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Aquatic Invertebrate Monitoring at Tallgrass Prairie National Preserve, 2009-2015

Natural Resource Data Series NPS/TAPR/NRDS—2016/1062

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Photograph of Fox Creek, Tallgrass National Preserve, Kansas.
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ON THE COVER
Photograph of Palmer Creek, Tallgrass National Preserve, Kansas.
Photograph courtesy of the National Park Service, Heartland Inventory and Monitoring Network.

Aquatic Invertebrate Monitoring at Tallgrass Prairie National Preserve, 2009-2015

Natural Resource Data Series NPS/TAPR/NRDS—2016/1062

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

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Executive Summary

Tallgrass Prairie National Preserve (TAPR) is the first National Park Service area established specifically for the preservation, protection, and interpretation of a tallgrass prairie ecosystem. The Heartland Inventory and Monitoring Network began monitoring water quality and invertebrate community structure of two streams (Palmer Creek and Fox Creek) within TAPR's boundary during September 2009, and have since monitored those streams in May 2013 and April 2015. We collected 9 benthic samples from each stream using a Surber stream bottom sampler. Habitat data were collected from the sampling net frame. Water quality data also were collected in association with the invertebrate samples. Water quality met the Kansas aquatic life criteria for prairie streams, while the aquatic invertebrate data provided mixed results. The Kansas Department of Health and Environment lists both Fox and Palmer creeks on their 303(d) list for impaired streams due to unidentified stressors. Observed variation in the benthic communities is likely due to seasonal and ambient environmental differences and is not cause for concern at this point. Fox Creek and Palmer Creek had similar scores for invertebrate community indices, and several intolerant taxa were represented in samples from both creeks. The invertebrate metrics presented in this report are similar to those observed for other regional streams that are undisturbed or only mildly disturbed. These preliminary data offer mixed results and are currently insufficient to fully characterize the integrity of Fox and Palmer creeks using established criteria.

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Introduction

A vast North American prairie once covered over 160 million hectares, but over 95% of this resource has been destroyed by human encroachment making it one of the most endangered biomes on the continent (Samson and Knopf 1994). Tallgrass Prairie National Preserve (TAPR) was the first National Park Service area established specifically for the preservation, protection, and interpretation of a large tract of remaining tallgrass prairie ecosystem (Hiebert 1998). Prairie streams were critical components of the Great Plains ecosystems, but many were permanently lost or impaired due to development and agricultural activities (Dodds et al. 2004). Many of the remaining prairie fragments are not sufficiently large enough to support proper ecological functioning of their resident streams (Hall et al. 2003, Dodds et al. 2004). Prairie streams continue to face anthropogenic threats and understanding their ecology has become critically important (Dodds et al. 2004). Streams and their watersheds at TAPR are largely protected, but they remain vulnerable to human disturbance. Periodic monitoring of their biological communities will help detect disturbances and their associated impacts.

Aquatic invertebrates are an important tool for understanding and detecting changes in lotic ecosystem integrity, and they can be used to reflect cumulative impacts that cannot otherwise be detected through traditional water quality monitoring. The broad diversity of invertebrate species occurring in aquatic systems similarly demonstrates a broad range of responses to different environmental stressors. Benthic invertebrates are relatively easy to collect, and they can be analyzed at many different levels of precision. They are sensitive to a wide variety of impacts that potentially may occur in the watershed, such as changes in chemical constituents (including metals), hydrological alterations, sedimentation and bank erosion, land use, and other changes in the watershed. Furthermore, changes in the diversity and community structure of benthic invertebrates are relatively simple to communicate to resource managers, administrators, and park visitors because the loss of biological communities is of interest and concern to these groups.

The Heartland Inventory and Monitoring Network (HTLN) began monitoring water quality and invertebrate community structure in Palmer and Fox creeks at TAPR in September 2009 according to the HTLN small streams monitoring protocol (Bowles et al. 2008). The monitoring objectives of this study 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 taxa richness, abundance, diversity, and region-specific multi-metric indices as indicators of water quality and habitat conditions. Cribbs and Bowles (2012) summarized the data collected during the initial 2009 sampling event. This report summarizes baseline aquatic invertebrate and associated habitat and water quality monitoring data collected from 2009 through 2015.

Methods

Methods and procedures used in this report follow Bowles et al. (2008). Sampling was conducted at permanent, randomly selected sites on Fox and Palmer creeks in 2009 (September), 2013 (May) and 2015 (April) (Figure 1).

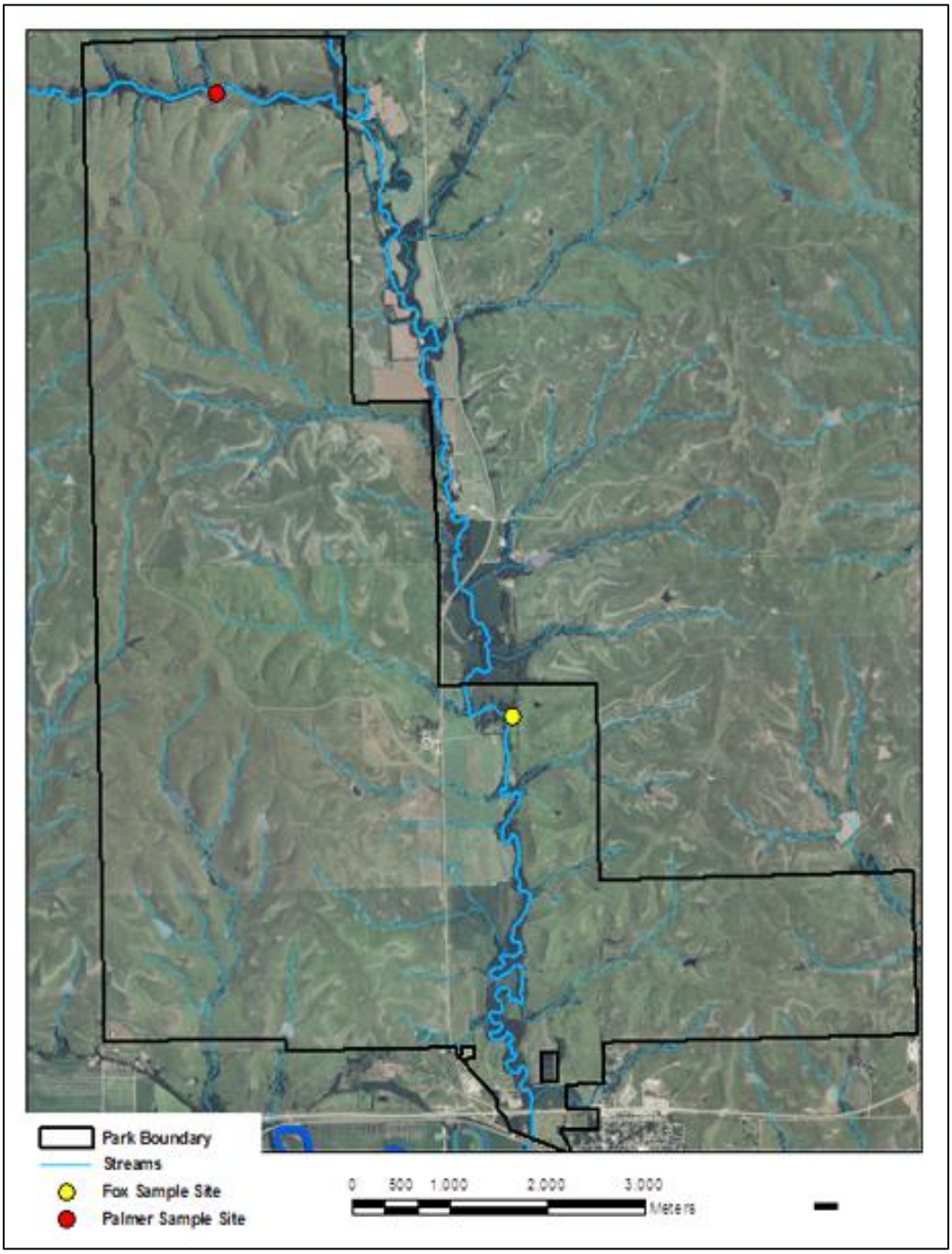

Figure 1. Location of sampling sites on Palmer Creek and Fox Creek, Tallgrass Prairie National Preserve.

Samples were collected at one reach of Palmer Creek and one reach of Fox Creek (Figure 1). Three successive riffles were sampled with three benthic invertebrate samples collected at each riffle, resulting in nine total samples for each creek. 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.

Metrics calculated for each sample included taxa richness, EPT (Ephemeroptera, Plecoptera, Trichoptera) richness, EPT ratio (EPT density/(EPT density + Chironomidae density), Shannon diversity index, Shannon evenness index (where 0 = minimum evenness, 1 = maximum evenness), % EPT abundance (i.e., the percentage of the total invertebrate abundance comprised of EPT), and Hilsenhoff biotic index (HBI). In addition to EPT richness, % EPT abundance is used to assess stream integrity in Kansas (Table 1) and is therefore included in this study as a basis for comparison to that state standard. Shannon index accounts for both abundance and evenness of the species present and index values are greater when all taxa in a sample are equally abundant. For biological data, values of Shannon's index typically range from 1.5 (low taxa richness and evenness) to 3.5 (high taxa richness and evenness). In comparison, evenness index values, indicating higher diversity and stream quality, increase as the index approaches 1. The HBI is calculated using tolerance values (TV) assigned to individual taxa. A TV between 0 and 3 would be classified as intolerant and values from 7 to 10 would be classified as tolerant (Barbour et al. 1999). By definition, HBI scores range from 0 to 10, with ten indicating the most disturbance. Higher metric values are associated with better stream conditions, except for HBI where smaller values indicate better conditions.

Table 1. Biological supporting criteria for EPT richness (Index) and percent EPT abundance according to the Kansas Department of Health and Environment (KDHE 2016a).

Supporting Criteria	EPT Index (richness)(Index)	% EPT Abundance
Fully supporting	≥13	≥48
Partially supporting	8-12	31-47
Non-supporting	≤8	≤30

The Kansas Department of Health and Environment (KDHE) biological criteria included in Table 1 are descriptors of the numerical benchmark values that describe the reference aquatic communities inhabiting waters that have been given a designated aquatic life use (KDHE 2016a). The primary purpose of these biological criteria is to establish regional attainment goals that are relevant to aquatic life use and resource protection. The categories of biological criteria are fully biological supporting; partially biological supporting; and non-biological supporting. We did not calculate the Macroinvertebrate Biotic Index (MBI) or the Kansas Biotic Index (KBI) used by the Kansas Department of Health and Environment (KDHE 2016a) because these two indices are based on less sensitive family level identifications than the HBI we used, which uses genus level identifications. The KBI is analogous to the family level HBI (Huggins and Moffett 1988).

For each sample, current velocity (meters/second) and depth (cm) were recorded directly in front of the sampling net frame. Qualitative habitat variables (embeddedness, periphyton, filamentous algae, aquatic vegetation, deposition, and organic material) were estimated within the sampling net frame as percentage categories (0, <10, 10-40, 40-75, >75). Habitat category midpoint values were used in analysis calculations. Dominant substrate size from the area within the sampling net frame was visually assessed using the Wentworth scale (Wentworth 1922). Stream discharge was measured upstream of the sampled riffles (Bowles et al. 2008). Water quality readings were recorded hourly using a calibrated YSI 6920 or YSI 6600 data logger. Due to the limitations of using water quality data obtained with data loggers, the invertebrate community is used here as a surrogate of the long-term water quality condition of Palmer and Fox creeks. Water quality criteria for Kansas streams are shown in Table 2.

Table 2. Kansas Aquatic Life Criteria (KDHE 2016a).

Water Temperature (^{o}C)	Dissolved Oxygen (DO in mg/L)	pH
Shall not exceed 32.0	Shall not fall below 5.0	6.5-8.5

Results

Fox Creek

Mean taxa richness ranged from 13.44 to 19.44 (Fig. 2). Mean EPT richness across years for Fox Creek ranged from 3.33 to 8.89. Conversely, mean % EPT abundance across years for Fox Creek ranged from 23% to 68%, indicating this stream ranged from non-supporting to fully supporting of biological life (Fig. 3). Based on Kansas Department of Health and Environment (KDHE) standards (Poulton et al. 2007) (Table 1), EPT richness was partially supporting in 2015, but not supporting in the other years.

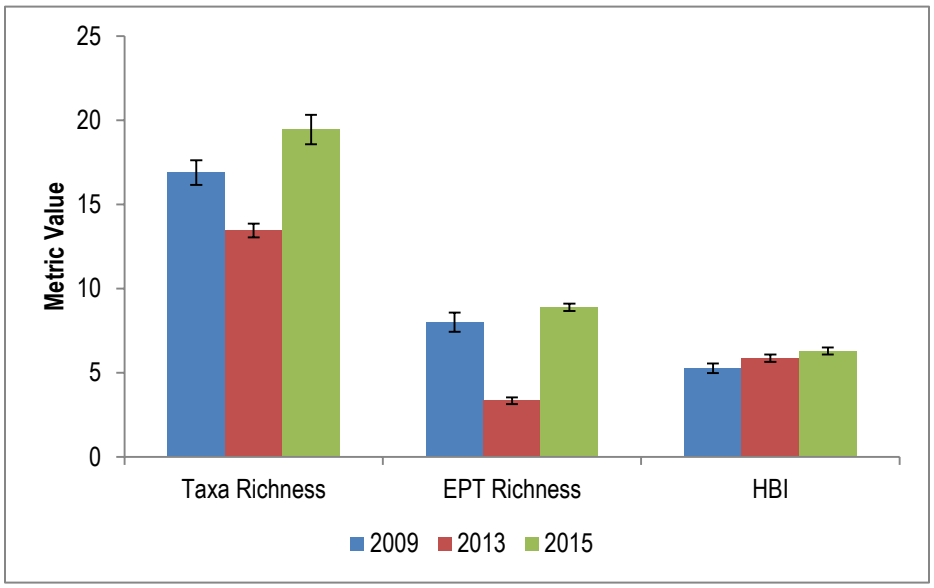

Figure 2. Means and standard errors (n=3) for richness metrics and HBI at Fox Creek, Tallgrass National Preserve.

The dominant taxa in most samples were Chironomidae (Diptera, TV=6), the caddisflies (Trichoptera) *Cheumatopsyche* and *Chimarra* (TV=6.6 and 2.8, respectively), and the mayfly (Ephemeroptera) family Baetidae (TV=4). The dominant EPT taxa were *Cheumatopsyche*, and the mayflies Baetidae, *Caenis* (TV=7.6), *Leptoplebia* (TV=6.4), and *Stenacron* (TV=7.1), all of which are tolerant of some disturbance. Stoneflies (Plecoptera, Perlidae, TV≤1) were present but generally poorly represented numerically. The EPT ratio for Fox Creek across years ranged from 0.47 to 0.77, indicating that the dipteran family Chironomidae largely did not dominate a substantial portion of the benthic community among samples.

HBI was moderate for all years and generally around 5 or 6, which indicates water quality is good to fair. Shannon's index among years ranged from 1.94 to 2.05. For biological data, values of Shannon's index range generally from 1.5 (low species richness and evenness) to 3.5 (high species evenness and richness). Taxa evenness ranged from 0.68 to 0.75, with 1.0 representing maximum evenness.

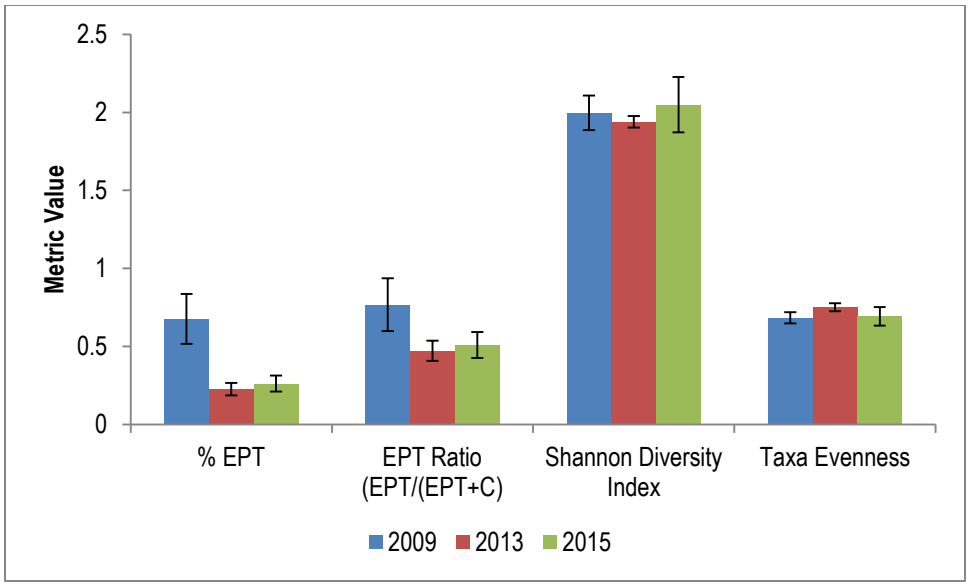

Figure 3. Means and standard errors (n=3) for diversity metrics at Fox Creek, Tallgrass National Preserve.

Palmer Creek

Invertebrate metrics for Palmer Creek exhibited a broad range of responses, which does not allow any conclusions to be drawn from this data at this time. Mean taxa richness across sampling years ranged from 12.78 to 15.89 (Fig. 4). Mean EPT richness ranged from 2.44 to 6.11, which would be classified as non-supporting under KDHE criteria. Mean % EPT abundance ranged from 4% to 52%, which largely did not support biological criteria established by KDHE (Fig. 5). EPT ratio ranged from 0.05 to 0.73. HBI ranged from 5.20 to 5.99, which indicates good to fair water quality.

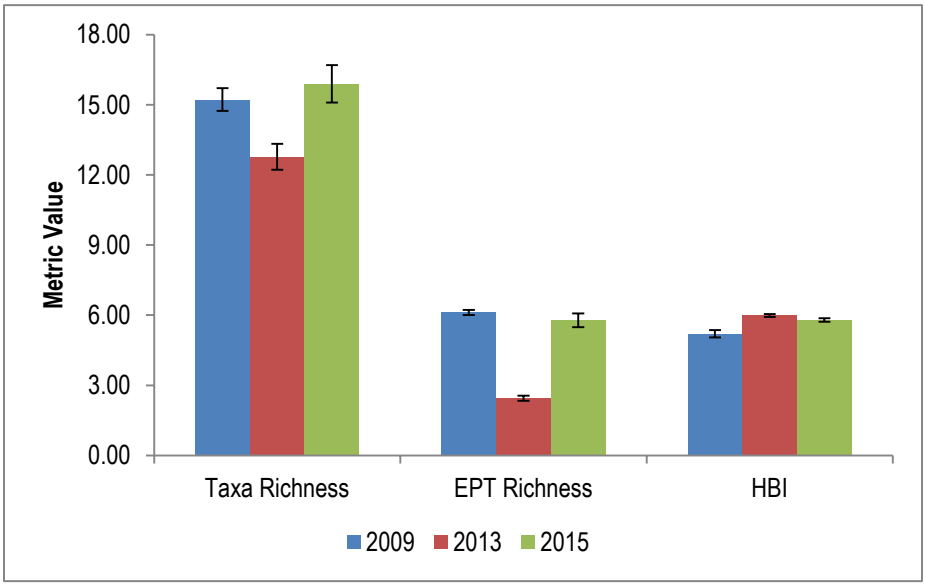

Figure 4. Means and standard errors (n=3) for richness metrics and HBI at Palmer Creek, TallgrassNational Preserve.

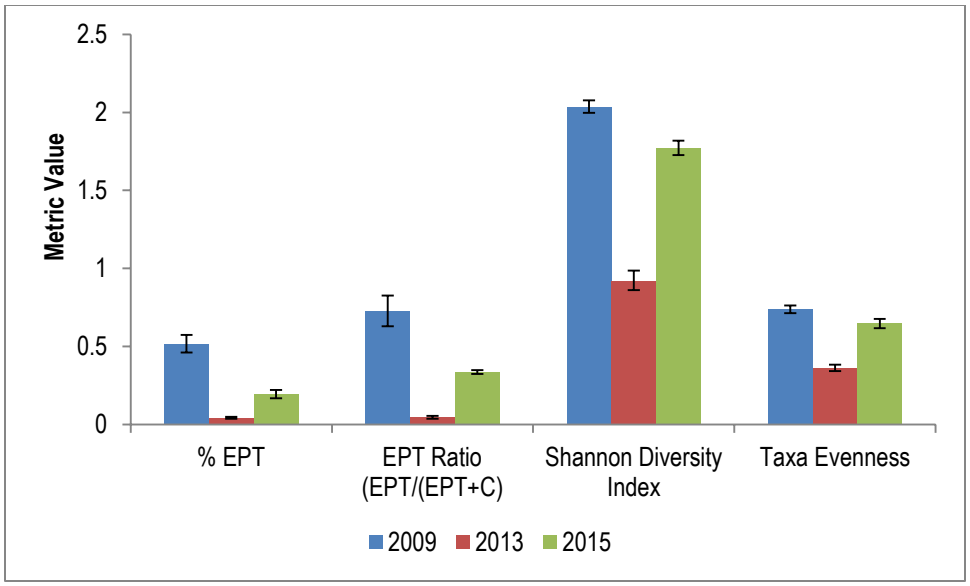

Figure 5. Means and standard errors (n=3) for diversity metrics at Palmer Creek, Tallgrass National Preserve.

The dominant taxa in most samples were Chironomide, Baetidae, the riffle beetle *Stenelmis* (Coleoptera, TV=5.4), and *Cheumatopsyche*. Dominant EPT taxa included the mayflies Baetidae and Stenonema (TV=3.4), caddisflies *Cheumatopsyche*, *Helicopsyche* (TV=0), *Chimarra* and *Hydroptila* (TV=6.2) and Baetidae (TV=4). Similar to Fox Creek, stoneflies were present but at low densities. Shannon's index among samples ranged from 0.92 to 2.04, which indicates low to mid-diversity. Taxa evenness ranged from 0.36 to 0.74, also a low to mid value range. Sensitive taxa that were found include the caddisflies *Rhyacopila* (Rhyacophilidae) and *Helicopsyche* (Helicopsychidae), and *Chimarra* (Trichoptera: Philopotamidae); all had tolerance values less than 3.

Habitat variables measured for Fox and Palmer creeks are shown in Table 3. Depth and current velocity values are consistent with riffle habitats. Substrate was predominantly small to large pebble (~22-64 mm), but it was generally larger in Palmer Creek. Other habitat variables (filamentous green algae, periphyton, and aquatic vegetation) generally had less than 54% coverage in the sample frame. Water quality parameters measured for Fox and Palmer creeks (Table 4) fell within Kansas state standards (Table 2). The water quality and habitat data presented in this report represent only a snapshot of the broad temporal range of conditions. As such, they are intended to describe the prevailing conditions that influence the structure of invertebrate communities. They may help explain variability between samples, but they should not be used as an analytical tool in the strictest sense (Bowles et al. 2008).

Table 3. Summary statistics for habitat variables associated with benthic samples collected from Fox and Palmer creeks, Tallgrass Prairie National Preserve. Values are means with standard errors in parantheses where appropriate, and n=3 in all instances.

Year	Depth (cm)	Current Velocity (m/sec)	Discharge (m^3/sec)	Substrate Size (Wentworth Scale)	% Embeddedness	% Filamentous Green Algae	% Periphyton	% Aquatic Vegetation
Fox Creek								
2009	7.56 (0.11)	0.38 (0.14)	0.02	13.89 (0.97)	32.22 (3.61)	47.22 (15.55)	35.83 (10.83)	0
2013	20.44 (2.91)	0.79 (0.07)	0.38	13.78 (0.48)	28.61 (3.61)	15.00 (6.94)	25.00 (0)	13.61 (8.48)
2015	15.89 (0.40)	0.66 (0.07)	0.16	15.00 (0.19)	28.61 (3.61)	33.61 (8.25)	28.61 (3.61)	5.56 (5.56)
Palmer Creek								
2009	3.22 (0.11)	0.12 (0.04)	0.0006	14.78 (0.68)	35.83 (6.25)	0.56 (0.56)	53.89 (3.61)	0
2013	10.67 (0.88)	0.37 (0.05)	0.07	15.11 (0.40)	25.00 (0)	21.94 (3.61)	35.83 (6.25)	15.56 (2.00)
2015	8.67 (0.96)	0.38 (0.04)	0.03	14.67 (0.38)	25.00 (0)	8.89 (2.00)	25.00 (0)	10.56 (4.82)

Table 4. Water quality data for Fox and Palmer creeks, Tallgrass Prairie National Preserve. Data were collected hourly with calibrated data loggers, except for May 2013 when readings were taken every 15 minutes.

Year	Statistics	Water Temperature (°C)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	pH	Turbidity (NTU)
Fox Creek						
September 2009	Mean	20.00	486.71	8.71	7.83	4.83
	Standard Error	0.08	0.57	0.08	0.00	0.10
	Minimum	17.89	473.00	7.02	7.72	2.90
	Maximum	22.48	500.00	11.13	7.97	8.70
	N	182	182	182	182	182
May 2013	Mean	6.40	425.20	13.60	8.16	6.18
	Standard Error	0.15	1.24	0.07	0.01	0.18
	Minimum	5.29	418.37	13.27	8.10	5.14
	Maximum	7.05	434.13	14.09	8.23	7.76
	N	16	16	16	16	16
April 2015	Mean	16.10	466.90	9.50	7.92	3.44
	Standard Error	0.26	2.24	0.31	0.02	0.06
	Minimum	14.14	452.00	7.82	7.84	3.00
	Maximum	17.96	480.00	11.38	8.04	3.90
	N	20	20	20	20	20

Table 4 (continued). Water quality data for Fox and Palmer creeks, Tallgrass Prairie National Preserve. Data were collected hourly with calibrated data loggers, except for May 2013 when readings were taken every 15 minutes.

Year	Statistics	Water Temperature (°C)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	pH	Turbidity (NTU)
Palmer Creek						
September 2009	Mean	18.42	587.54	8.01	7.60	1.96
	Standard Error	0.05	1.51	0.10	0.01	0.35
	Minimum	16.5	488	5.57	7.31	0
	Maximum	19.59	610	10.99	7.89	54.8
	N	188	188	188	188	188
May 2013	Mean	6.76	444.67	13.35	7.57	1.97
	Standard Error	0.04	0.67	0.09	0.13	0.19
	Minimum	6.68	444.00	13.22	7.31	1.60
	Maximum	6.82	446.00	13.51	7.73	2.20
	N	3	3	3	3	3
April 2015	Mean	14.50	543.78	8.01	7.65	0.49
	Standard Error	0.59	0.64	0.07	0.01	0.06
	Minimum	11.54	540.00	7.56	7.52	0.30
	Maximum	18.25	548.00	8.93	7.71	1.10
	N	18	18	18	18	18

Discussion

All metrics varied considerably among sampling years although there was overlap among years for some. This suggests that the natural range of variation in these prairie streams is quite broad. Factors potentially influencing the results presented here are that Palmer Creek receives substantial baseflow from small springs in its basin whereas Fox Creek does not. Additionally, the 2009 sampling event occurred during a drought in which each stream was barely flowing. In contrast, the 2013 sampling event was unseasonably cold, including snowfall, and stream flows were higher than measured for the other two years. It is likely these conditions may have influenced aquatic invertebrate community structure at those times. Previous surveys of Fox Creek and Palmer Creek indicated these streams did not meet aquatic life criteria, and the state of Kansas lists both Fox and Palmer creeks on the 303(d) list for impaired streams (KDHE 2016b). Both streams are listed as medium priority, and the impaired use is listed as aquatic life and the impairment as "biology." Our data show similar results. The majority of the Palmer Creek watershed within TAPR is characterized as prairie, and it is subject to minimal anthropogenic disturbance. In comparison, numerous anthropogenic stressors occur in Fox Creek's watershed upstream of TAPR. The intermittent nature of prairie streams, including those in this study, may also serve as seasonal stressors, which could cause them to appear impaired (Lytle 2002). This notion is substantiated in that water quality collected in this study met the Kansas aquatic life criteria (KDHE 2016a) for prairie streams. Additionally, several intolerant taxa were represented in samples from Fox Creek and Palmer Creek, including Plecoptera. The invertebrate metrics presented in this report are generally comparable to those observed for other regional streams, and suggest the data for Fox and Palmer creeks fall within a normal range for the region (MacFarlane 1983, Harris et al. 1991, 1999, Bass 1994, 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). Although the available data are inconclusive, continued monitoring of invertebrate communities will provide important water quality information to TAPR resource managers regarding the health of Fox Creek and Palmer Creek's respective watersheds.

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 ed. EPA 841-B-99-002, U.S. Environmental Protection Agency, Washington, DC.

Bass, D. 1994. Community Structure and Distribution Patterns of Aquatic Macroinvertebrates in a Tall Grass Prairie Stream Ecosystem Proceedings Oklahoma Academy Science **74**:3-10.

Bowles, D. E., M. H. Williams, H. R. Dodd, L. W. Morrison, J. A. Hinsey, C. E. Ciak, G. A. Rowell, M. D. DeBacker, and J. L. Haack. 2008. Monitoring protocol for aquatic invertebrates of small streams in the Heartland Inventory & Monitoring Network. Natural Resource Report NPS/HTLN/NRR—2008/042. National Park Service, Fort Collins, CO.

Cribbs J. Tyler and D. E. Bowles. 2012. Aquatic invertebrate monitoring at Tallgrass Prairie National Preserve, 2009 status report. Natural Resource Data Series NPS/HTLN/NRDS—2012/268. National Park Service, Fort Collins, Colorado.

Dodds, W. K., K. Gido, M. R. Whiles, K. M. Fritz, and W. J. Matthews. 2004. Life on the Edge: The Ecology of Great Plains Prairie Streams. BioScience **54**:205-216.

Hall, D. L., B. S. Bergthold, and R. W. Sites. 2003. The influence of adjacent land use on macroinvertebrate communities of prairie streams in Missouri. Journal of Freshwater Ecology **18**:55-68.

Harris, M. A., B. C. Kondratieff, and T. P. Boyle. 1991. Invertebrate assemblages and water quality in six National Park units in the Great Plains. National Park Service, Water Resources Division, Fort Collins, Colorado.

Harris, M. A., B. C. Kondratieff, and T. P. Boyle. 1999. Macroinvertebrate community structure of three prairie streams. Journal of the Kansas Entomological Society **72**:402-425.

Hiebert, R.D. 1998. Opportunities to enhance and maintain the tallgrass prairie ecosystem with the boundaries of Tallgrass Prairie National Preserve. United States Department of Interior, United States National Park Service, unpublished report.

Huggins, D. G., and M. Moffett. 1988. Proposed biotic and habitat indices for use in Kansas Streams. Report No. 35 of the Kansas Biological Survey. University of Kansas, Lawrence, Kansas. Second printing (electronic reformatting), November 2003.

Hutchens, J. J., Jr., J. A. Schuldt, C. Richards, L. B. Johnson, G. E. Host, and D. H. Breneman. 2009. Multi-scale mechanistic indicators of Midwestern USA stream macroinvertebrates. Ecological Indicators **9**:1138–1150

Kansas Department of Health and Environment (KDHE). 2016a. Kansas surface water quality standards. Topeka, Kansas. http://www.kdheks.gov/tmdl/kswqs.htm

Kansas Department of Health and Environment (KDHE). 2016b. Methodology for the Evaluation and Development of the 2016 Section 303 (D) list of impaired water bodies for Kansas. file:///C:/Users/Jhinsey/Documents/PUBLICATIONS/Water%20quality/TAPR/KDHE_2016_303_d_Methodology_Feb-18-2016_Final.pdf

Kosnicki, E., and R. W. Sites. 2007. Least-desired index for assessing the effectiveness of grass riparian filter strips in improving water quality in an agricultural region. Environmental Entomology **36**:713-724.

Lytle, D.A. 2002. Flash floods and aquatic insect life-history evolution: Evaluation of multiple models. Ecology **83**:370–385.

MacFarlane, M. B. 1983. Structure of benthic macroinvertebrate communities in a Midwestern plains stream. Freshwater Invertebrate Biology **2**:147-153.

Poulton, B. C., T. J. Rasmussen, and C. J. Lee. 2007. Assessment of biological conditions at selected stream sites in Johnson County, Kansas and Cass County and Jackson counties, Missouri, 2003 and 2004. U.S. Geological Survey Special Investigations Report 2007-5108.

Samson, F., and F. Knopf. 1994. Prairie conservation in North America.BioScience **44**:418–421.

Sarver, R., S. Harlan, C. Rabeni, and S. Sowa. 2002. Biological Criteria for Wadeable/Perennial Streams of Missouri. Missouri Department of Natural Resources, Jefferson City, Missouri.

Whiles, M. R., B. L. Brock, A. C. Franzen, and S. C. Dinsmore, II. 2000. Stream Invertebrate Communities, Water Quality, and Land-Use Patterns in an Agricultural Drainage Basin of Northeastern Nebraska, USA. Environmental Management **26**:563-576.

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

Zelt, R. B., and J. D. Frankforter. 2003. Water-quality assessment of the central Nebraska basins—entering a new decade. USGS Fact Sheet 013–03. US Geological Survey, Lincoln, Nebraska.

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