National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Fish Community Monitoring at Wilson's Creek National Battlefield

2006–2016 Status Report

Natural Resource Data Series NPS/HTLN/NRDS—2018/1155

ON THE COVER
Wilson's Creek at Wilson's Creek National Battlefield
Photography by NPS/Heartland Inventory and Monitoring Network

Fish Community Monitoring at Wilson's Creek National Battlefield

2006–2016 Status Report

Natural Resource Data Series NPS/HTLN/NRDS—2018/1155

Hope R. Dodd,[1] Jeffrey M. Williams[2]

[1]National Park Service
Heartland I&M Network
Wilson's Creek National Battlefield
6424 W. Farm Road 182
Republic, MO 65738

[2]Missouri State University
Biology Department
901 S. National Avenue
Sporingfield, MO 65897

Editing and Design by
Tani Hubbard

National Park Service &
Northern Rockies Conservation Cooperative
12661 E. Broadway Blvd.
Tucson, AZ 85748

March 2018

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

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Data Series is intended for the timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available from Heartland Inventory and Monitoring Network website, and the Natural Resource Publications Management website.

Please cite this publication as:

Dodd, H. R., and J. M. Williams. 2018. Fish community monitoring at Wilson's Creek National Battlefield: 2006–2016 status report. Natural Resource Data Series NPS/HTLN/NRDS—2018/1155. National Park Service, Fort Collins, Colorado.

NPS 410/144025, March 2018

Contents

Figures

Page

Tables

Page

Abstract

In 2006, fish community, water quality, and physical habitat monitoring began in Wilson's Creek National Battlefield at Wilson's Creek, Skegg's Branch (also known as Schuyler Creek), and Terrell Creek. The purpose of this monitoring is to determine the status and long-term trends in fish community composition and to correlate this community data to water quality and habitat conditions. Prior to initiating our long-term monitoring, previous one-time studies of fish communities in Wilson's Creek assessed the water quality and biotic integrity of this urban stream (Donegan 1984; Foster 1988; Foster 1989; Petersen and Justus 2005), but little is known about the fish communities or water quality conditions of Skegg's Branch and Terrell Creek.

Based on our data, the fish communities within Wilson's Creek National Battlefield were found to be diverse. Although water quality has been an issue due to wastewater effluent and runoff from urban areas, Wilson's Creek maintains high species richness, number of intolerant species, and diversity, resulting in a high biotic integrity rating. However, fish assemblages in Wilson's Creek did show a large number of anomalies (disease, eroded fins, lesions, tumors, and blackspot parasite) compared to communities in the other two streams sampled. The high quality rating for the fish community in Wilson's Creek can be misleading because anthropogenic disturbances as well as abiotic factors may explain these findings. Fish communities at Skegg's Branch and Terrell Creek had a large proportion of darter, sculpin, and madtom species (sensitive to siltation and poor water quality), suggesting that these two smaller tributaries of Wilson's Creek are in good condition.

Acknowledgments

We would like to thank David Bowles, Tyler Cribbs and Jan Hinsey from Heartland I&M Network and the many technicians and interns who assisted with field work. Also, thanks to Jen Haack (Heartland I&M Network) for GPS/GIS assistance. We would like to acknowledge the staff at Wilson's Creek National Battlefield for their support.

Introduction

Wilson's Creek National Battlefield contains portions of three perennial streams: Wilson's Creek, Skegg's Branch (also named Schuyler Creek), and Terrell Creek (Figure 1). All three streams are influenced by springs, and have varying degrees of urban and agricultural land use within their watersheds. Wilson's Creek is an urban stream; its watershed drains the city of Springfield, Missouri. Roundtree and Radar springs along with effluent from a wastewater treatment facility enter Wilson's Creek upstream of the park (Figure 2).

Historically, both point-source and non-point source pollution in Wilson's Creek and its tributaries created low dissolved oxygen conditions (Emmett et al. 1978) unsuitable for aquatic biota. Improvements to the wastewater treatment facility improved water quality (Consoer, Townsend and Associates and Hydroscience, Inc. 1980), resulting in a moderately diverse fish community (Donegan 1984; Foster 1988; Foster 1989). However, due to non-point pollution from urban and rural sources in the Wilson's Creek watershed, this stream has been listed on the Missouri Department of Natural Resources 303(d) list of impaired waters for *Escherichia coli* and polycyclic aromatic hydrocarbons (PAH) contamination and is considered impaired for whole body contact recreation and aquatic life (MO DNR 2018).

The Skegg's Branch has largely rural land use within its watershed. However, its headwaters are located in the town of Republic, Missouri, which has shown increased development and population growth in the last decade. The summer base flow of Skegg's Branch is largely derived from Campground Spring located downstream of Republic, Missouri (Figure 1). Therefore, the expansion of this town may lead to declines in water quality and biotic integrity of both Campground Spring and Skegg's Branch.

Land use in the Terrell Creek watershed is predominately agricultural (hay and cattle), although this watershed also drains a golf course and a quarry. Double Spring, located within the park, contributes most of Terrell Creek's base flow during summer months (Figure 1). Upstream of the spring, Terrell Creek becomes intermittent during years of low precipitation.

Previous studies of fish communities in Wilson's Creek have been used to assess the water quality and biotic integrity of this stream (Donegan 1984; Foster 1988; Foster 1989; Peterson and Justus 2005), but little is known about the fish communities or water quality conditions of Skegg's Branch and Terrell Creek. Fish communities are an important component of Ozark stream systems. Changes or shifts in stream habitat complexity and water quality often determine the composition of biotic communities (Lazorchak et al. 1998). Trends in fish community composition and the associated habitat conditions serve as strong indicators of 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). Moreover, the intrinsic value of fish to the public as environmental indicators and as recreational opportunities makes the status of fish diversity a valuable interpretive topic for park visitors and an informative tool for protecting the aquatic resources at Wilson's Creek National Battlefield.

Objectives of fish community monitoring at Wilson's Creek National Battlefield are

1. to determine the status and long term trends in fish richness (number of fish species collected), diversity, abundance (total number of fish collected per sampling effort), and community composition (percent abundance of each species), and

2. to correlate the long-term community data to overall water quality and habitat condition.

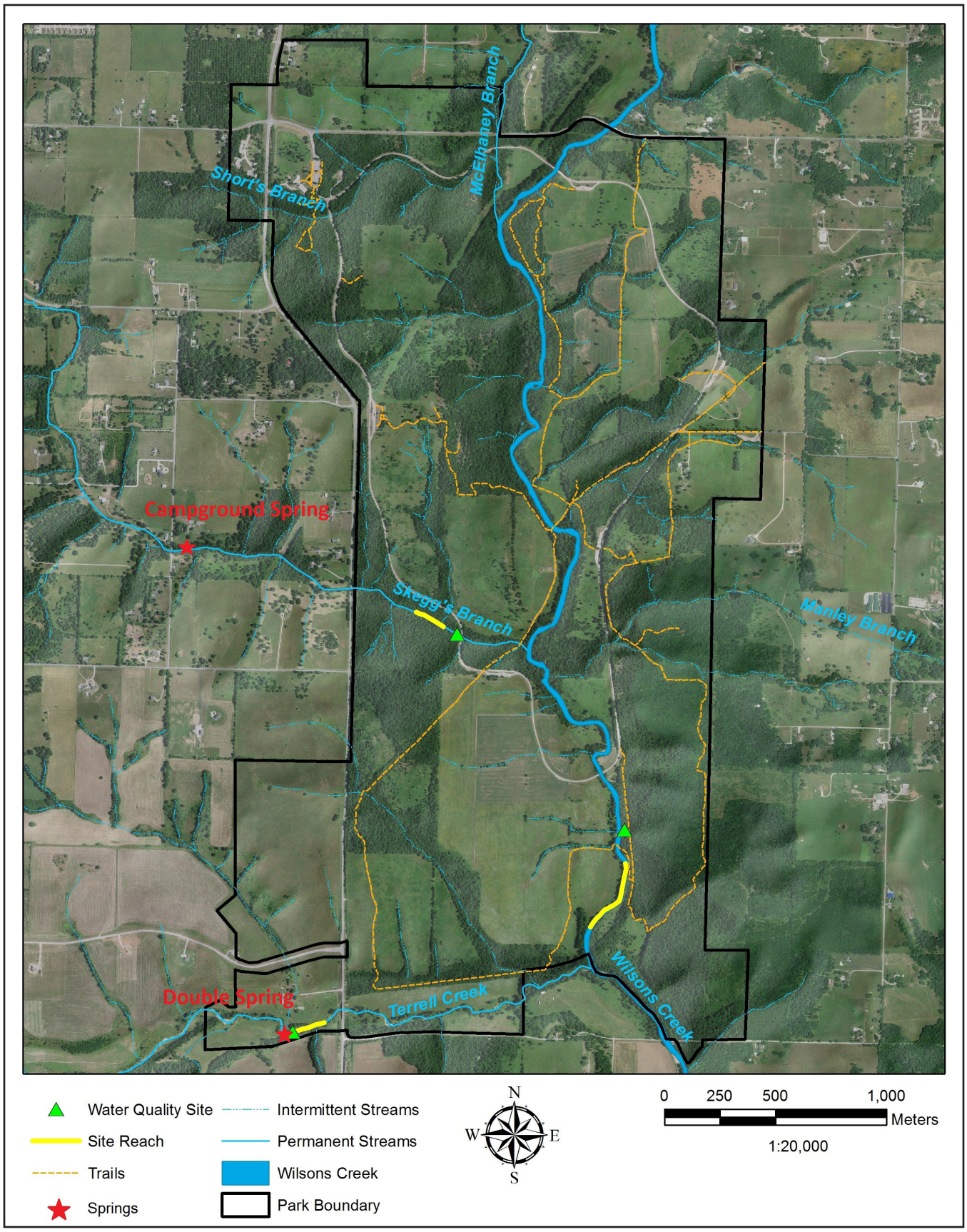

Figure 1. Location of fish and water quality monitoring sites on Wilson's Creek, Skegg's Branch, and Terrell Creek at Wilson's Creek National Battlefield.

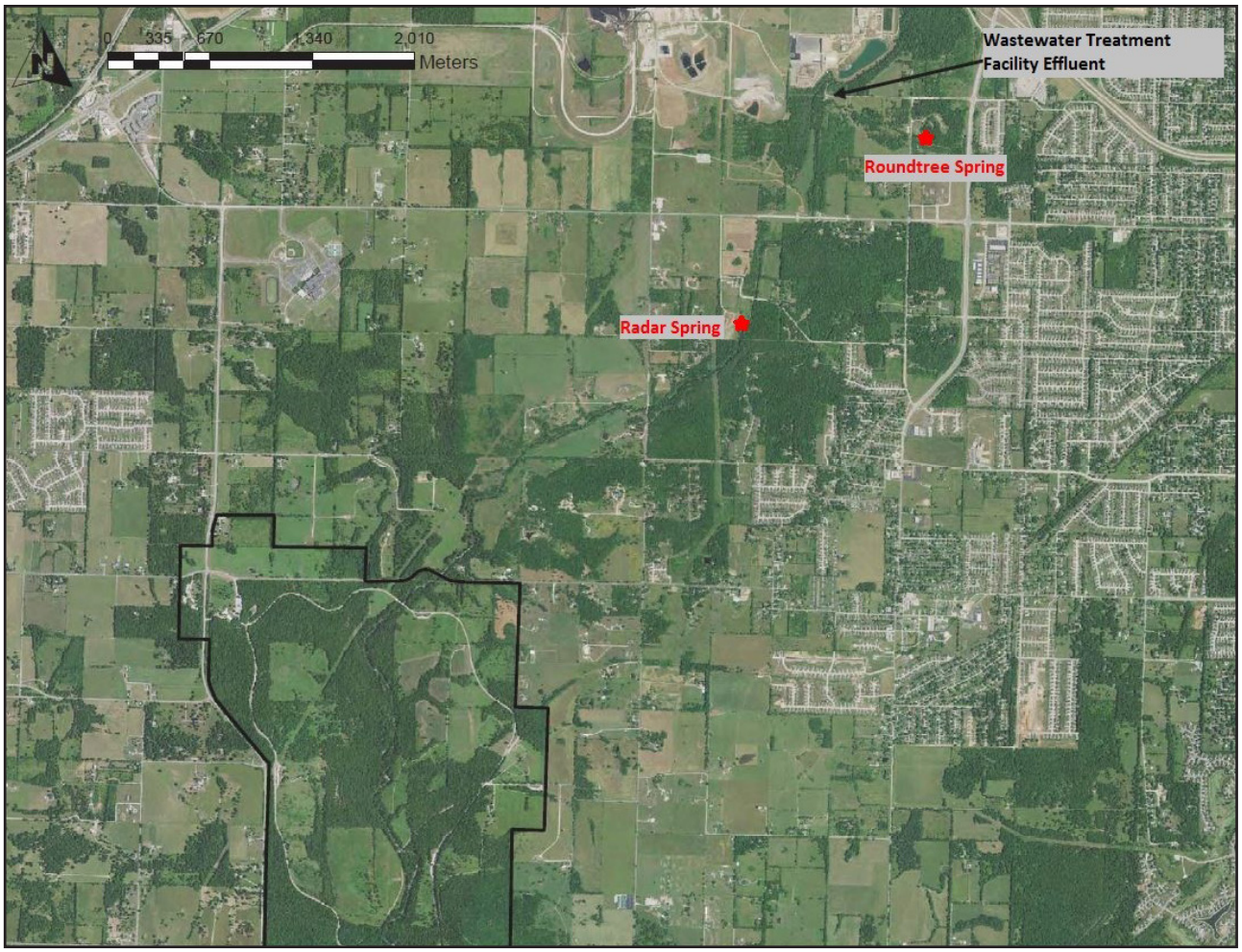

Figure 2. Location of Roundtree and Radar springs and the wastewater treatment facility effluent within the Wilson's Creek watershed.

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 Site Selection

Portions of three wadeable streams run through the park: Wilson's Creek (~ 5.3 km), Skegg's Branch (~ 0.9 km), and Terrell Creek (~ 1.7 km). Sampling reaches were selected at the downstream end of each stream either near the park boundary (for Wilson's Creek) or upstream of the confluence with another stream, Skegg's Branch (Figure 1). Terrell Creek, which is also a tributary to Wilson's Creek, was sampled upstream of Highway ZZ bridge to avoid the localized influence of this structure on channel morphology and fish habitat. Reach length was defined as 20 times the mean wetted stream width (MWSW) with a minimum of 150 m, allowing inclusion of representative channel units (riffle, run, and pool habitats) located within the stream (Moulton et al. 2002).

Fish Collection

Fish communities were sampled in June of 2006 and May of 2007, 2010, 2013, and 2016. Fish were collected throughout the reach using a single pass with a pulsed DC backpack electrofishing unit in Skegg's Branch and Terrell Creek, and a DC tow barge unit in Wilson's Creek. During sampling, fish were collected with nets and placed in aerated buckets. All fish were identified to species, if practical, and counted. A subsample of 30 individuals per species were measured and weighed, and any anomalies (deformities, eroded fins, lesions, tumors, and blackspot parasite) were recorded. Fish that were too small or that were difficult to identify in the field were preserved for later identification in the laboratory. All other fish were released back into the sample reach.

Habitat and Water Quality

Physical habitat and water quality data were collected in conjunction with fish sampling. An 11-transect method was used to collect data on general channel morphology, fish cover, and bank conditions throughout the entire reach. In-stream habitat (depth, velocity, substrate, etc.) and fish cover (presence of woody debris, filamentous algae, boulders, hydrophytes, etc.) were assessed at three points per transect (see Dodd et al. 2008 for a list of all habitat parameters collected). Fish cover along the banks (undercut banks, overhanging terrestrial vegetation, etc.) and bank/riparian stability were assessed on the left and right banks at each transect. Hourly water quality data (temperature, dissolved oxygen, pH, specific conductance, and turbidity) were collected using calibrated loggers deployed near the reach (Figure 1) for at least 24 hours.

Data Analysis

Biological metrics were calculated for each reach and each year sampled. These metrics reflect fish community diversity (species richness and Simpson's Diversity Index [SI]), abundance (catch per unit effort), composition (number and percent composition of specific taxa), and overall stream integrity (Index of Biotic Integrity [IBI]). Community diversity was assessed using Simpson's Index, which gives the probability that two individuals picked at random from the site are the same species. Therefore, Simpson's Index decreases with increasing diversity. Because of this inverse relationship with diversity, we used 1-SI in the analyses. A 1-SI value of 1 indicates a completely diverse community and a value of 0 indicates no diversity. For composition, the number and percent composition of sucker (Catastomidae), sunfish (Centrarchidae; excluding bluegill [*Lepomis macrochiru*]) and green sunfish [*L. cyanellus*]), and combined darter/sculpin/madtom species (*Etheostoma* and *Percina*/*Cottus*/*Noturus*) were calculated because these metrics are typically used in several IBI calculations (Karr 1981; Dauwalter et al. 2003; Smogor 2005) and these species demonstrate sensitivity to human disturbance.

The IBI developed by Dauwalter et al. (2003) was used to assess overall stream health and includes seven metrics: (1) percent of individuals as algivorous/herbivorous, invertivorous, and piscivorous; (2) percent with an anomaly (disease, eroded fins, lesions, or tumors) or blackspot parasite; (3) percent as green sunfish, bluegill, yellow bullhead (*Ameiurus natalis*), or channel catfish (*Ictalurus punctatus*); (4) percent invertivores; (5) percent top carnivores;

(6) number of darter/sculpin/madtom species; and (7) number of lithophilic (sand/gravel) spawning species. Each of the seven raw metric values was scored from 0 to 10 based on upper and lower thresholds developed for the Ozarks region. The metric scores were added to calculate an IBI score that ranges from 0 to 100. Based on this IBI score, the overall integrity of the stream is classified from very poor to excellent: very poor = 0-20; poor = 20-40; fair = 40-60; good = 60-80; excellent (reference condition) = 80-100. Additional details for calculating biological metrics used in this report can be found in Dodd et al. (2008) and Dauwalter et al. (2003).

Physical habitat and water quality data were summarized using averages with standard errors (SE) or percentages, where appropriate. Physical habitat data were summarized as in-stream habitat, fish cover, and bank stability. Analysis of in-stream substrate data used the Wentworth code (Wentworth 1922) for particle sizes (see Dodd et al. 2008 for the code categories and size ranges). Stream bank stability was assessed using categories of bank angle, percent vegetation, height, and substrate type. Water quality data were summarized using averages and standard errors.

Results

Fish Community

Thirty-four species were collected among all sites and years sampled. Wilson's Creek had the highest number of species in each year (Figure 3) with an average richness of 25.2 species (n = 5 years), but was more variable among years (standard deviation = 1.6). Skegg's Branch had the lowest species richness in all years with an average of 7.8 species (n = 5 years) and was the least variable among years (standard deviation = 0.8). Fish communities were most diverse at Wilson's Creek each year (average = 0.79, n = 5 years; Figure 4) with lower variability in diversity across years (standard deviation = 0.1) compared to Skegg's Branch (average = 0.54, standard deviation = 0.2) and Terrell Creek (average = 0.5, standard deviation =0.2).

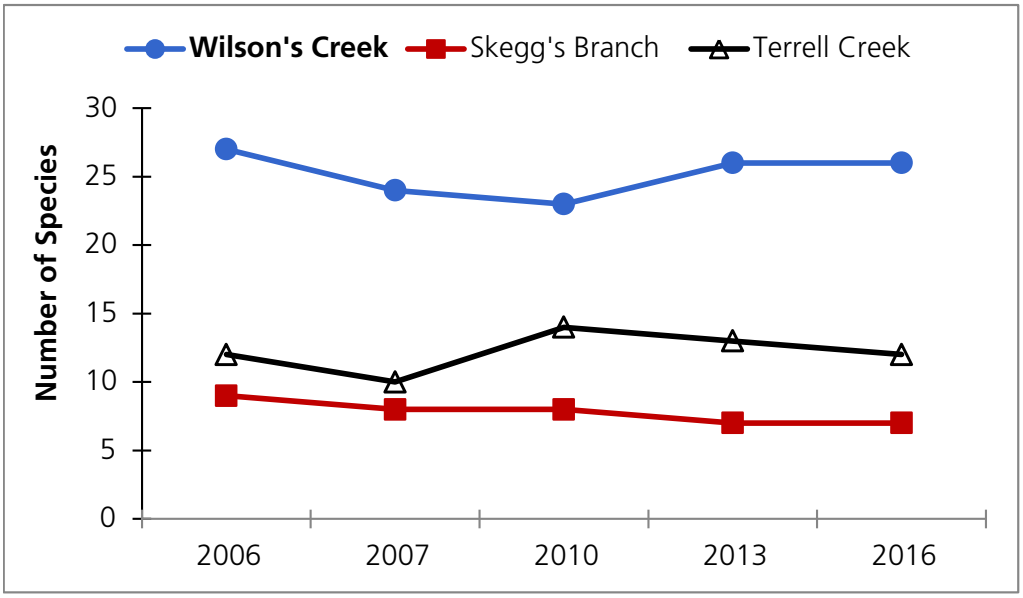

Figure 3. Species richness for reaches sampled at Wilson's Creek National Battlefield.

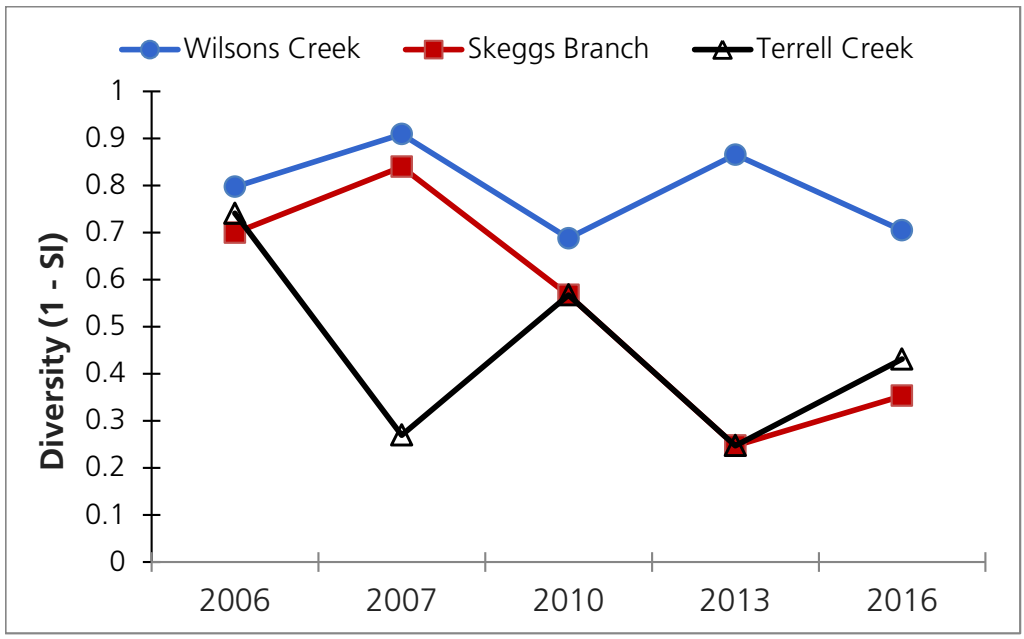

Figure 4. Community diversity (1 - Simpson's Index) for reaches sampled at Wilson's Creek National Battlefield.

Low diversity at Skegg's Branch in 2013 and 2016 and at Terrell Creek in 2007, 2013, and 2016 was due to high composition (>75%) of knobfin sculpin (*Cottus immaculatus*, a new species previously known as Ozark sculpin, *C. hypselurus* prior to 2010). This species is sensitive to poor habitat and water quality. In addition to having relatively high numbers of species and relatively high diversity, Wilson's Creek also had the highest number of species intolerant to human disturbance (siltation, poor water quality, etc.), ranging from 11 to 13 species. Number of intolerant species at Terrell Creek ranged from 4 to 6 species. Skegg's Branch had 4 to 5 intolerant species present among years.

Average relative fish abundance was high at Skegg's Branch (16.2 fish/min, n = 5 years), compared to Wilson's Creek (11.0 fish/min, n = 5 years) and Terrell Creek (9.9 fish/min, n = 5 years; Figure 5). Abundance was lowest during 2007 for Wilson's Creek and lowest in 2013 for Skegg's Branch and Terrell Creek. Skegg's Branch had the highest variability in abundance across years (standard deviation = 8.2) compared to Wilson's Creek (standard deviation = 2.6) and Terrell Creek (standard deviation = 2.5). The high variability was due to a large number of stoneroller species (*Campostoma* spp.) in 2006 and knobfin sculpins in 2010 at Skegg's Branch. All three streams showed a general decrease in number of stoneroller species (species tolerant to disturbance) and an increase in the number of knobfin sculpin across years.

In general, Wilson's Creek had higher numbers of species and percent composition of sucker, sunfish (excluding the tolerant bluegill and green sunfish species) and benthic darter/sculpin/madtom species compared to its two smaller tributaries (Table 1). Skegg's Branch, the smaller of the two tributaries, had no sunfish or sucker species present. Wilson's Creek rated as having good to excellent stream integrity and had higher IBI scores and ratings than Skegg's Branch and Terrell Creek (Figure 6). Both of these tributaries rated as fair to good among years (Figure 6). Wilson's Creek had an average IBI score of 84 (excellent rating, standard deviation = 10.5) across years compared to an average score of 64 (good rating, standard deviation = 6.0) for Skegg's Branch and 59 (fair rating, standard deviation = 8.4) for Terrell Creek. Higher IBI scores for Wilson's Creek compared to the tributaries is likely due to the higher percentage of invertivores and higher numbers of darters/sculpins/madtoms species and lithophilic spawners (require clean gravel).

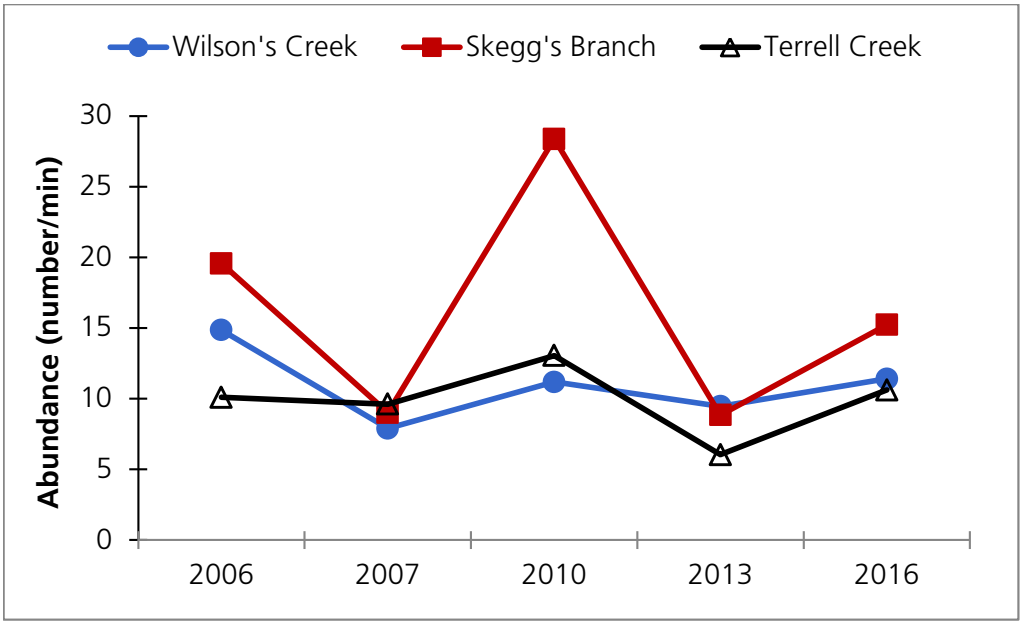

Figure 5. Fish abundance for reaches sampled at Wilson's Creek National Battlefield.

Table 1. Number of species and percent community composition of sucker, sunfish, and darter/sculpin/madtom (benthic) species at reaches sampled within Wilson's Creek National Battlefield.

Fish Species	Composition Metric	Wilson's Creek					Skegg's Branch					Terrell Creek				
		2006	2007	2010	2013	2016	2006	2007	2010	2013	2016	2006	2007	2010	2013	2016
suckers	No. of Species	2	3	3	2	2	0	0	0	0	0	1	1	2	1	0
	% Composition	1.3	1.2	7.5	0.8	4.3	0	0	0.0	0	0	2.6	0.4	0.8	0.3	0
sunfish	No. of Species*	2	3	3	3	3	0	0	0	0	0	0	0	3	1	1
	% Composition*	4.2	17.9	13.3	24.9	6.3	0	0	0.0	0	0	0	0	0.5	1.6	0.9
darter/sculpin/madtom	No. of Species	8	8	8	9	8	4	5	4	4	4	3	4	5	4	5
	% Composition	19.1	49.1	66.4	48.6	73.1	15.7	52.9	69.6	95.1	84.6	32.9	90.4	81.1	82.5	95.0

*Exclues bluegill and green sunfish (species tolerant to poor water quality)

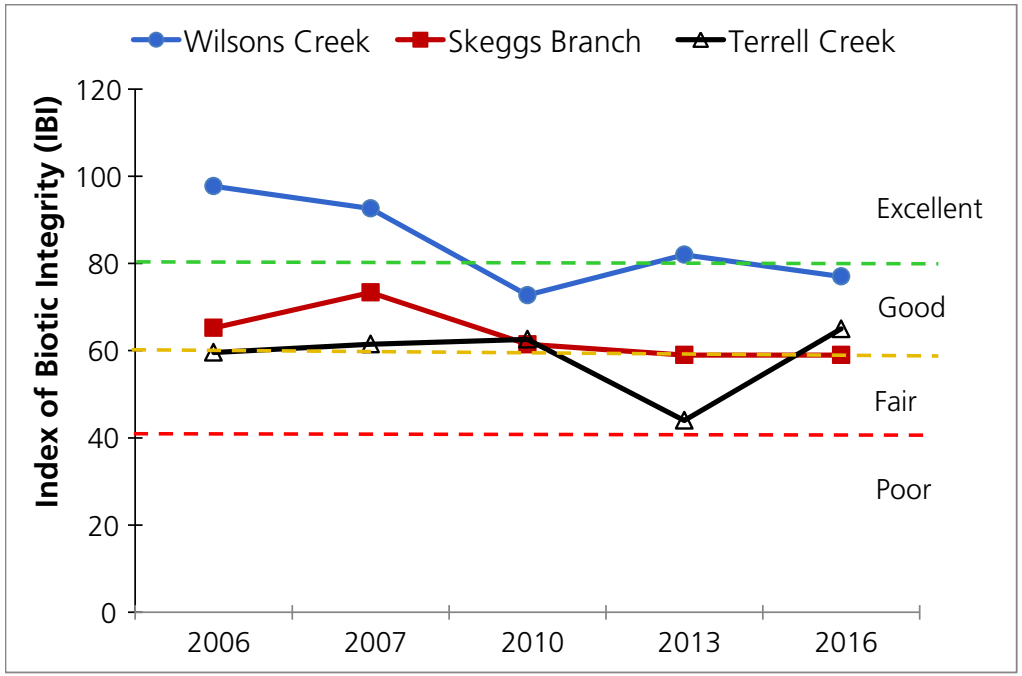

Figure 6. Index of Biotic Integrity scores and ratings for each reach sampled at Wilson's Creek National Battlefield.

Habitat and Water Quality

Wilson's Creek was wider, deeper, and had more flow than its two tributary streams (Figures 7-9). Terrell Creek showed greater variability in stream width and depth across years. Skegg's Branch was the smallest (Figures 7 and 8) but had similar average velocities as Terrell Creek (Figure 9). Substrate in Wilson's Creek and Skegg's Branch consisted of small to large pebbles (Wentworth sizes 12-14, 16-45 mm). Terrell Creek consisted of slightly smaller substrates of course gravel to small pebbles (Wentworth sizes 11-13, 11.3-32.0 mm) in 2006, 2007, and 2010, but consisted of large pebbles in 2013 and 2015.

Fish cover in the streams was primarily small woody debris, filamentous algae, and hydrophytes (aquatic plants and mosses). All three streams had a large portion of small woody debris present in each year sampled (52-67% in Wilson's Creek, 39-67% in Skegg's Branch, and 55-64% in Terrell Creek 55-64%). Wilson's Creek also had 61% of transects with filamentous algae present in 2007 and 55% with hydrophytes in 2010. Skegg's Branch had a high percentage of filamentous algae in 2007 (94%) and 2013 (100%), and hydrophytes in 2006 (67%) and 2016 (88%). The sampled area of Terrell Creek had high percentages of hydrophytes in 2006 (64%) and 2007 (58%) and filamentous algae in 2007 (79%), 2010 (79%), and 2013 (64%). The hydrophytes in Skegg's Branch and Wilson's Creek were dominated by mosses in comparison to Terrell Creek where other aquatic plants were dominant.

Banks at Wilson's Creek were higher, steeper, and less stable than those at Terrell Creek or Skegg's Branch (Table 2). Over 80% of the banks at Wilson's Creek had angles greater than 60 degrees and heights greater than 2 m during most years sampled, indicating a higher potential for bank erosion. A larger portion of banks at Terrell Creek had angles less than 60 degrees, vegetation cover greater than 80%, and bank heights less than 2 m, but did consist largely of erodible silt substrate. Skegg's Branch had a higher percentage of banks with angles greater than 60 degrees and less vegetation (larger percentage of banks with 50-80% cover) than banks in Terrell Creek. However, this stream also had a higher percent of bedrock and cobble/boulder substrate, a more stable substrate than silt.

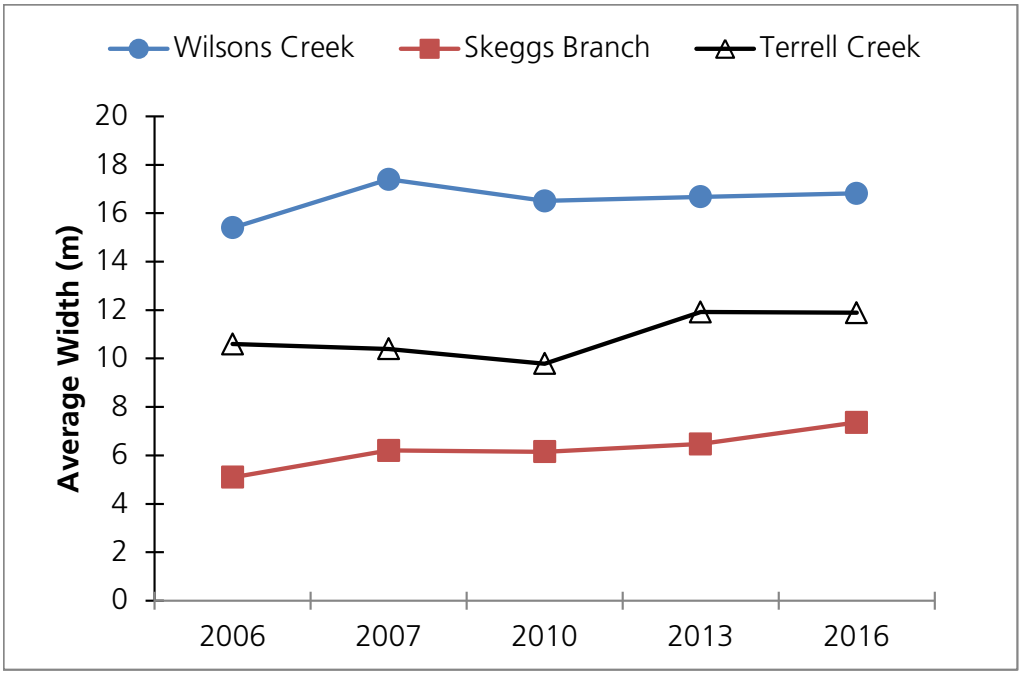

Figure 7. Average width for reaches sampled at Wilson's Creek National Battlefield.

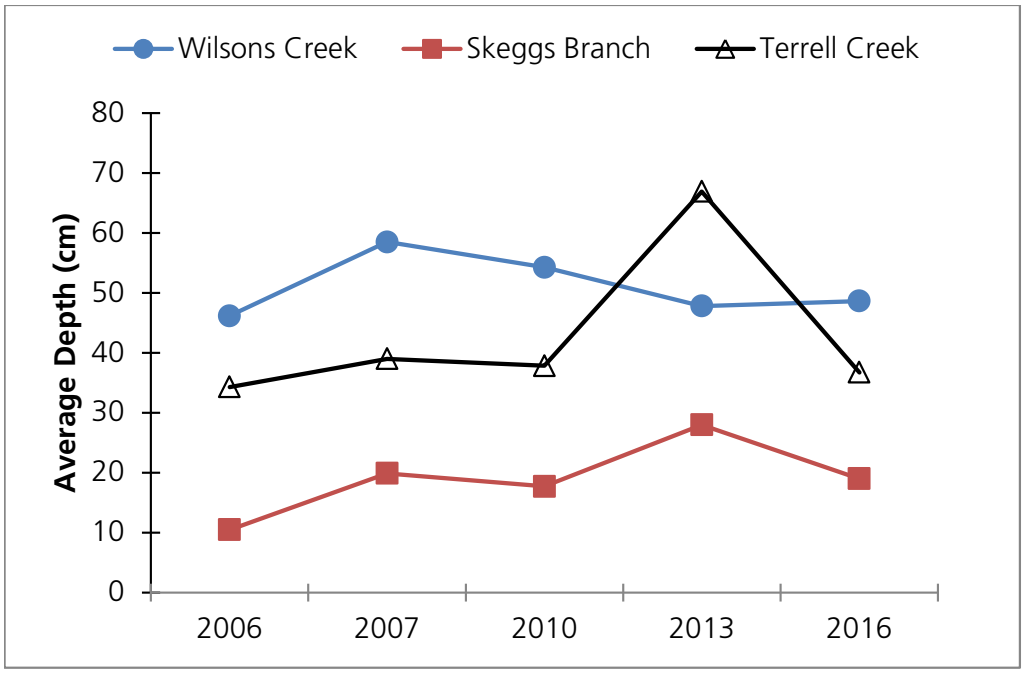

Figure 8. Depth for reaches sampled at Wilson's Creek National Battlefield.

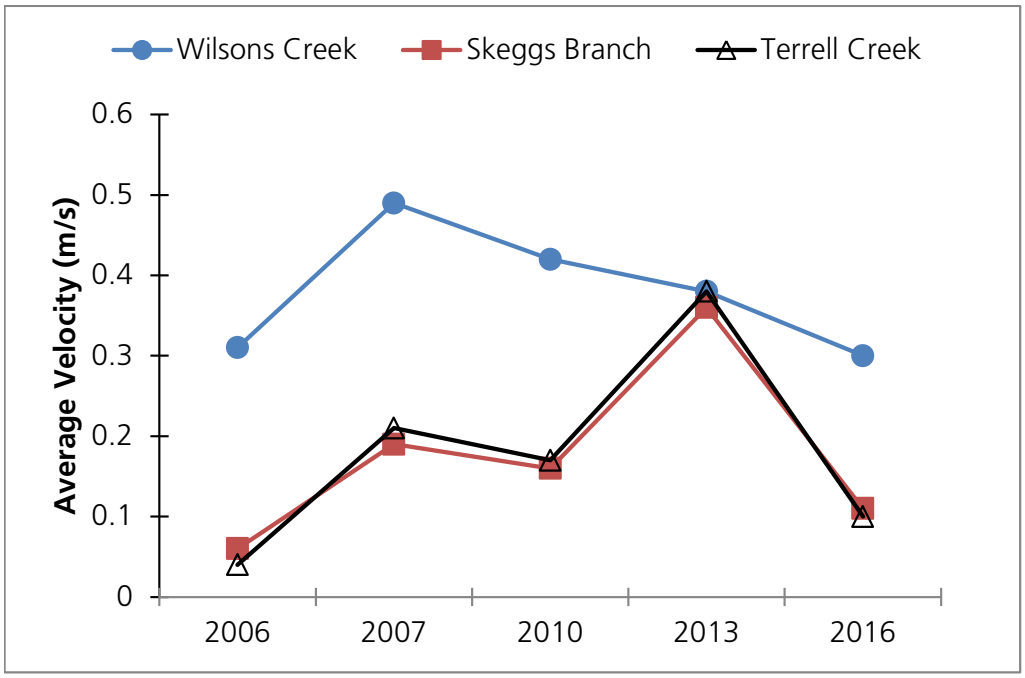

Figure 9. Velocity for reaches sampled at Wilson's Creek National Battlefield.

Table 2. Bank angle, vegetation, height, and substrate characteristics (in percent of total bank) for each reach sampled at Wilson's Creek National Battlefield.

		Wilson's CreeK					Skegg's Branch					Terrell Creek				
Characteristic	**Category**	**2006**	**2007**	**2010**	**2013**	**2016**	**2006**	**2007**	**2010**	**2013**	**2016**	**2006**	**2007**	**2010**	**2013**	**2016**
Angle	< 60o	14	18	36	9	18	45	45	32	36	5	68	73	59	55	68
	> 60o	86	82	64	91	82	55	55	64	64	95	32	27	41	45	32
	>80%	91	100	82	100	82	55	82	82	73	77	100	86	91	82	77
	50-80%	5	0	18	0	9	32	18	18	27	23	0	14	9	18	23
	<50%	5	0	0	0	9	14	0	0	0	0	0	0	0	0	0
Height	<1m	0	45	0	0	0	5	0	14	18	0	45	9	18	32	18
	1-2m	18	50	9	9	41	64	55	55	41	55	36	41	50	36	55
	2-3m	18	5	64	59	41	0	32	18	18	27	0	27	9	0	0
	>3m	64	0	27	32	18	32	14	14	23	18	18	23	23	32	27
Substrate	Silt	55	59	41	73	68	0	59	32	36	41	100	77	27	50	14
	Sand/Gravel	23	14	36	5	5	64	9	45	45	41	0	5	55	27	73
	Cobble/Boulder	18	14	0	9	14	14	14	0	0	5	0	14	14	18	9
	Bedrock	5	14	23	9	14	23	18	23	18	14	0	5	5	0	5

Wilson's Creek typically had higher average water temperatures (Figure 10), turbidity (Figure 11), and specific conductance (Figure 12) than its two tributaries, likely due to a more open canopy and the influence of surface runoff from urban areas and wastewater treatment effluent. Skegg's Branch and Terrell Creek, which are heavily influenced by springs located in or near the park, had lower water temperatures in most years. All three streams stayed below the state standard of 35°C (MO DNR 2014) in all years. Across years, pH was relatively stable and was similar between the three streams (Figure 13). Average dissolved oxygen was similar between Wilson's and Terrell creeks for most years sampled, but Terrell Creek had higher variability in average dissolved oxygen across years (Figure 14) while Wilson's Creek had larger daily fluctuations in concentrations within years. All three streams stayed within dissolved oxygen standards (>5 mg/L; MO DNR 2014) each year.

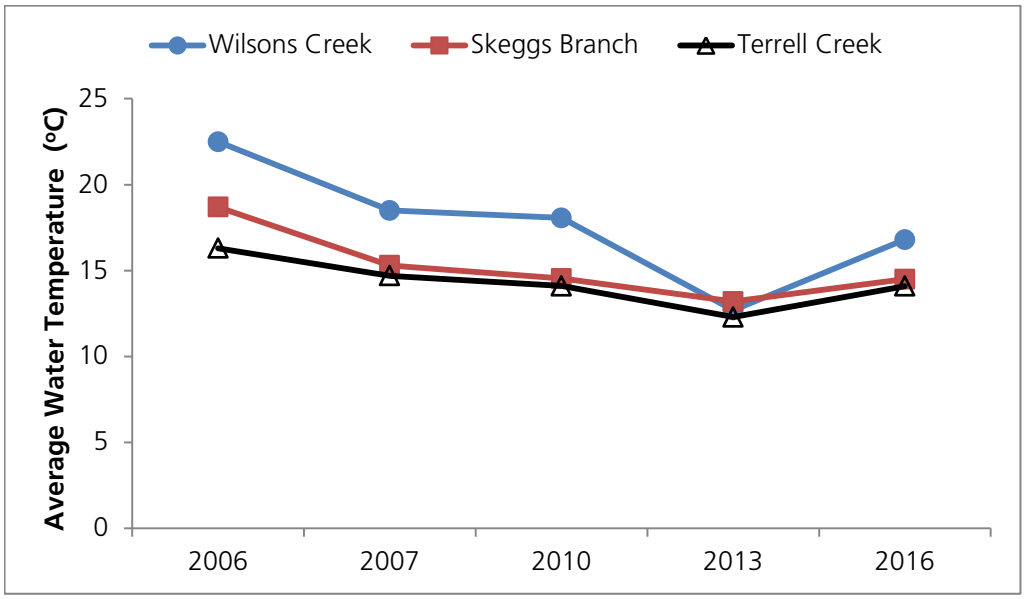

Figure 10. Average water temperature for each reach sampled at Wilson's Creek National Battlefield.

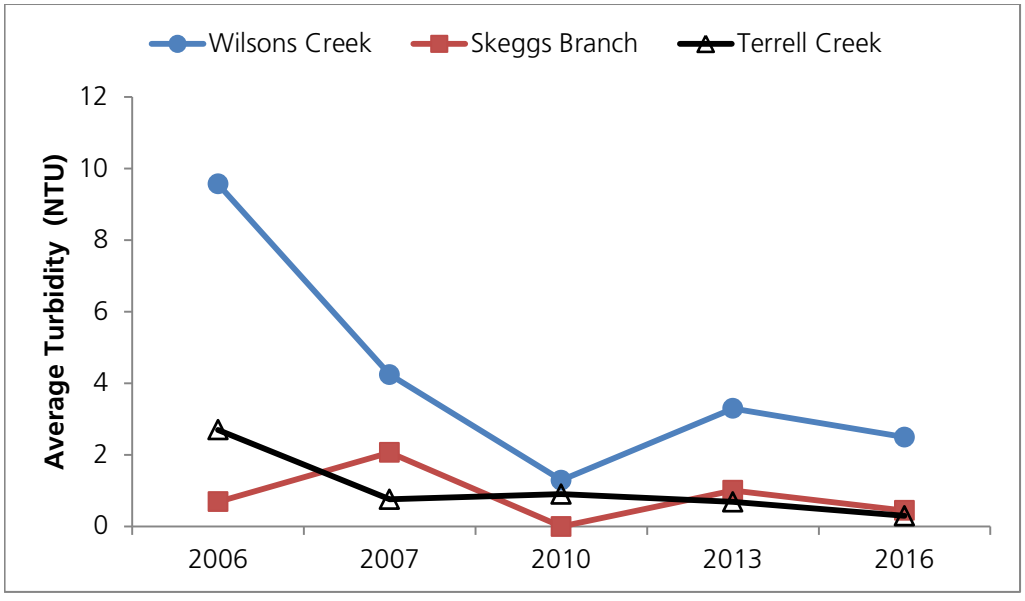

Figure 11. Average turbidity for each reach sampled at Wilson's Creek National Battlefield.

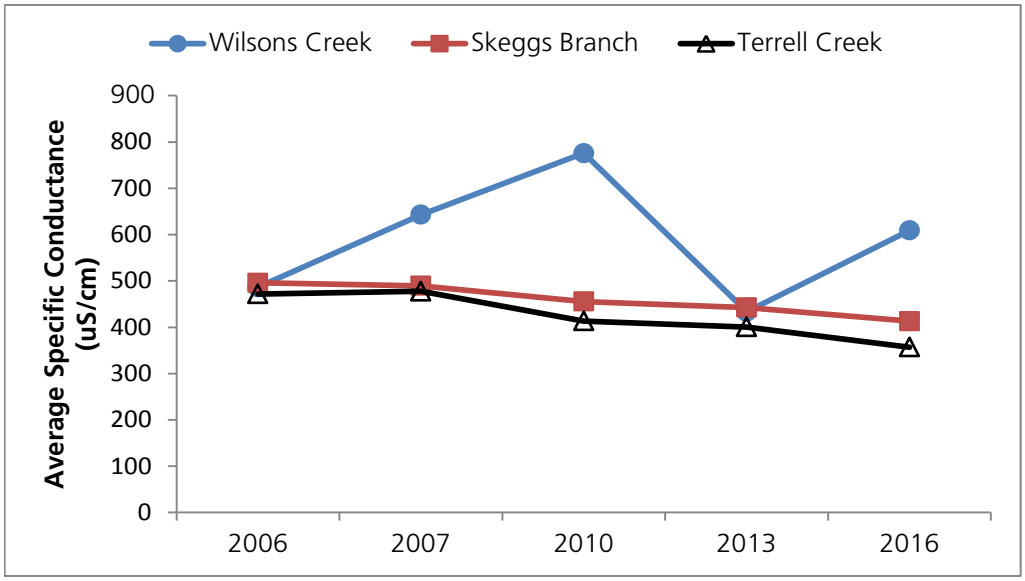

Figure 12. Average specific conductance for each reach sampled at Wilson's Creek National Battlefield.

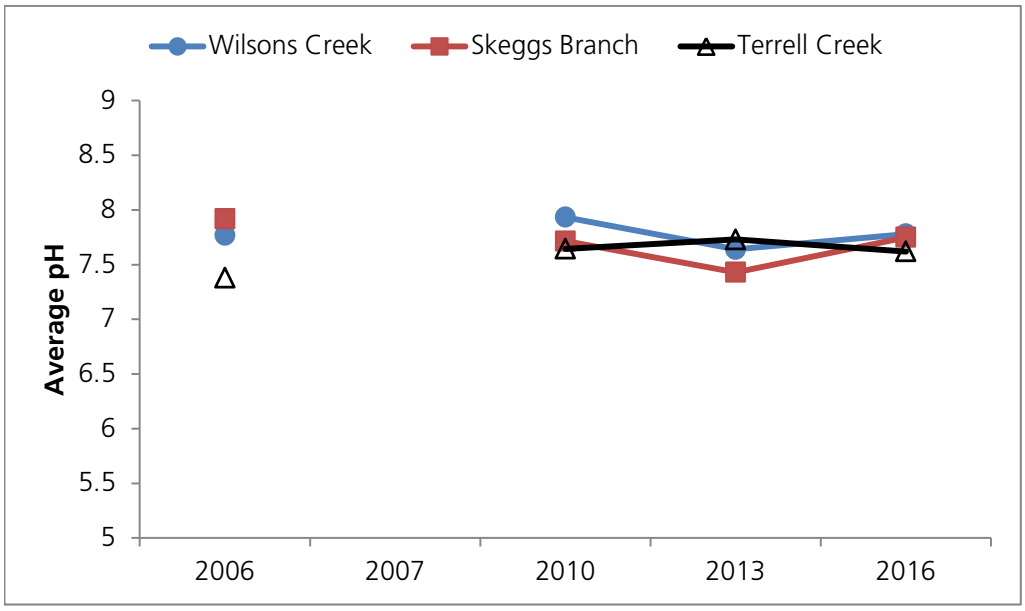

Figure 13. Average pH for each reach sampled at Wilson's Creek National Battlefield. Missing pH data for 2007 was due to a faulty meter.

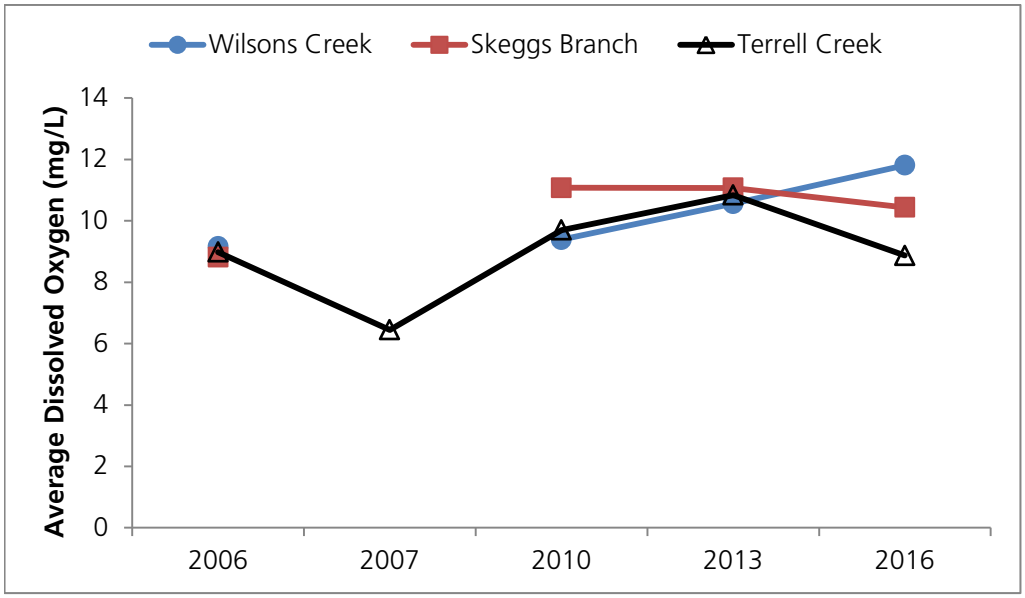

Figure 14. Dissolved oxygen for each reach sampled at Wilson's Creek National Battlefield. Dissolved oxygen was not collected for Wilson's Creek or Skegg's Branch in 2007.

Discussion

Fish communities within Wilson's Creek National Battlefield are diverse as evidenced by the numerous species present, high composition of sensitive darter, sculpin, and madtom species, and good IBI score ratings. Although water quality has been an issue due to wastewater effluent and runoff from urban areas, Wilson's Creek maintains a high biotic integrity rating. However, the high quality fish community in Wilson's Creek can be misleading because anthropogenic disturbances as well as abiotic factors are likely the explanation for these findings. Wilson's Creek is large compared to the smaller tributaries in the park, which would allow both larger species (suckers, sunfish, and bass) and smaller species to inhabit this stream. In addition, Wilson's Creek is likely a more productive system than the other streams within the park because of the upstream inputs of nitrogen and phosphorus from the wastewater treatment facility. While a highly productive system can create a food-rich environment for fish and increase species richness and fish abundance, this nutrient rich system can also create major algae blooms, causing daily dissolved oxygen levels to fluctuate substantially.

During our late spring/early summer sampling, Wilson's Creek demonstrated larger fluctuations in daily dissolved oxygen compared to Skegg's Branch or Terrell Creek. Although dissolved oxygen stayed above the state standard of 5 mg/L, higher water temperatures and lower water levels by late summer could increase the diel fluctuations in dissolved oxygen, reducing levels below state standards and adding stress to the fish communities in Wilson's Creek. Higher percentages of fish in Wilson's Creek had anomalies (disease, eroded fins, lesions, tumors, and blackspot parasite), which indicates fish communities are more stressed compared to Skegg's Branch and Terrell Creek.

Although Skegg's Branch and Terrell Creek had fewer species, fewer intolerant species, and lower diversity than Wilson's Creek, both streams had a larger proportion of sensitive darter, sculpin, and madtom species (particularly knobfin sculpins). The reason for lower richness and diversity in these two tributaries is possibly due to their smaller size and the influence of springs near the sample sites creating cooler water temperatures than in Wilson's Creek. In general, spring-dominated streams generally have a lower diversity in comparison to surface water streams. Overall, fish communities in the park are in good condition. Although nutrient enrichment and bacterial contamination are issues for Wilson's Creek, this stream has a diverse fish community.

Literature Cited

Barbour, M. T., J. Gerritsen, B. D. Snyder, and J. B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrate, and fish, 2nd edition. EPA 841-B-99-002, U.S. Environmental Protection Agency, Washington, DC.

Consoer, Townsend and Associates, Consulting Engineers. 1980. Waste load allocation study: James River – Wilson Creek, Little Sac River – South Dry Sac Creek. Report to Missouri Department of Natural Resources, Jefferson City, Missouri.

Dauwalter, D. C., E. J. Pert, and W. E. Keith. 2003. An index of biotic integrity for fish assemblages in Ozark Highland Streams of Arkansas. Southeastern Naturalist 2:447-468.

Dodd, H. R., D. G. Peitz, G. A. Rowell, D. E. Bowles, and L. M. Morrison. 2008. Protocol for monitoring fish communities in small streams in the Heartland Inventory and Monitoring Network. Natural Resource Report NPS/HTLN/NRR—2008/052. National Park Service, Fort Collins, Colorado.

Donegon, D. S. 1984. Wilson's Creek fish species diversity. Wilson's Creek Natural Resource Survey Unpublished report, Republic, Missouri.

Emmett, L. F., J. Skelton, R. R. Luckey, D. E. Miller, T. L. Thompson, and J. W. Whitfield.

1978. Water resources and geology of the Springfield area, Missouri. Missouri Department of Natural Resources, Division of Geology and Land Survey, Water Resources Report 34.

Foster, D. 1988. Fish survey of Wilson's Creek. National Park Service, Ozark National Scenic Riverways, Van Buren, Missouri.

Foster, D. 1989. Fish survey of Wilson's Creek. National Park Service, Ozark National Scenic Riverways, Van Buren, Missouri.

Karr J. R. 1981. Assessment of biotic integrity using fish communities. Fisheries 6:21–27.

Lazorchak, J. M., Klemm, D. J., and D. V. Peck. 1998. Environmental monitoring and assessment program-surface waters: field operations and methods for measuring the ecological condition of wadeable streams. EPA/620/R-94/004F. U.S. Environmental Protection Agency, Washington, DC.

Missouri Department of Natural Resources (MO DNR). 2018. Section 303(d) listed waters. Available at https://dnr.mo.gov/env/wpp/waterquality/303d/docs/updated-2018-303d-list.pdf (accessed November 2018).

Missouri Department of Natural Resources (MO DNR). 2014. Rules of Department of Natural Resources, Division 20 – Clean Water Commission, Chapter 7 – Water quality. Code of State Regulations. Accessed at http://dnr.mo.gov/env/wpp/cwforum/adv-uncl-waters-wetlands.htm.

Moulton, S. R. III, J. G. Kennen, R. M. Goldstein, and J. A. Hambrook. 2002. Revised protocols for sampling algal, invertebrate, and fish communities as part of the National Water-Quality Assessment Program. U.S. Geological Survey, Reston, Virginia. Open-file Report 02-150.

Peitz, D. G. 2005. Fish community monitoring in prairie park streams with emphasis on Topeka shiner (*Notropis Topeka*): summary report 2001-2004. National Park Service, Fort Collins, Colorado.

Petersen, J. C. and B. G. Justus. 2005. The fishes of Wilson's Creek National Battlefield, Missouri, 2003. U.S. Geological Survey, Little Rock, AR. Scientific Investigations Report 2005-5127.

Pflieger, W. L. 1997. The fishes of Missouri. Missouri Department of Conservation, Jefferson City, Missouri.

Robison, H. W., and T. M. Buchanan. 1988. Fishes of Arkansas. University of Arkansas Press, Fayetteville, Arkansas.

Smogor, R. 2005. Draft manual for interpreting Illinois fish IBI scores. Illinois Environmental Protection Agency, Bureau of Water, Surface Water Section.

Wentworth, C. K. 1922. A scale of grade and class terms for clastic sediments. Journal of Geology 30:377-392.

NPS 410/144025, March 2018

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
1201 Oak Ridge Drive, Suite 150
Fort Collins, Colorado 80525