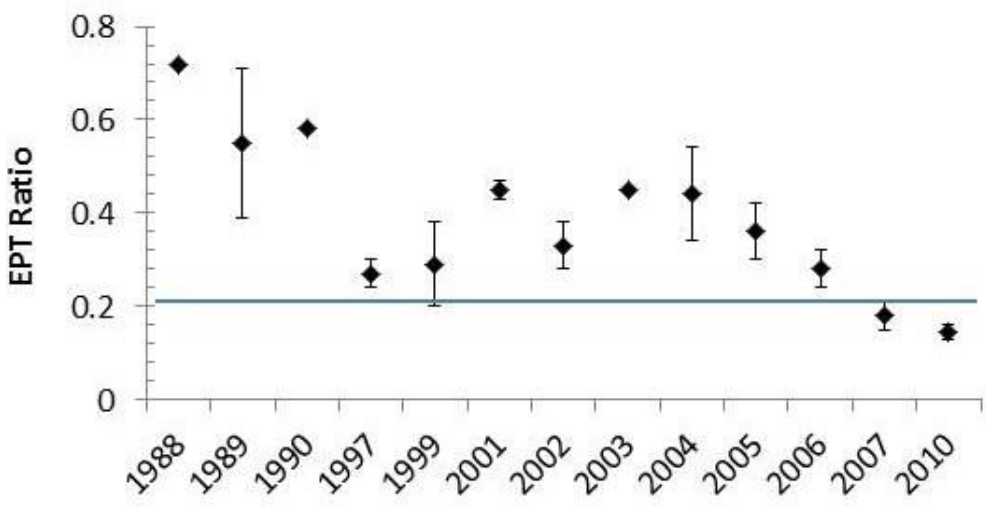

Figure 20. Control chart for EPT ratio at Skegg's Branch, Wilson's Creek National Battlefield, 1988-2010. Points are means for a given sampling date, and the vertical bars are standard errors. The horizontal line represents the control limit corresponding to a 0.05 Type I error rate.

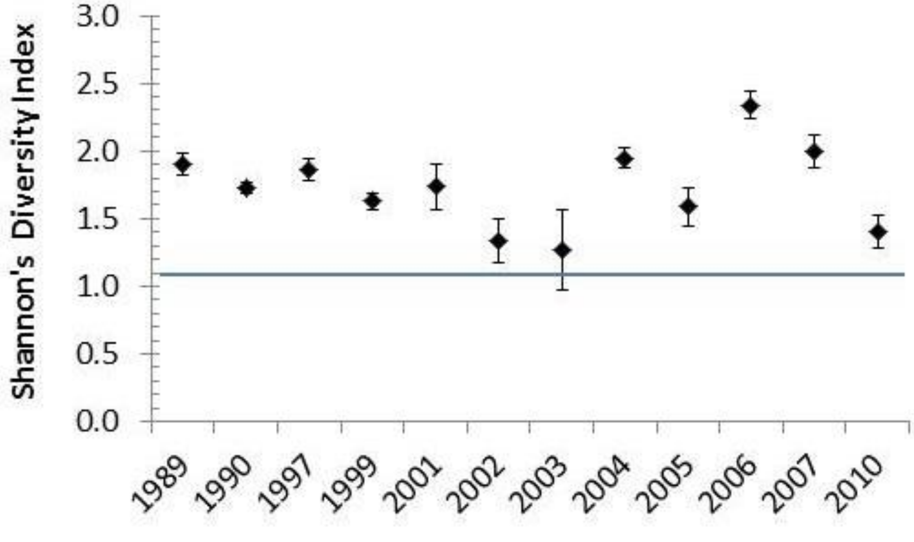

Figure 21. Control chart for Shannon Index (genera) at Skegg's Branch, Wilson's Creek National Battlefield, 1988-2010. Points are means for a given sampling date, and the vertical bars are standard errors. The horizontal line represents the control limit corresponding to a 0.05 Type I error rate.

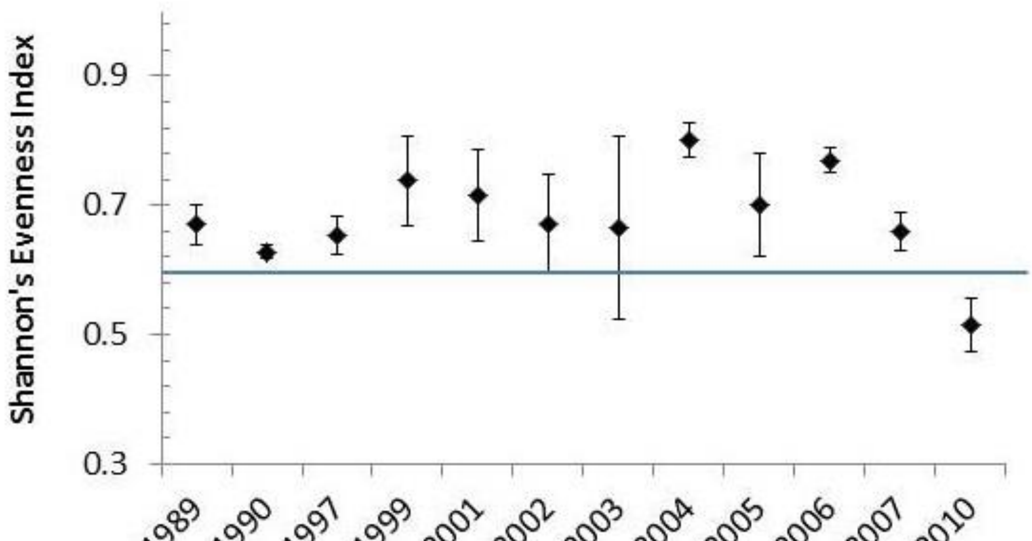

Figure 22. Control chart for Shannon Evenness Index at Skegg's Branch, Wilson's Creek National Battlefield, Missouri, 1988-2010. Points are means for a given sampling date, and the vertical bars are standard errors. The horizontal line represents the control limit corresponding to a 0.05 Type I error rate.

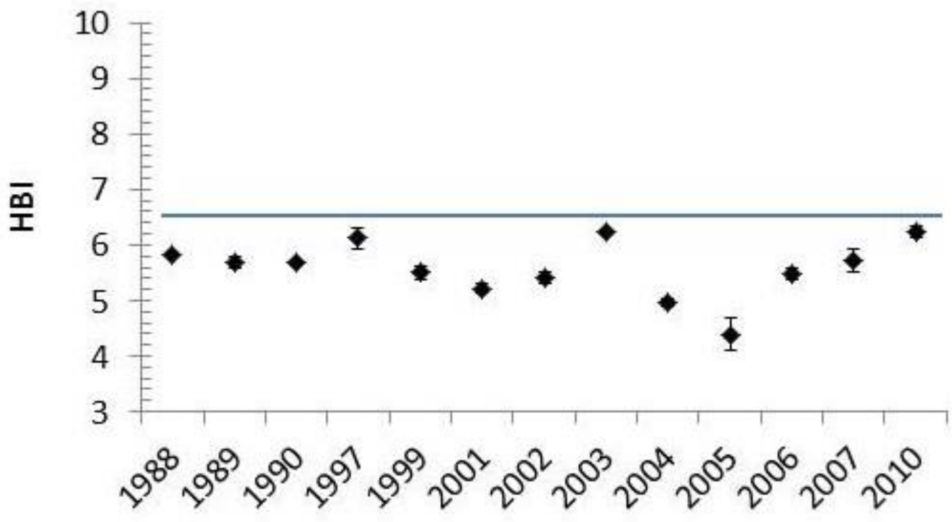

Figure 23. Control chart for Hilsenhoff's Biotic Index at Skegg's Branch, Wilson's Creek National Battlefield, Missouri, 1988-2010. Points are means for a given sampling date, and the vertical bars are standard errors. The horizontal line represents the control limit corresponding to a 0.05 Type I error rate. Hilsenhoff Biotic Index was based on family-level scores prior to 2005.

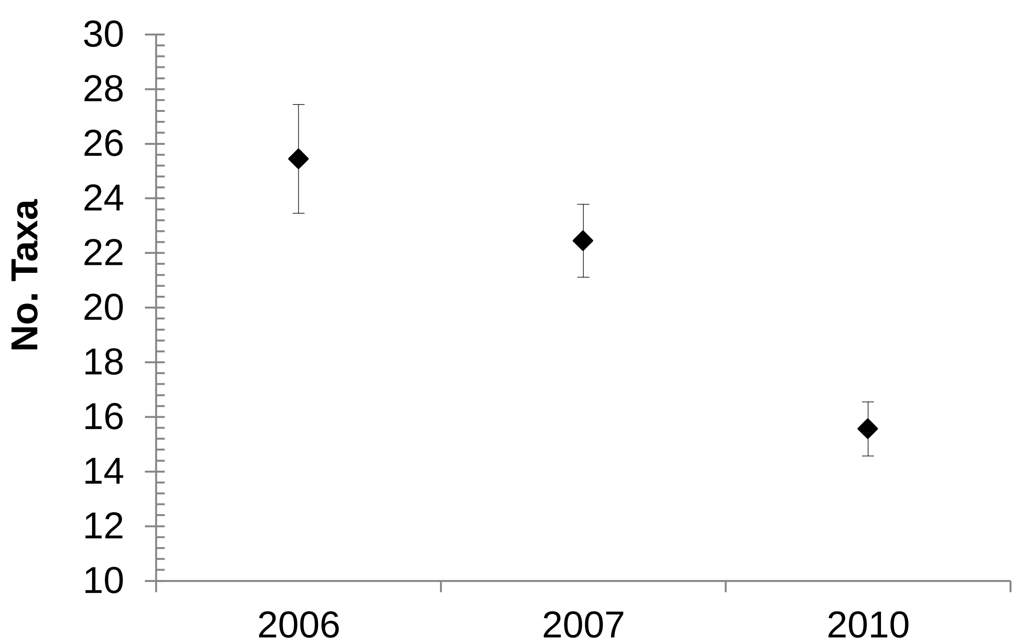

Figure 24. Taxa richness for Terrell Creek, Wilson's Creek National Battlefield, Missouri, 2006-2007, 2010. Points are means for a given sampling date, and the vertical bars are standard errors.

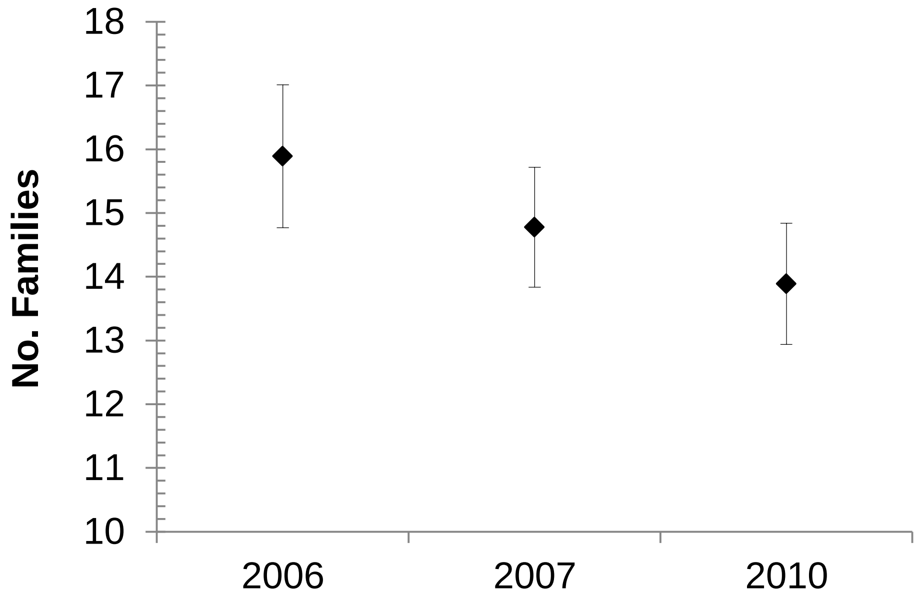

Figure 25. Family richness for Terrell Creek, Wilson's Creek National Battlefield, Missouri, 2006-2007, 2010. Points are means for a given sampling date, and the vertical bars are standard errors.

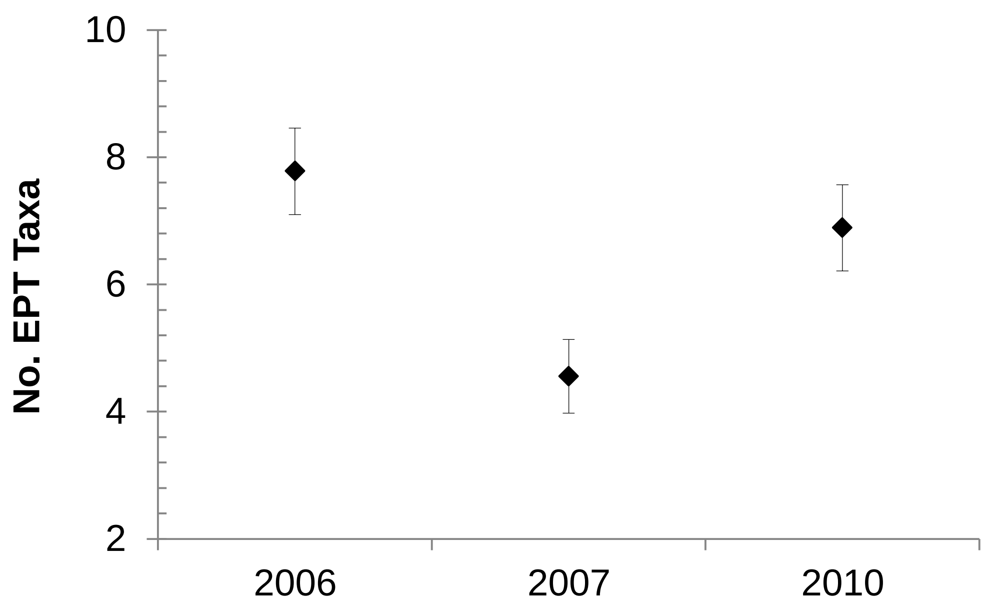

Figure 26. Ephemeroptera, Plecoptera and Trichoptera (EPT) richness for Terrell Creek, Wilson's Creek National Battlefield, Missouri, 2006-2007, 2010. Points are means for a given sampling date, and the vertical bars are standard errors.

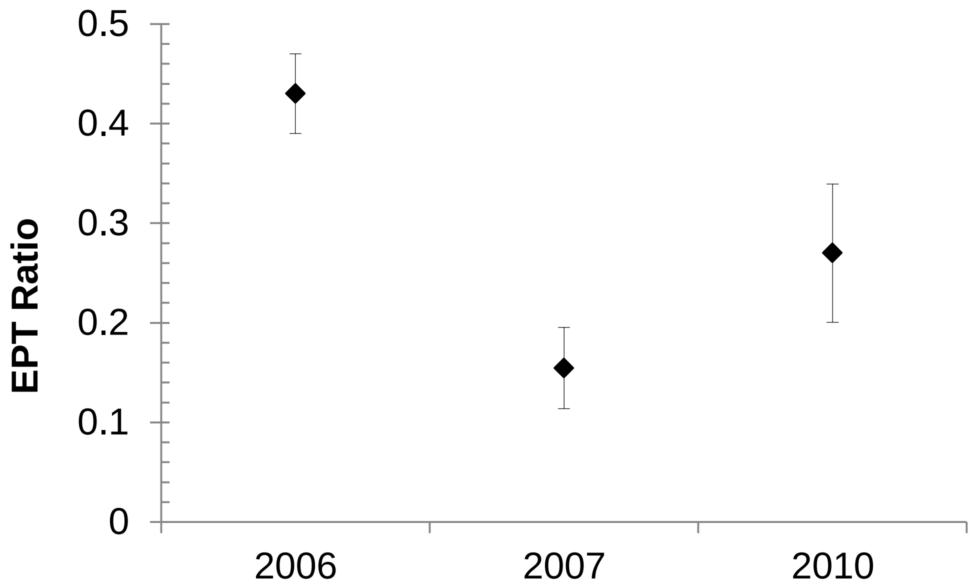

Figure 27. EPT ratio for Terrell Creek, Wilson's Creek National Battlefield, Missouri, 2006-2007, 2010. Points are means for a given sampling date, and the vertical bars are standard errors.

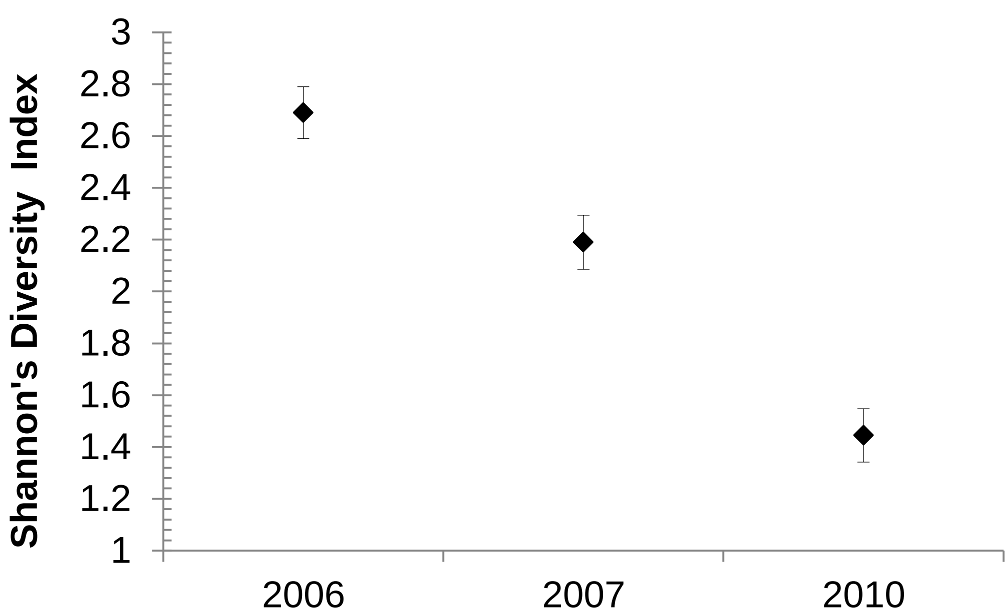

Figure 28. Shannon Index (genera) for Terrell Creek, Wilson's Creek National Battlefield, Missouri, 2006-2007, 2010. Points are means for a given sampling date, and the vertical bars are standard errors.

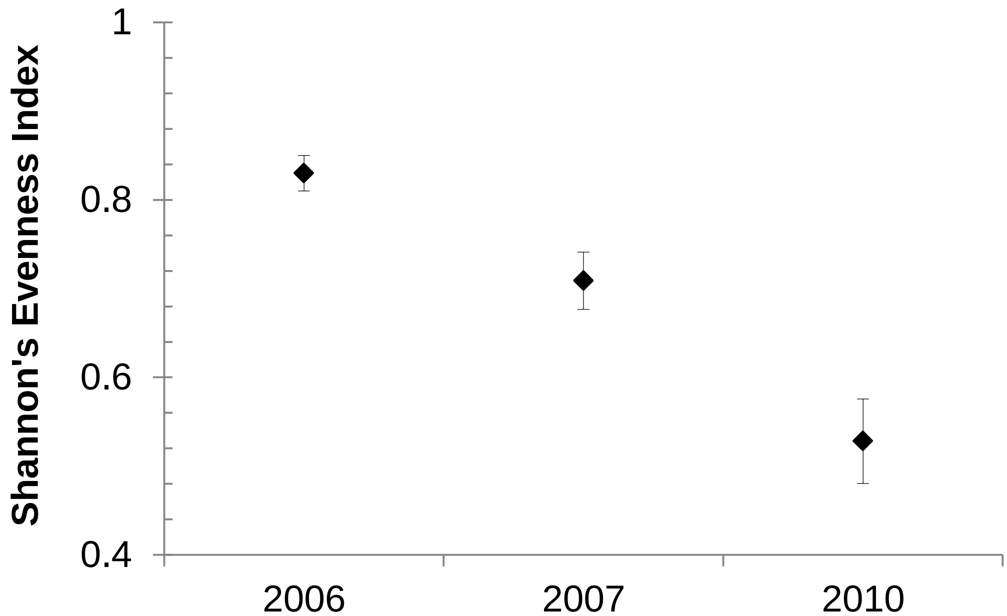

Figure 29. Shannon Evenness Index for Terrell Creek, Wilson's Creek National Battlefield, Missouri, 2006-2007, 2010. Points are means for a given sampling date, and the vertical bars are standard errors.

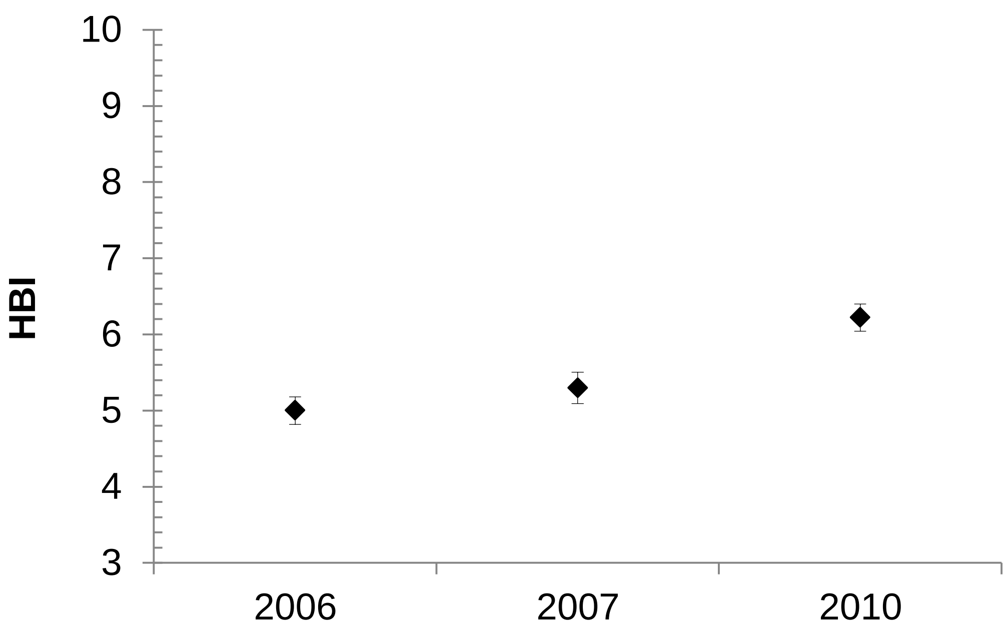

Figure 30. Hilsenhoff's Biotic Index for Terrell Creek, Wilson's Creek National Battlefield, Missouri, 2006-2007, 2010. Points are means for a given sampling date, and the vertical bars are standard errors.

Table 6. Mann-Kendall trend statistic results for invertebrate metrics for Wilson's Creek and Skegg's Branch, Wilson's Creek National Battlefield, Missouri. P-values in bold are significant at $\alpha = 0.05$

Stream	Parameter	Kendall Statistic	Z	P
Wilson's Creek	Taxa richness	-22	-0.95	0.08
	Family Richness	-18	-0.77	0.44
	EPT richness	-22	-0.95	0.34
	EPT Ratio	-3	-0.09	0.93
	Shannon's diversity index	62	2.75	0.01
	Shannon's evenness index	52	2.30	0.02
	HBI	19	0.81	0.42
Skegg's Branch	Taxa richness	-16	-0.92	0.36
	Family Richness	-15	-0.86	0.39
	EPT richness	-19	-1.10	0.27
	EPT Ratio	-45	-2.69	0.01
	Shannon's diversity index	-2	-0.07	0.95
	Shannon's evenness index	0	0.00	0.00
	HBI	-8	-0.43	0.67

Table 7. SCI scores for streams at Wilson's Creek National Battlefield.

Year	Wilson's Creek	Skegg's Branch	Terrell Creek
1988	14	n/a	n/a
1989	14	20	n/a
1990	8	18	n/a
1996	16	n/a	n/a
1997	18	20	n/a
1998	16	n/a	n/a
1999	14	16	n/a
2000	12	n/a	n/a
2001	16	18	n/a
2002	16	16	n/a
2003	18	16	n/a
2004	12	16	n/a
2005	20	16	n/a
2006	16	20	20
2007	18	20	20
2010	14	18	18
16-20 not impaired, 10-14 impaired, 4-8 very impaired			

Discussion

The invertebrate metrics presented in this report are generally similar to those observed for other regional streams (Jones *et. al.* 1981, MacFarlane 1983, Harris *et al*. 1991, 1999, Whiles *et al*. 2000, Hall *et al*. 2003, Sarver *et al*. 2002, Zelt and Frankforter 2003, Kosnicki and Sites 2007, Poulton *et al*. 2007, Hutchens *et al*. 2009). Control charts showed that invertebrate metrics generally did not exceed their respective control limits indicating the data are within the expected range of variation. Stream invertebrate communities are notoriously variable temporally and spatially with variation being influenced by a number of factors, including life history, water chemistry, precipitation events, and changes in physical habitat. The range of variation in benthic metrics reported here is well within the expected natural range of variation (Jones *et al*. 1981, Kosnicki and Sites 2007, Poulton *et al*. 2007). However, EPT richness and the Hilsenhoff Biotic Index (HBI) for Wilson's Creek were lower and higher, respectively, than expected in comparison to other regional stream, indicating potential problems with water quality in that stream. Because Wilson's Creek was already impaired before monitoring began in 1988, control charts and Mann-Kendall tests will only tell us if the stream is getting better or worse. Only the SCI (which is based on a reference stream) can tell us if this stream is absolutely impaired. Indeed, the SCI shows that Wilson's Creek was impaired in seven of the years it was sampled. An SCI score for a given year is strongly influenced by the water quality and flow conditions that precede sampling. Thus, the variability seen in SCI scores for Wilson's Creek likely reflects the highly variable physical and chemical conditions occurring in this urban stream.

The extant condition of the respective invertebrate communities of Skegg's Branch and Terrell Creek indicate they are not impaired. In comparison to both Wilson's Creek and Skegg's Branch, Terrell Creek had higher taxa richness, EPT richness and diversity. In turn the SCI scores for these streams indicate they are not impaired. Some variation in the invertebrate community was observed among sampling years at Terrell Creek, but differences in metric values among years do not necessarily reflect biological differences in benthic community structure. The higher richness and diversity values observed for Terrell Creek may be due to this stream receiving a substantial portion of its base flow from springs compared to the other streams. Although the SCI showed that Skegg's Branch was not impaired in any year sampled, the EPT ratios in Skegg's Branch have decreased during the past few years and this metric exceeded the control limit in 2007 and 2010. Trend analysis for this metric also showed a significant decline across years in Skegg's Branch. Because the EPT ratio is the ratio of largely intolerant Ephemeroptera, Plecoptera, and Trichoptera to largely tolerant Chironomidae, decreasing values for this metric indicate that pollution tolerant Chironomidae comprise an increasingly larger portion of the benthic community than expected. Increases in sediments and contaminants in runoff into Skegg's Branch associated with recent development in Republic, Missouri may be starting to depress the aquatic invertebrate fauna of this stream. Housing developments in the city of Republic are located within the drainage basin of Skegg's Branch and may contribute to point source and non-point source pollution. Increasing impervious surfaces in and around housing developments increases contaminated runoff and alters the flow dynamics of Skegg's Branch.

Poor water quality conditions and habitat degradation in Wilson's Creek are well-documented (Black 1997, Richards and Johnson 2002). The State of Missouri presently lists 29 km of Wilson's Creek as water-quality impaired under the U.S. Clean Water Act section 303(d) because of high levels of fecal coliform bacteria (Missouri Department of Natural Resources

2009; http://www.dnr.mo.gov/ENV/wpp/waterquality/303d/2009) and this impairment has contributed to the biological impoverishment of this system (Missouri Department of Natural Resources 2007, 2009). The state attributes this toxicity to non-point source pollution from urban areas and considers Wilson's Creek a high priority for development of a Total Maximum Daily Load (TDML), as required by the Clean Water Act. Additionally, the Southwest Wastewater Treatment Plant (City of Springfield, Missouri) provides most of the baseflow for Wilson's Creek. Although upgrades and improvements to the wastewater treatment plant have improved the water quality of Wilson's Creek, those improvements are insufficient to counter the prevailing urbanized conditions in the watershed. Although Wilson's Creek is impaired, the invertebrate data collected from 2005-2010 generally indicate that stream integrity has not diminished beyond that reported in earlier studies (Harris *et al*. 1999, Peitz and Cribbs 2005, Bowles 2010).

There are few available options to park management for mitigating water quality impairment of streams that flow through, but originate outside WICR because impacts to water quality originate upstream of the park boundaries. Indeed the impacts of urbanization often are so pervasive that mitigation strategies are rarely effective (Booth 2005, Bernhardt *et al*. 2005, Paul *et al*. 2009). The excellent quality associated with Terrell Creek suggests that park management actions tend to ensure stable conditions within small watersheds. Designing riparian buffer zones, stormwater management systems, and other features specifically protecting aquatic resources will serve to provide the maximum benefit to already impaired or degraded streams as well.

Maintaining and widening of riparian buffer zones along these streams in the park will aid in protecting aquatic life as well as in-stream habitat from local chemical runoff and sedimentation. Restoring native grasses to areas where they occurred historically, and maintaining native trees and shrubs on stream banks serves to stabilize riparian buffers. Properly functioning buffer zones reduce bank erosion by reducing stream velocity and the amount of water entering the streams. A reduction in impervious surfaces and the use of pervious sidewalks, trails and parking lots within the park also may help to stabilize the riparian zone and in-stream habitat. The long history and continuing efforts of aquatic invertebrate monitoring at WICR provides a sound tool to recognize both deterioration and chronic decline of water quality. Continued sampling on Terrell Creek will provide an interesting comparison with those creeks that originate beyond Wilson's Creek National Battlefield's management control.

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The NPS has organized its parks with significant natural resources into 32 networks linked by geography and shared natural resource characteristics. HTLN is composed of 15 National Park Service (NPS) units in eight Midwestern states. These parks contain a wide variety of natural and cultural resources including sites focused on commemorating civil war battlefields, Native American heritage, westward expansion, and our U.S. Presidents. The Network is charged with creating inventories of its species and natural features as well as monitoring trends and issues in order to make sound management decisions. Critical inventories help park managers understand the natural resources in their care while monitoring programs help them understand meaningful change in natural systems and to respond accordingly. The Heartland Network helps to link natural and cultural resources by protecting the habitat of our history.

The I&M program bridges the gap between science and management with a third of its efforts aimed at making information accessible. Each network of parks, such as Heartland, has its own multi-disciplinary team of scientists, support personnel, and seasonal field technicians whose system of online databases and reports make information and research results available to all. Greater efficiency is achieved through shared staff and funding as these core groups of professionals augment work done by individual park staff. Through this type of integration and partnership, network parks are able to accomplish more than a single park could on its own.

The mission of the Heartland Network is to collaboratively develop and conduct scientifically credible inventories and long-term monitoring of park "vital signs" and to distribute this information for use by park staff, partners, and the public, thus enhancing understanding which leads to sound decision making in the preservation of natural resources and cultural history held in trust by the National Park Service.

www.nature.nps.gov/im/units/htln/

Heartland Network
Natural Resource Monitoring

NPS 410/120911, June 2013

National Park Service
U.S. Department of the Interior

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