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Evaluation of EPT macroinvertebrate metrics in small streams located within the non-connected stormwater management region of Kansas City, Missouri, USA

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Abstract: *During 2012-2014, we evaluated macroinvertebrate communities in streams draining the non-connected stormwater management region (Municipal Separate Storm Sewer System, or MS4) within the Kansas City metropolitan area utilizing the Missouri bioassessment protocols. Trends in aquatic life impairment status based on Missouri's Macroinvertebrate Stream Condition Index (MSCI), as well as richness and abundance of EPT indicator metrics (Ephemeroptera, Plecoptera, Trichoptera), were compared between rural control sites and both transitional and urban stream sites representing varying stages of land use conversion. As compared to non-urban control sites, EPT taxa richness was significantly lower at MS4 urban sites during all three years (p = 0.007 – 0.013) and MS4 transitional sites during one of three years (p=0.48). EPT abundance (%) was significantly lower at MS4 urban sites during all years (p = 0.008 – 0.013) and MS4 transitional sites during one of three years (p=0.34). Mean EPT abundances ranged between 0.6% - 10.3% at urban MS4 sites, and always exceeded 18% at control sites. Both EPT richness and abundance were lower at the MS4 control site but means for EPT and other core metrics at this site were most often similar to non-urban control sites based on analysis of variance (ANOVA). MS4 transitional sites with active development in their watersheds were partially-supporting in their impairment status, and EPT metrics had lower means and generally more variability than control sites. Temporal trends indicate non-urban control and MS4 control sites consistently meet fully-supporting impairment status based on overall MSCI scores, but no study sites currently meet regional expectations (as defined by state reference streams) for either of the EPT metrics. Results indicate that Missouri and Kansas biocriteria for both EPT metrics are not consistently being met at any stream sites in the Kansas City metro area, including fully-supporting control sites and MS4 streams that receive stormwater runoff in watersheds with urban development that is well-established or currently transitioning to urban or suburban land uses.*

Key words: *macroinvertebrates*, *metrics*, *stormwater*, *urban*

Introduction

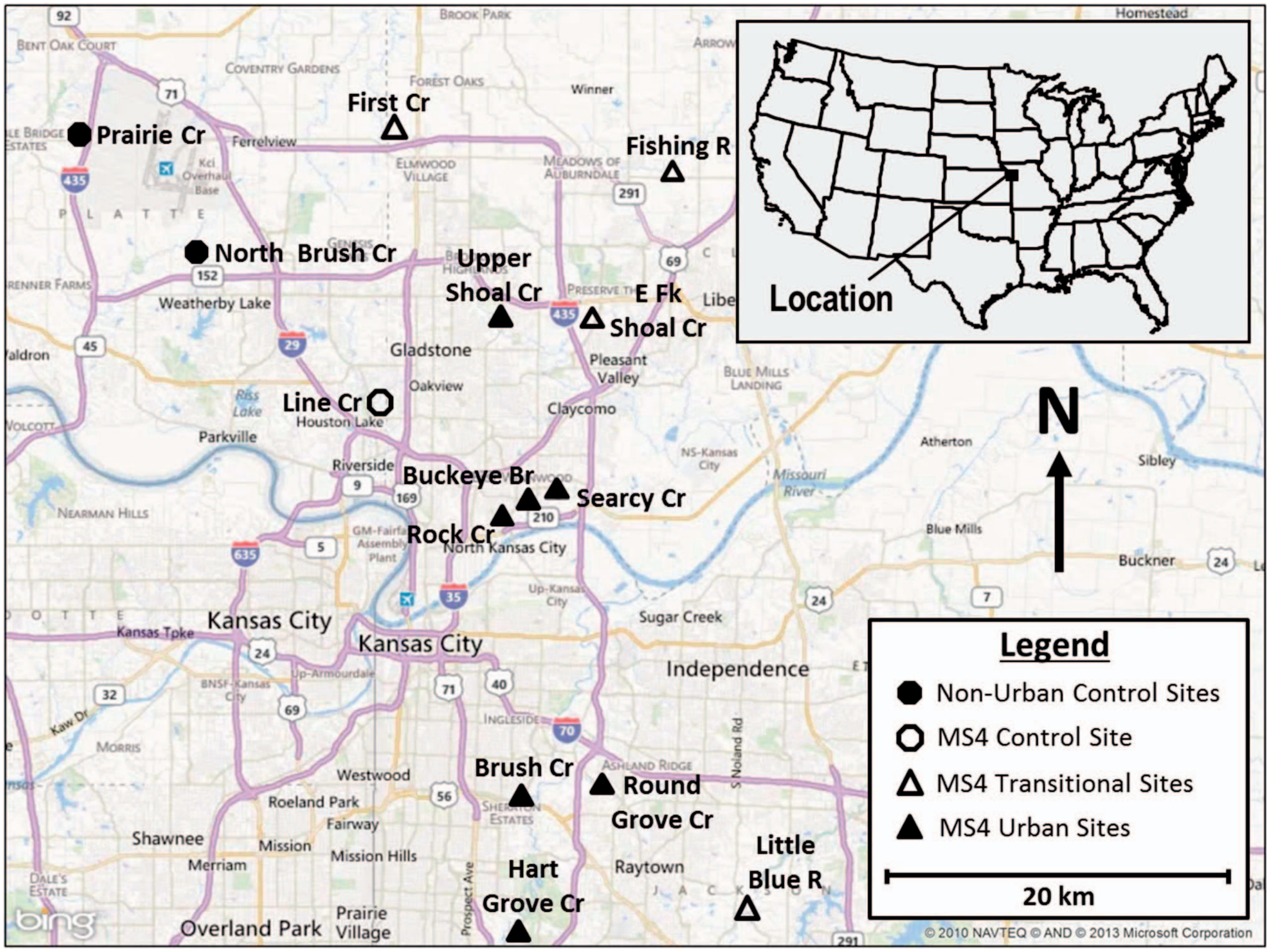
Ecological studies conducted in urban waterways have increased in recent years in an attempt to understand and diagnose the mechanisms that cause declines in water quality, aquatic life, and ultimately, reductions in the value of streams as a viable provider of ecosystem services. Given that the conversion from rural to urban land use is expected to increase exponentially within large urban centers as the human population rises (Paul and Meyer 2001, Meyer et al. 2005), the management of urban stream corridors for the protection of aquatic life and support of ecosystem services has become an important and necessary goal for human society. Urbanization often results in alterations of conditions in area streams, including increased soil erosion, changes in hydrologic characteristics, and loading of contaminants associated with urban runoff (USEPA 2005, Chadwick et al. 2006). All of these changes have been identified among the main causes of degradation in the aquatic life inhabiting urban streams, including loss of fish and aquatic macroinvertebrate species and replacement with more tolerant organisms (Booth and Jackson 1997a, Walsh et al. 2005a, Brown et al. 2009, Cuffney et al. 2010).

The routing of stormwater runoff in the centralized portions of metropolitan areas with older urban development is typified by extensive, connected sewer networks (combined sewers), whereas more recently developed areas drain into non-connected, or separated storm sewers (Municipal Separate Storm Sewer Systems, or MS4's; USGPO 2017). Even though drainage connections differ in both of these types of storm-water management networks, receiving streams may be exposed to similar ecological declines in their respective watersheds. In 1992, the U.S. Environmental Protection Agency (USEPA) established the MS4 program as a framework for municipalities to monitor quality of streams draining developed areas with separated sewer systems (USEPA 2007). Cities over 100,000 in human population are required to monitor aquatic life in these stream systems to fulfill permit obligations under the program. In Missouri, the city of Kansas City (KCMO) is one of four metropolitan areas with this requirement, where stream quality has been monitored since the first permit was issued. The KCMO permit authorizes the city to discharge stormwater into area stream systems under the auspices of the National Pollution Discharge Elimination System (NPDES) and the Clean Water Act (CWA). The USEPA relegates the issuance and administration of these permits to state regulatory agencies, in this case the Missouri Dept. of Natural Resources (MDNR). Municipalities must meet conditions specified in the permit, including conducting biosurveys to assess stream quality and identify long-term trends in characteristics of the stream biotic community, as well as reporting the condition and aquatic life impairment status of these streams to the MDNR and USEPA on an ongoing basis.

Aquatic macroinvertebrates represent the most widely utilized group of organisms for measuring the attainment of both narrative and numeric aquatic life criteria (Barbour et al. 1995, Rosenberg and Resh 1993, Davis and Simon 1995). In this regard, they are an important complement to assessments of water and habitat quality that are commonly conducted on stream ecosystems. Aquatic macroinvertebrates also reflect the effects of more subtle or indirect causes of stream degradation such as that resulting from non-point sources, making them the preferred indicator for evaluating urban waterways containing multiple stressors that are difficult or expensive to measure with chemical monitoring alone (Cairns and Pratt 1993, Allen 2004). In particular, the macroinvertebrate metrics associated with the EPT insect orders (Ephemeroptera=mayflies, Plecoptera=stoneflies, Trichoptera=caddisflies) are among the most sensitive and widely utilized indicators because the richness and abundance of these organisms can be affected by a wide range of stressors (Lenat 1988), including changes in land use (Garie and McIntosh 1986, Lenat and Crawford 1994), impervious surfaces (Klein 1979, Wang et al. 2001, Booth and Jackson 1997b, Walsh et al. 2005a, 2005b), urban intensity (Walsh et al. 2001, Cuffney et al. 2010), habitat loss (Richards et al. 1996), nutrient enrichment (Lewis 1986, Gücker et al. 2006, Evans-White et al. 2009, de Barruel and West 2003), and point sources such as wastewater discharges (Suozzo 2005, Dyer and Wang 2002). For these reasons, they are also commonly included in multi-metric indices where several macroinvertebrate indicators are integrated to determine an overall score that reflects the relative quality or condition of a water body (Ohio EPA 1987, 1989, Karr and Kerans 1991, Kerans and Karr 1994, Barbour et al. 1995, DeShon 1995).

Since 2007, the city of Kansas City, Missouri, has been conducting biological assessments with macroinvertebrate communities in smaller watersheds (< 25 km^2) located within the MS4 region of the city. In cooperation with KCMO, the U.S. Geological Survey (Columbia Environmental Research Center) has conducted these evaluations once or twice per year since 2011, utilizing the biological assessment protocols designed to measure aquatic life support status in Missouri stream systems (MDNR 2012). However, assessments conducted prior to 2011 did not utilize the complete MDNR protocol, and none of the macroinvertebrate data from the MS4 evaluations had been previously published for the Kansas City region. Further, the macroinvertebrate indicator metrics used for evaluating stream condition and aquatic life impairment in wadeable streams of Missouri have not been evaluated for use in urban stream systems similar to those included in the MS4 assessments. Here we evaluate the two commonly-reported EPT indicator metrics adopted for use in stream assessment programs, one of which is used in nearby Kansas for aquatic life use support (% EPT abundance, Kansas Dept. of Health and Environment 2008) and another which is included as part

Figure 1. Map of west-central Missouri and eastern Kansas (including the Kansas City metropolitan area), showing locations of 14 stream sites within the MS4 non-connected stormwater management region that were evaluated for aquatic macroinvertebrate communities in spring 2012-2014. Further descriptions of the sampling sites are found in Table 1.



of stream quality evaluations in both Kansas and Missouri (EPT taxa richness). In this paper, we present 2012-2014 biological assessment results including the aquatic life attainment status of stream sites within the MS4 network of KCMO, and how the responses of these two indicator metrics differ across sites with rural, urban, and rapidly urbanizing land uses.

Materials and Methods

Study Area

This region of west-central Missouri is located in the Central Great Plains ecoregion (Hoekstra et al. 2010) but contains riffle-pool dominated streams. The watersheds we studied are generally smaller (< 25 mi^2) than that of regional reference streams identified by MDNR and listed in Missouri's Water Quality Standards. Therefore, control sites of similar size were designated to improve relative comparisons. Study sites and site groupings (Fig. 1, Table 1) were chosen by the city (KCMO) to represent conditions varying in stages of urban development and planning. These site groups included rural locations (non-urban control, 2 primarily rural, non-MS4 sites with little or no ongoing development within the watersheds), transitional with suburban and/or commercial land use conversion in progress (MS4 transitional, 4 urban MS4 sites in which watersheds have ongoing development and impervious surface cover of 5-15%), and urban MS4 containing older previously converted lands that have a mix of well-established suburban and commercial land uses (MS4 urban, 7 MS4 sites with impervious surface cover $>$15%). One additional urban site located within the MS4 region of KCMO known to have an intact riparian corridor with a primarily forested buffer and a habitat quality score comparable to controls (Line Creek) is treated separately (MS4 control) in this study to enhance comparisons among sites. Further description of the sampling site locations are given in Table 1. Some sampling sites were added or removed from active stream quality evaluations over time, so not all stream sites were assessed every year or season.

Table 1. Location, drainage unit, predominant land uses and site category designations for 14 stream sites evaluated with aquatic macroinvertebrate communities in the MS4 separated stormwater management region of Kansas City, Missouri, during spring season 2012-2014. Site categories were determined by the city of Kansas City, Missouri, based on varying stages of urban development and planning. Drainage Units are based on Sarver et al. (2002) and include CPBL = Central Plains tributaries between Blue-Blackwater/Lamine Rivers, CPNP = Central Plains tributaries between Nishnabotna/Platte Rivers.

Stream Site	Missouri County	Ecological Drainage Unit	Predominant Land Uses	[1]Watershed Percent (%) Impervious	Site Category
North Brush Cr.	Platte	CPBL	rural/suburban residential	4.3	Non-Urban Control
Prairie Cr.	Platte	CPNP	rural/suburban residential	9.2	Non-Urban Control
Fishing R.	Clay	CPBL	agriculture/suburban residential	9.1	MS4 Transitional
First Cr.	Clay	CPNP	agriculture/suburban residential	7.9	MS4 Transitional
Little Blue R.	Jackson	CPBL	agriculture/suburban residential	14.3	MS4 Transitional
East Fork Shoal Cr.	Clay	CPBL	suburban residential/commercial	6.7	MS4 Transitional
Line Cr.	Platte	CPBL	suburban residential/park	27.2	MS4 Control
Upper Shoal Cr.	Clay	CPBL	urban residential/commercial	18.7	MS4 Urban
Rock Cr.	Clay	CPBL	urban residential/commercial	24.4	MS4 Urban
Searcy Cr.	Clay	CPBL	urban residential/commercial	23.3	MS4 Urban
Buckeye Cr.	Clay	CPBL	urban residential/park	28.6	MS4 Urban
Brush Cr.	Jackson	CPBL	commercial/urban residential	37.5	MS4 Urban
Hart Grove Cr.	Jackson	CPBL	commercial/urban residential	27.5	MS4 Urban
Round Grove Cr.	Jackson	CPBL	commercial/urban residential	22.1	MS4 Urban

[1]From 2012 land cover data, Mid-America Regional Council, Kansas City, Missouri

Aquatic Macroinvertebrate Assessment

Aquatic macroinvertebrates were sampled during spring seasons (April 2012, 2013, 2014) using the Semi-Quantitative Macroinvertebrate Stream Bioassessment Project Procedure (MDNR 2012), which is the standard protocol utilized by the state of Missouri for evaluating the quality of wadeable perennial streams. This protocol includes separate samples taken from three stream habitats: a) riffles (flowing water over cobble or gravel substrate); b) non-flow (depositional substrate in pools or margins with no flow); and c) root mats (overhanging roots from bank vegetation and associated accumulations of organic debris). Samples from each habitat were processed separately, but data from each habitat were combined within a site or replicate to provide site-level estimates of abundance, richness, and EPT metric values. Three replicates (triplicates) were taken from one non-urban control site (North Brush Creek), one urban MS4 site (Round Grove Creek) and the MS4 control site (Line Creek) to enhance statistical comparisons. From each habitat, macroinvertebrates were sampled with a rectangular-framed aquatic kicknet (23 cm x 46 cm, with 500-µm mesh netting). Each sample replicate in each habitat consisted of a composite of six net samples taken at multiple stream locations (1.0-m^2 areas for riffle and non-flow habitats, 1-m lengths of shoreline for rootmat habitats). Each composite sample was placed in labeled bottles and preserved with 90% buffered ethyl alcohol.

Laboratory Processing

Laboratory processing of macroinvertebrate samples followed the MDNR protocol (MDNR 2012), and included subsampling from a gridded tray, random selection of grid numbers, and sorting under a microscope with 10X magnification until a desired target number was reached (600 for riffle habitat and 300 for non-flow and rootmat habitat). Larval midge specimens (Diptera: Chironomidae) were mounted on labeled glass slides with CMCP-10 mounting media (Masters Chemical Co., Des Plaines, IL) and allowed to cure for one month before identification with the use of a compound microscope. Macroinvertebrate organisms were identified to the lowest practicable taxonomic level, usually genus or species. Standard taxonomic references used for macroinvertebrate identification included Merritt et al. (2008) for insects, and Thorp and Covich (1991) and Pennak (1989) for non-insect macroinvertebrates. The level of taxonomic identification, the assignment of tolerance values for calculating the Missouri Biotic Index (MoBI), and a complete list of other references used for specific taxonomic groups are given in the *Taxonomic Levels for Macroinvertebrate Identifications* document developed by the MDNR (MDNR 2016a). Voucher specimens of all macroinvertebrate taxa were retained for verification purposes.

Calculation of Indicator Metrics

To provide community-level comparisons among sites and site groups, 34 macroinvertebrate indicator metrics were initially calculated from the data, including core metrics utilized by Missouri and Kansas for evaluating aquatic life support status in streams (Kansas Department of Health and Environment 2008, MDNR 2012), national Rapid Bioassessment protocols commonly used to assess community-level responses to disturbance or stress (Barbour et al. 1999), and those utilized during special studies conducted in the Ozark Plateau and Central Plains regions (Poulton et al. 2007, 2010, 2015, Freeland-

Table 2. Macroinvertebrate Stream Condition Index (MSCI) scores for 14 stream sites evaluated in Kansas City, Missouri, in spring season 2012-2014. Scores are based on site comparisons with aquatic macroinvertebrate data for reference streams with riffle-pool (RP) prevalence within the Central Plains tributaries between Blue-Blackwater/Lamine drainage unit (CPBL). Ranges in MSCI scores correspond with the following aquatic life impairment levels: 16-20 = Fully-Supporting, 10-14 = Partially-Supporting, 4-8 = Non-Supporting. *= denotes samples not taken.

Stream Site	Spring 2012	Spring 2013	Spring 2014
North Brush Cr.	16	16	16
Prairie Cr.	14	14	14
Fishing R.	16	12	12
First Cr.	10	10	*
Little Blue R.	*	*	14
East Fork Shoal Cr.	12	12	14
Line Cr.	16	16	16
Upper Shoal Cr.	12	14	*
Rock Cr.	12	12	*
Searcy Cr.	*	*	10
Buckeye Cr.	*	*	10
Brush Cr.	*	*	8
Hart Grove Cr.	*	*	10
Round Grove Cr.	12	12	12

Riggert et al. 2016). This paper reports the results for the two EPT metrics (EPT richness, percent EPT abundance) and the remaining core metrics utilized by MDNR for determining the aquatic life impairment status of Missouri streams (Total Taxa Richness, Missouri Biotic Index, and Shannon Diversity Index). The Macroinvertebrate Stream Condition Index (MSCI), which integrates individual scores for each of the four core metrics (5=fully-supporting, 3=partially-supporting, and 1=non-supporting) into one overall score (Table 2), was determined for each site and year based on state biocriteria designated for riffle/pool-dominated streams located within the Ecological Drainage Units (EDU) that include the KCMO area (Sarver et al. 2002, Sowa et al. 2007, MDNR 2012). For each metric, macroinvertebrate biocriteria for Missouri are determined from quartile (fully-supporting criteria) and range bisection (partially-supporting criteria) values from the distribution of available reference sites in each of the EDU's. These criteria for each metric represent the "expected" values for a stream site in meeting the warmwater aquatic life designated use (aquatic life expectations). Our study sites were scored individually for each metric and time period utilizing these values as cut-off ranges, as per the state protocols (MDNR 2012). Since our study sites were considered predominately riffle/pool streams and reference data for one of the EDU's (CPNP=Central Plains tributaries between the Nishnabotna and Platte Rivers) were only available for glide/pool-dominated streams, the two sites located in that EDU (Prairie Cr. and First Cr.) were scored based on criteria for riffle-pool dominated streams in the adjacent EDU where the other study sites were located (CPBL=Central Plains tributaries between the Blue-Blackwater and Lamine Rivers). Means for the replicated sites (North Brush Cr., Line Cr. and Round Grove Cr.) were used to assign individual metric scores for those sites. MSCI scores were used to determine impairment status of the sites, as well as for interpreting the data for the EPT indicator metrics.

Data Analysis

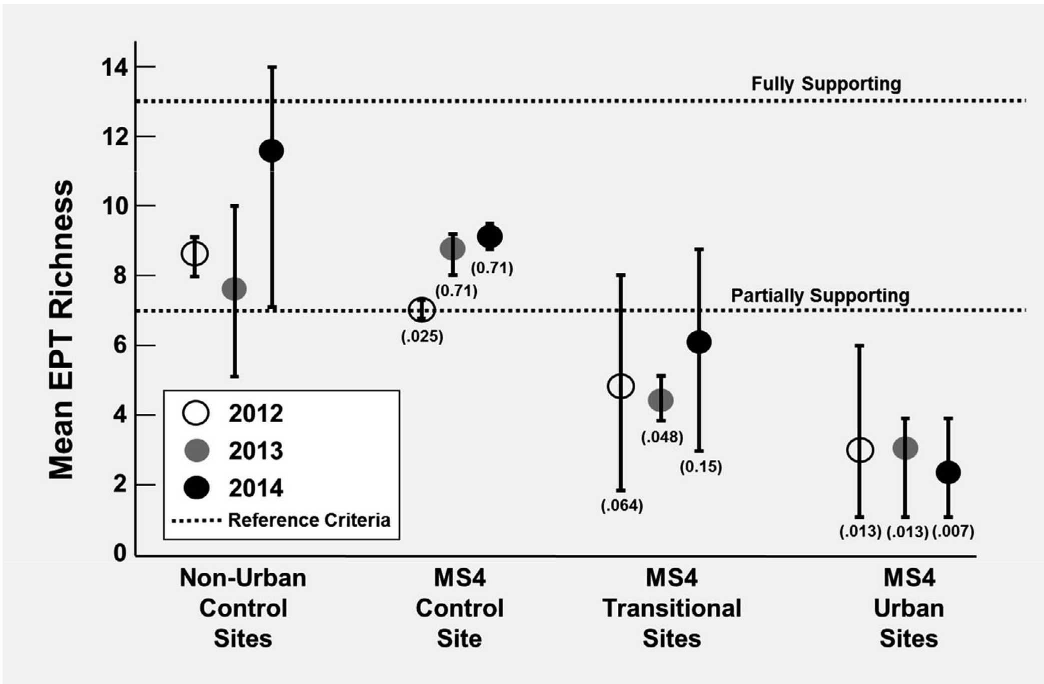
All analyses were conducted using release 9.2 of the Statistical Analysis System for Windows (SAS Institute, Cary, NC, SAS 2009). Between site groups (listed above), we determined significant differences in values for the two EPT metrics for each sampling year (2012-2014) using Kruskal-Wallis/Mann-Whitney U tests ($\alpha = 0.05$). These tests were performed on means between the non-urban control sites and the other site groupings individually, to determine significant differences in mean values between non-urban stream sites and other MS4 site categories. Among all study sites and for each year separately, we also tested for differences in means for all five metrics using a non-parametric analysis of variance (ANOVA, p-value <0.05), and applied the partial sum of squares from the variance of replicated sites towards the non-replicated sites during analysis. Since ANOVA does not identify which means are significantly different when more than two means are involved, we used least-squares means ($\alpha = 0.05$) and simultaneous confidence intervals to make pairwise comparisons among site means to determine which were significantly different (Snedecor and Cochran 1982). For these tests, sites were assigned capital letters designating the among-site differences in means, with early letters ("A") indicating the highest or best values (except for the Missouri Biotic Index metric, where lower values have a higher rating).

Results

In this study, 217 macroinvertebrate taxa were collected across all study sites, 28 of which were non-insect taxa (mollusks, worms, leeches, crustaceans, water mites, hyrdozoans). Across all sites and years, total richness of macroinvertebrate taxa within a sample replicate ranged from 28-79 and EPT richness ranged from 1-14. Among the 189 insect taxa, 34 of these were EPT, and relative abundance of these three dominant orders ranged from 1-47% in the samples. There were also 55 midge (Diptera: Chironomidae) taxa, and 27 non-midge Diptera taxa. In addition to these, the study sites generally contained a wide diversity of other aquatic macroinvertebrates, including dragonflies and damselflies (Odonata), aquatic beetles (Coleoptera: families Elmidae, Hydrophilidae, Dytiscidae and Haliplidae) and aquatic heteropterans (Hemiptera).

Across all three years, the Macroinvertebrate Stream Condition Index (MSCI) scores consistently rated one of the non-urban control sites (North Brush Cr.) and the MS4 control site (Line Cr.) as fully-supporting of the beneficial use

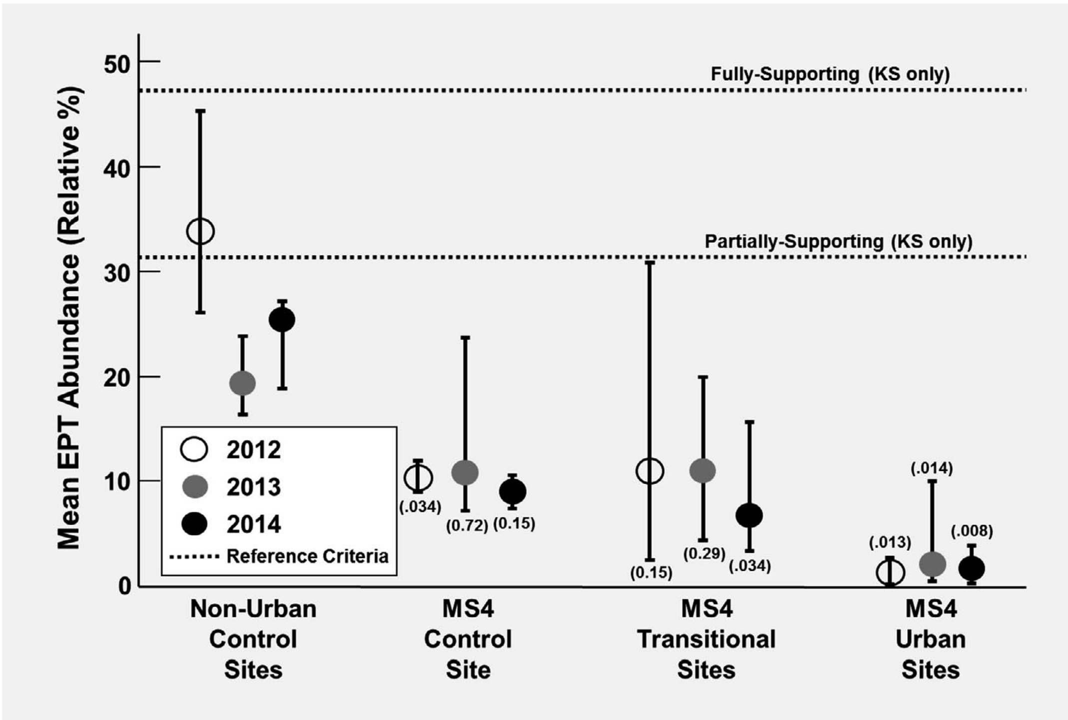
Figure 2. Mean (and range bar) EPT richness in relation to state reference criteria (Missouri and Kansas) for 14 stream sites in the Kansas City non-connected stormwater management region (MS4) evaluated during spring 2012-2014. Within each year, p-values given in parentheses were generated from paired comparisons between control sites and each of the other sites grouped individually (Mann-Whitney U tests, $\alpha = 0.05$).



designation as defined by Missouri's Water Quality Standards (protection of warmwater aquatic life) overall (Table 2). Results also indicate lower biotic condition at the MS4 transition sites (MSCI range of 10-14) and MS4 urban sites (MSCI range of 8-12). However, except for one replicate sample taken at North Brush Cr. in 2014, the EPT richness metric (Fig. 2) was always rated less than fully-supporting based on spring sampling (as compared to the other 3 core metrics), with a majority of samples taken at either urban or transitional MS4 streams obtaining a score of 1 (non-supporting) for this metric (Fig. 2). Similarly, the EPT abundance metric was always below the 48% threshold for full-support of aquatic life in Kansas wadeable streams (Fig. 3). For both EPT metrics, means at urban MS4 sites were significantly lower than that of non-urban control site means during all three years (Figs. 2–3). However, the MS4 transitional sites were more highly variable in both EPT metrics, with means significantly different than those controls sites for only one of the 3 years studied (2013 for EPT richness and 2014 for EPT abundance, Figs. 2–3).

Based on analysis of variance (ANOVA), significant differences among sites were most often observed with the sites that had either the highest or lowest biotic condition based on MSCI scores. The MS4 control site and one or both of the non-urban control sites were significantly different than one or more sites in the other MS4 groups (Table 3), however this pattern was not consistent across metrics or evaluation years. In 2014, North Brush Cr. and Line Cr. had significantly different mean values for Shannon Diversity index (four MS4 urban sites), Total Taxa richness (five urban MS4 sites), and Missouri Biotic index (one MS4 transition site, Table 3). For EPT richness, both non-urban control sites were significantly different than other sites in 2012 (two MS4 transition and three MS4 urban sites) and 2014 (one MS4 transition and three MS4 urban sites). For EPT abundance, both non-urban control sites were significantly different than other sites in 2012 (two MS4 transition, four MS4 urban sites) and 2014 (one MS4 transition, five MS4 urban sites). However, in 2013 individual sites stood out as being different for specific metrics, including Rock Cr. (EPT abundance) and East Fork Shoal Cr. (Shannon Diversity index), which had significantly lower mean values than all other sites (Table 3). The MS4 control site (Line Cr.) was often in the same group of means as one or both of the non-urban control sites and had similar mean values and significant differences for EPT richness (2013 and 2014), EPT abundance (2013), Total Taxa richness (2014), Missouri Biotic index (2013), and Shannon Diversity (2013 and 2014). There were no significant differences among sites in mean Total Taxa richness in 2013 or in mean Missouri Biotic index or Shannon Diversity index in 2012 (Table 3).

Figure 3. Mean (and range bar) EPT abundance (relative %) in relation to state reference criteria (Kansas only) for 14 stream sites in the Kansas City non-connected stormwater management region (MS4) evaluated during spring 2012-2014. Within each year, p-values given in parentheses were generated from paired comparisons between control sites and each of the other sites grouped individually (Mann-Whitney U tests, $\alpha = 0.05$).



Discussion

For evaluating stream quality, the EPT metrics have the most widespread usage among state agencies that include macroinvertebrate communities in their bioassessment programs (Barbour et al. 1995). Missouri and Kansas utilize one or both EPT metrics in calculating their multi-metric scores (MO=MSCI, and KS= mean metric score) for assessment of stream quality in their respective states (MDNR 2012, Kansas Dept. of Health and Environment 2008). Attributes associated with the EPT insect orders are key indicators of stream quality because a majority of species in those groups are sensitive to a wide variety of ecological disturbances, including water quality stressors and loss of habitat (Pratt et al. 1981, Wallace et al. 1996). These metrics have also been identified as among the best indicator metrics for measuring effects associated with urbanization (Wang & Kanehl 2003, Deacon et al. 2005, Purcell et al. 2009, Cuffney et al. 2010), localized point sources (Poulton et al. 2015), and for documenting recovery of water quality after pollution abatement activities (Crawford et al. 1992, Lydy et al. 2000). The EPT metrics are also included in multi-metric indices that have more widespread applicability for assessing stream condition, such as the Benthic Macroinvertebrate Index of Biotic Integrity (B-IBI, Kerans and Karr 1994) and the Invertebrate Community Index (ICI, DeShon 1995). Additionally, richness metrics including that of EPT have direct connection to biodiversity studies conducted in a wide variety of flowing waters (Moore and Palmer 2005).

Results from previous regional studies have suggested that when determining the impairment status of wadeable streams, the EPT indicator metrics may often limit the ability of a stream site to obtain a fully-supporting rating for aquatic life (Poulton et al. 2007, Rasmussen et al. 2009, 2012). Our study results demonstrate that these regional streams cannot meet expectations for taxonomic richness (as defined by state reference streams), including that of EPT, even if overall site scores such as the MSCI indicate fully-supporting aquatic life status. This is congruent with the conclusions of other studies that urban streams often do not meet warmwater aquatic life criteria (Yoder et al. 1999). Among the evaluations included in our study (three evaluation years and 14 sites, including replicates, Table 2), each sample with a fully-supporting MSCI score always had one or both of the taxa richness metrics (total and/or EPT) receive a fully-supporting score of 5. With the exception of Prairie Cr. in 2013 where 4 additional EPT taxa would have resulted in a fully-supporting rating, most sites were not near

Table 3. Significant differences in means (values are represented by capital letters with A>B>C>D) for five macroinvertebrate metrics based on analysis of variance (pairwise comparisons from non-parametric ANOVA) among 14 stream sites evaluated with aquatic macroinvertebrate communities in the MS4 separated stormwater management region of Kansas City, Missouri during spring season 2012-2014. Stream sites with the same letter within each metric and sampling year indicate means are not significantly different ($\alpha = 0.05$). ns = not significant.

	Macroinvertebrate Metric				
Stream Site and Sampling Year	EPT Richness	EPT Abundance (%)	Total Taxa Richness	Missouri Biotic Index	Shannon Diversity Index
Spring 2012					
North Brush Cr.	A	A	A	ns	ns
Prairie Cr.	A	A	BCD	ns	ns
Fishing R.	AB	A	AB	ns	ns
First Cr.	C	B	D	ns	ns
East Fork Shoal Cr.	D	B	CD	ns	ns
Line Cr.	ABC	B	ABC	ns	ns
Upper Shoal Cr.	BC	B	ABCD	ns	ns
Rock Cr.	D	B	D	ns	ns
Round Grove Cr.	D	B	D	ns	ns
Spring 2013					
North Brush Cr.	A	A	ns	B	A
Prairie Cr.	B	A	ns	AB	A
Fishing R.	B	A	ns	AB	A
First Cr.	B	A	ns	A	A
East Fork Shoal Cr.	AB	A	ns	B	B
Line Cr.	A	A	ns	B	A
Upper Shoal Cr.	A	A	ns	AB	A
Rock Cr.	B	B	ns	AB	A
Round Grove Cr.	B	A	ns	AB	A
Spring 2014					
North Brush Cr.	A	A	A	AB	A
Prairie Cr.	A	A	AB	AB	AB
Fishing R.	B	AB	B	AB	AB
Little Blue R.	A	AB	AB	B	AB
East Fork Shoal Cr.	A	B	B	B	AB
Line Cr.	A	AB	A	AB	A
Searcy Cr.	AB	B	B	AB	B
Buckeye Cr.	B	B	BC	AB	B
Brush Cr.	B	B	C	A	B
Hart Grove Cr.	B	B	BC	A	B
Round Grove Cr.	AB	B	B	AB	AB

the criteria of 13 EPT taxa (Fig. 2) or the criteria of 67 for Total Taxa richness. In our study, the EPT taxa richness metric only received a score of 5 at North Brush Cr. in 2014, and the total taxa richness metric received this score only at North Brush Cr. (2012, 2014), Line Cr. (2012, 2014), and Fishing R. (2012), with each of these evaluations resulting in a fully-supporting MSCI score (Table 2). Since several EPT macroinvertebrates are known to emerge from the streams in the central US in late winter (Feb.-March) just before the recommended spring sampling begins (Edmunds et al. 1976, Stewart and Stark 1993, Wiggins 1996), it is possible that higher EPT richness may exist a short time before stream sites are evaluated in spring season. Other stream sites in Johnson County, Kansas adjacent to the KCMO metro region have also not met expectations for EPT metrics (Poulton et al. 2007, Rasmussen et al. 2009, 2012); no sites sampled in those studies met the Kansas threshold of >12 for EPT richness, and nearly every site included in those bioassessment studies was below the 48%

threshold for EPT abundance. Similarly, the EPT abundance metric never met those expectations at any of our KCMO study sites, even though non-urban control sites and the MS4 control site had higher means than MS4 urban sites in both 2012 and 2014 (Fig. 3).

Our study results also show relative consistency in MSCI scores over the three study years at sites that have remained stable in their level of development and land use conversion (Table 2), including the non-urban control (North Brush Cr., Prairie Cr.), MS4 control (Line Cr.) and one of the MS4 urban sites with older, well-established suburban and commercial development (Round Grove Cr.). Control sites were significantly higher in EPT abundance and richness than urban MS4 sites with older, less-active development (Figs. 2–3). In contrast, recent and ongoing suburban development has increased directly upstream from our Fishing R. site, which has changed from fully-supporting in 2012 to partially-supporting based on MSCI scores determined during our study years (Table 2). Other sites in the MS4 transition grouping, which were located in watersheds with impervious surfaces greater than non-urban controls (Table 1) also had intermediate MSCI scores and values for the EPT metrics during this period (Figs. 2–3), indicating that ongoing land use conversions from rural to urban in their respective watersheds may have coincided with recent declines of EPT organisms. We consider these results as important for showing that the general groupings of study sites we designated were appropriate for outlining the gradient in levels of development in the KCMO area and the potential changes in EPT organisms that may be occurring in regional streams.

Because state reference streams for western Missouri have slightly larger watershed sizes (> 25 mi^2) than the areas upstream of our KCMO study sites (Sarver et al. 2002), we recognize that our determinations of aquatic life status may be tentative. However, we designated rural control sites outside the KCMO city limits that were more similar in size to the urban MS4 study sites so they could also be compared directly with one another as well as be evaluated with the state biological assessment framework. We had also pre-determined that Line Cr. had more potential to sustain a fully-supporting aquatic life rating compared to other MS4 urban sites in the KCMO area that receive stormwater runoff, because of the adjacent park lands and extensive riparian corridor directly upstream of our study site. In addition, Line Cr. had previously obtained a habitat quality score (not shown) comparable to non-urban control sites (based on MDNR *Stream Habitat Assessment Project Procedure*, MDNR 2010). Even though Line Cr. is currently listed as impaired based on *E. coli* bacteria levels (MDNR 2016b), our study results showed a consistent fully-supporting community of aquatic life across all three years of evaluation. In general, Line Cr. had higher mean values than either of the other MS4 site groups for EPT richness and a higher mean EPT abundance than the urban MS4 sites (Figs. 2–3), and it was comparable to our non-urban control sites in nearly all of the core indicator metrics (Table 3). These EPT metric trends are significant because they demonstrate the ability of urban stream sites within the MS4 region of KCMO to meet aquatic life expectations defined by state reference streams. It also demonstrates that locally-designated control sites can also meet state expectations, even if their watershed sizes are smaller than state reference streams from which the biocriteria were derived. To outline causes for differences in aquatic life use attainment among urban sites, further analyses of habitat, substrate measurements, and stormwater characteristics at our study sites are ongoing.

Potentially, a slight increase or decrease in the number of EPT taxa at a site could affect the overall results of these assessments by changing the estimates for both EPT and Total Taxa richness. This means that MSCI scores and corresponding impairment status of urban streams receiving stormwater runoff may change with the loss of very few macroinvertebrate taxa if a site is already near the margin of numerical criteria threshold values for any of the indicator metrics. This may be an important implication for small transitional watersheds that are currently experiencing rapid ecological changes as a result of population growth and land use conversion to suburban or urban development, where sensitive macroinvertebrate taxa such as those belonging to the EPT insect orders may be the first to disappear from a community. This conclusion is supported by components of the Biological Condition Gradient model, that indicates loss of sensitive taxa and declines in species richness are among the first biological responses observed when stream degradation progresses towards a greater level of aquatic life impairment (Davies and Jackson 2006). Among the few sites in our study that remain fully-supporting, all of them are near the fully-supporting criteria threshold for one or more of the core macroinvertebrate indicators. For example, two sites evaluated in spring 2012 were at or just above the spring criteria threshold of 67 for Total Taxa richness (North Brush Cr.= 70, Line Cr. = 67), and would be rated partially-supporting with the loss of only a few taxa. Considering a recent study in a stream within the same EDU as our study sites (Blue River) that documented a loss of 13 EPT macroinvertebrate taxa downstream of a point source (Graham et al. 2010, Poulton et al. 2015), this scenario remains a possibility for streams in the MS4 area of KCMO. Another implication of these results is that when a stream site is near the cutoff threshold for the fully-supporting criteria, the impairment status of a site may experience more seasonal or year-to-year fluctuations. Our ANOVA results support this conclusion, because several sites in the MS4 transitional grouping were not significantly different than either the control or urban MS4 sites for most of the indicator metrics, and significant differences that did occur with these other site groups were not consistent across study years (Table 3).

In this study, we arbitrarily grouped sites to represent a progression in the varying stages of conversion from rural to urban land use that is occurring in the Kansas City metro region. We used this criteria because large cities often do not have a clear border between urban development zones (Theobald 2001) or the two types of storm sewer connectivity, and some investigators have demonstrated that localized reach-scale parameters and riparian land use in the immediate radial buffer zone are better predictors of biological effects than watershed-scale land cover measurements (Strayer et al. 2003, Roy et al. 2003, Deacon et al. 2005). Considering this, our site categories were designated to provide a general, descriptive framework to allow testing of EPT indicator responses across groups of similar sites. Even though our study did not attempt to quantify development activity or determine the direct causes for EPT declines, our results suggest that this progression in development parallels reductions in these sensitive groups and the declines in biotic condition based on MSCI scores. The urban MS4 stream sites contain a significantly reduced EPT macroinvertebrate fauna as compared to controls. Except for the MS4 control site at Line Cr., mean EPT abundances never exceeded 11% at MS4 sites and mean EPT taxa richness values were always in the non-supporting range with six or fewer taxa (Figs. 2–3). At Brush Cr. and Buckeye Branch, the only EPT taxa present were tolerant net-spinning caddisflies (Hydropsychidae: *Hydropsyche betteni*, *Cheumatopsyche* spp.), and both mayflies and stoneflies were absent. Other urban sites such as Searcy Cr., Hart Grove Cr. and Round Grove Cr. were dominated by pollution-tolerant organisms and rarely had more than two EPT taxa (Fig. 2). All of the study sites in the urban MS4 group were located in watersheds that had been previously developed into suburban and commercial land uses, and therefore the most rapid ecological changes in these streams may have occurred several years before the beginning of the MS4 stream assessment program. Discussions with MDNR personnel have indicated that reference streams in the CPBL ecological drainage unit do have some level of stream degradation and therefore, metric expectations are not as high when compared to some other regions in Missouri (D. Michaelson, pers. comm.). This conclusion would equate to some of the KCMO area streams meeting fully-supporting status, even though they may have experienced some measurable decline in stream quality since the beginning of urban development. Other literature suggests that loss of macroinvertebrate taxa, in particular EPT organisms, may occur in the early stages of urban development within a watershed (Brown et al. 2009, Cuffney et al. 2010), and our study results that show depressed EPT organisms at transitional sites with active land use conversion support this conclusion. Our MS4 transitional sites with impervious surface cover greater than non-urban controls do have intermediate values for the EPT metrics, yet they appear to have more year-to-year variability in these indicators. Temporal trends across all three evaluation years indicate non-urban and MS4 control sites consistently meet fully-supporting impairment status based on overall MSCI scores, yet none of our study sites consistently meet regional expectations for the EPT metrics. This is also supported by previous macroinvertebrate evaluations in Johnson County, Kansas, streams adjacent to the KCMO area that also cannot meet expectations for EPT metrics, many of which are similar in watershed size, imperviousness and land use as compared to our study sites (Poulton et al. 2007, Rasmussen et al. 2009, 2012).

Macroinvertebrate community indicators are often used as stand-alone evidence in assessing stream impairment because they represent a more direct measurement of aquatic life status as compared to point-based water quality analysis (Lenat 1988, Wallace et al. 1996, Engel and Voshell 2002). However, we recognize the importance of using multiple indicators for diagnosing the causes for declines in aquatic life, especially in urban streams where multiple co-occurring stressors associated with stormwater runoff and degraded water quality may occur intermittently or in pulses (Folt et al. 1999, Culp and Baird 2006). For this study, the macroinvertebrate indicators we evaluated are utilized in screening-level assessments of relative biotic condition that reflect the overall combined effects of multiple stressors that co-exist over longer periods of time. Therefore, analysis of water or habitat quality data and the identification of stressors in these streams were beyond the scope of this portion of the overall study. As compared to the remaining core indicator metrics used for evaluating Missouri streams, the EPT metrics are most often less than fully-supporting in these KCMO-area urban streams, leading to decreased MSCI scores and a decline in aquatic life impairment status. Even though we did not evaluate the effects of individual stressors on these indicators, several scenarios could result in an increase of EPT organisms at urban sites, including the improvement of stream condition due to changes in management practices, water quality abatements, or rehabilitation of riparian and bank habitat. Overall, our data suggest that the grouping of sites accurately reflects the ecological changes that are potentially affecting EPT organisms in the region, and that the KCMO sites evaluated in this study are likely experiencing the same declines in EPT richness and abundance that have been reported in other urbanizing watersheds in the U.S. (Morley and Karr 2002, Brown et al. 2009).

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Literature Cited

Allen, J.D., 2004. Landscapes and riverscapes: The influence of land use on stream ecosystems. Ann. Rev. Ecol. Evol Syst. 35: 257–284.

Barbour, M.T., Gerritsen, J., Snyder, B.D., and Stribling, J.B. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers–periphyton, benthic macroinvertebrates, and fish (2nd ed.): U.S. Environmental Protection Agency Report, EPA 841/B-99/002, 18 p.

Barbour, M.T., Stribling, J.B., and Karr, J.R. 1995. Multimetric approach for establishing biocriteria and measuring biological condition, *in* Davis, W.S., and Simon, T.P., eds., Biological assessment and criteria–tools for water resource planning and decision making: Boca Raton, Florida, Lewis Publication, chap. 6, p. 63–77.

Booth, D.B., and Jackson, C.R. 1997a. Urbanization of aquatic systems-impacts, solutions, and prognoses, Northwest Environmental Journal, 7: 93–118.

Booth, D.B., and Jackson, C.R. 1997b. Urbanization of aquatic systems – Degradation thresholds, stormwater detention, and the limits of mitigation. JAWRA 22(5): 1–20.

Brown, L.R., Cuffney, T.F., Coles, J.F., Fitzpatrick, F., McMahon, G., Steuer, J.J., Bell, A.H., and May, J.T. 2009. Urban streams across the USA: lessons learned from studies in 9 metropolitan areas, J. N. Am. Benthol. Soc., 28(4):1051–1069, DOI: 10.1899/08-153.1, Published online: 27 October 2009.

Cairns, J. Jr., and Pratt J.R. 1993. A history of biological monitoring using benthic macroinvertebrates. *in* Rosenberg, D.M., and V.H. Resh, eds. Freshwater Biomonitoring and benthic macroinvertebrates, Chapman and Hall, Inc., New York, pp. 10–27.

Chadwick, M.A., Dobberfuhl, D.R., Benke, A.C., Huryn, A.D., Suberkropp, K., and Thiele, J.E. 2006. Urbanization affects stream ecosystem function by altering hydrology, chemistry, and biotic richness: Ecological Applications 16(5): 1796–1807.

Crawford, C.G., Wangsness, D.J., and Martin, J.D. 1992. Recovery of benthic-invertebrate communities in the White River near Indianapolis, Indiana, USA, following implementation of advanced treatment of municipal wastewater. Arch. Hydrobiol. 126(1): 67–84.

Cuffney, T.F., Brightbill, R.A., May, J.T., and Waite, I.R. 2010. Responses of benthic macroinvertebrates to environmental changes associated with urbanization in nine metropolitan areas. Ecological Applications 20(5): 1384–1401.

Culp, J.M., and Baird D.J. 2006. Establishing cause-effect relationships in multi-stressor environments. *In:* Methods in Stream Ecology, 2nd edn (eds. F.R. Hauer and G.A. Lamberti), pp835-854. Elsevier, Oxford, UK.

Davies, S.P., and Jackson, S.K., 2006. The Biological Condition Gradient–a conceptual model for interpreting change in aquatic ecosystems. Ecol. Appl. 16 (4): 1251–1266.

Davis, W.S., and Simon, T.P., eds. 1995. Biological assessment and criteria–tools for water resource planning and decision making: Boca Raton, Florida, Lewis Publication, 415 p.

Deacon, J.R., Soule, S.A., and Smith, T.E. 2005. Effects of urbanization on stream quality at selected sites in the seacoast region in New Hampshire, 2001-03. U.S. Geological Survey Scientific Investigations Report 2005-5103. 18 p.

de Barruel, M., and West, N. 2003. A benthic macroinvertebrate survey of secret ravine: the effects of urbanization on species diversity and abundance. Water Resources Center Archives, restoration of rivers and streams, University of California eScholarship Repository, multi-campus research unit. 19 p.

DeShon, J.E. 1995. Development and application of the Invertebrate Community Index (ICI). *in* Davis, W.S., and Simon, T.P., eds., Biological assessment and criteria–tools for water resource planning and decision making: Boca Raton, Florida, Lewis Publication, chap. 15, p. 217–244.

Dyer, S.D., and Wang X. 2002. A comparison of stream biological responses to discharge from wastewater treatment plants in high and low population density areas. Envirn. Toxicol. And Chemistry 21(5): 1065–1075.

Edmunds, G.F., Jensen S.L., and Berner, L. 1976. The Mayflies of North and Central America. University of Minnesota Press, Minneapolis, MN. 344p ISBN 978-0-8166-5756-8, accessed July 2017 http://www.jstor.org/stable/10.5749/j.cttttqnh.

Engel, S.R. & Voshell, J.R. Jr. 2002. Volunteer Biological Monitoring: Can it accurately assess the ecological condition of streams? American Entomologist 48 (3): 164–177.

Evans-White, M.A., Dodds, W.K., Huggins, D.G., and Baker, D.S. 2009. Thresholds in macroinvertebrate biodiversity and stoichiometry across water-quality gradients in Central Plains (USA) streams: J. N. Am. Benthol. Soc. 28 (4): 855–868.

Folt, C.L., Chen, C.Y., Moore, M.V., and Burnaford J. 1999. Synergism and antagonism among multiple stressors. Limn. and Oceanog. 44: 864–877.

Freeland-Riggert BT, Cairns, S.H, Poulton, B.C., and Riggert, C.M. 2016. Differences Found in the Macroinvertebrate Community Composition in the Presence or Absence of the Invasive Alien Crayfish, *Orconectes hylas*. PLoS ONE 11(3): e0150199. doi:10.1371/journal.pone.0150199.

Garie, H.L., and McIntosh, A. 1986. Distribution of benthic macroinvertebrates in a stream exposed to urban runoff: Water Resources Bulletin 22: 447–455.

Graham, J.L., Stone, M.L., Rasmussen, T.J., and Poulton, B.C., 2010. Effects of wastewater effluent discharge and treatment facility upgrades on environmental and biological conditions of the upper Blue River, Johnson County, Kansas and Jackson County, Missouri, January 2003 through March 2009: U.S. Geological Survey Scientific Investigations Report 2010–5248, 85 p.

Gücker, B., Brauns, M., and Pusch, M.T. 2006. Effects of wastewater treatment plant discharge on ecosystem structure and function of lowland streams. J. N. Am. Benthol. Soc. 25(2): 313–329.

Hoekstra, J. M., Molnar, J. L., Jennings, M., Revenga, C., Spalding, M. D., Boucher, T. M., Robertson, J. C., Heibel, T. J., and Ellison, K. 2010. Molnar, J. L., ed. *The Atlas of Global Conservation: Changes, Challenges, and Opportunities to Make a Difference*. University of California Press. ISBN 978-0-520-26256-0.

Kansas Department of Health and Environment. 2008. Kansas integrated water quality assessment, Information available on the Web, accessed June 2017 at http://www.kdheks.gov/befs/download/2008IR_040108FINAL.pdf.

Karr, J.R., and Kerans B.L. 1991. Components of biological integrity: Their definition and use in development of an invertebrate IBI: Chicago, IL, U.S. Environmental Protection Agency Report 905-R-92-003 Environmental Sciences Division, 16 p.

Kerans, B.L., and Karr, J.R. 1994. A benthic index of biotic integrity (B-IBI) for rivers of the Tennessee valley. Ecological Applications 4: 768–785.

Klein, R.D. 1979. Urbanization and stream quality impairment: Water Resources Bulletin 15: 119–126.

Lenat, D.R. 1988. Water quality assessment using a qualitative collection method for benthic macroinvertebrates. J.N. Am. Benthol. Soc. 7: 222–233.

Lenat, D.R., and Crawford, K. 1994. Effects of land use on water quality and aquatic biota of three North Carolina Piedmont streams. Hydrobiologia 294: 185–199.

Lewis, M.A. 1986. Impact of a municipal wastewater effluent on water quality, periphyton, and invertebrates in the Little Miami River near Xenia, Ohio. Ohio J. Sci 86 (1): 2–8.

Lydy, M.J., Crawford, C.G., and Frey, J.W. 2000. A comparison of selected diversity, similarity and biotic indices for detecting changes in benthic-invertebrate community structure and stream quality. Arch. Environ. Contam. Toxicol. 39: 469–479.

Merritt, R.W., Cummins, K.W., and Berg, M.B. (eds). 2008. Aquatic Insects of North America, 4th edition. Kendall-Hunt Publishing, Dubuque, IA. 1158p.

Meyer, J.L., Paul, M.J., and Taulbee, K. 2005. Stream ecosystem function in urbanizing landscapes: J. N. Am. Benthol. Soc. 24(3): 602–612.

Missouri Dept. of Natural Resources (MDNR). 2010. Stream habitat assessment project procedure: Division of Environmental Quality, Environmental Services Program, Jefferson City, Mo., 40 p.

Missouri Dept. of Natural Resources (MDNR). 2012. Semi-quantitative macroinvertebrate stream bioassessment project procedure: Division of Environmental Quality, Environmental Services Program, Jefferson City, Mo., 29 p.

Missouri Dept. of Natural Resources (MDNR). 2016a. Taxonomic levels for macroinvertebrate identifications: Division of Environmental Quality, Environmental Services Program, Jefferson City, Mo., 40 p.

Missouri Department of Natural Resources (MDNR). 2016b. Missouri Integrated Water Quality Report and Section 303(d) list, 2016. Information available on Web, accessed July 2017, at http://dnr.mo.gov/env/wpp/waterquality/303d/docs/2016-ir-305b-report.pdf.

Moore, A.A., and Palmer, M.A. 2005. Invertebrate biodiversity in agricultural and urban headwater streams: Implications for conservation and management. Ecological Applications, 15(4), 2005, pp. 1169–1177.

Morley, S.A., and Karr, J.R. 2002. Assessing and restoring the health of urban streams in the Puget Sound basin. Conservation Biology 16(6): 1498–1509.

Ohio Environmental Protection Agency. 1987. Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters. Division of Water Quality Monitoring and Assessment, Columbus, Ohio.

Ohio Environmental Protection Agency. 1989. Addendum to biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters. Division of Water Quality Monitoring and Assessment, Columbus, Ohio.

Paul, M.J., and Meyer, J.L. 2001. Streams in the urban landscape: Annual Review of Ecology and Systematics, v. 32, p. 333–365.

Pennak, RW. 1989. Freshwater Invertebrates of the United States – Protozoa to Mollusca. 3rd edition. New York: John Wiley and Sons, Inc.; 1989.

Poulton, B.C., Rasmussen, T.J., and Lee, C.J. 2007. Assessment of biological conditions at selected stream sites in Johnson County, Kansas and Cass and Jackson Counties, Missouri, 2003 and 2004. USGS Scientific Investigations Report 2007-5108. 68 pp.

Poulton B.C., Allert, A.L., Besser, J.M., Schmitt, C.J., Brumbaugh, W.G., and Fairchild J.F. 2010. A macroinvertebrate assessment of Ozark streams located in lead-zinc mining areas of the Viburnum Trend in southeastern Missouri, USA. Environmental Monitoring and Assessment 163:619–641.

Poulton, B.C., Graham, J.L., Rasmussen, T.J. and Stone, M.L. 2015. Responses of Macroinvertebrate Community Metrics to a Wastewater Discharge in the Upper Blue River of Kansas and Missouri, USA. Journal of Water Resource and Protection, 7, 1195–1220. *http://dx.doi.org/10.4236/jwarp.2015.715098*.

Pratt, J.M., Coler, R.A., and Godfrey, P.J. 1981. Ecological effects of urban stormwater runoff on benthic macroinvertebrates inhabiting the Green River, Massachusetts: Hydrobiologia 83: 29–42.

Purcell, A.H., Bressler, D.W., Paul, M.J., Barbour, M.T., Rankin, E.T., Carter, J.L., and Resh, V.H. 2009. Assessment tools for urban catchments: Developing biological indicators based on benthic macroinvertebrates. JAWRA 45(2): 306–319.

Rasmussen, T.J., Poulton, B.C., and Graham, J.L. 2009. Quality of Streams in Johnson County, Kansas, and Relations to Environmental Variables, 2003–07: U.S. Geological Survey Scientific Investigations Report 2009-5235. 95 pp.

Rasmussen, T.J., Stone, M.S., Poulton, B.C., and Graham, J.L. 2012. Quality of streams in Johnson County, Kansas, 2002–10: U.S. Geological Survey Scientific Investigations Report 2012–5279, 103 p.

Richards, C., Johnson, L.B., and Host, G.E. 1996. Landscape-scale influences on stream habitats and biota: Canadian Journal of Fisheries and Aquatic Sciences 53: 295–311.

Rosenberg, D.M, and Resh, V.H., 1993. Introduction to freshwater biomonitoring and benthic macroinvertebrates, *in* Rosenberg, D.M, and Resh, V.H., eds., Freshwater biomonitoring and benthic macroinvertebrates, Chapman and Hall, Inc., New York, p. 1–9.

Roy, A.H., Rosemond, A.D., Paul, M.J., Leigh, D.S., and Wallace, J.B. 2003. Stream macroinvertebrate response to catchment urbanization (Georgia, U.S.A.). Freshwater Biology 48: 329–346

Sarver, R., Harlan, S., Rabeni, C.F., and Sowa S.P. 2002. Biological criteria for wadeable/perennial streams of Missouri. Missouri Department of Natural Resources, Air & Land Protection Division, Environmental Services Program, Jefferson City, Mo., 22 p.

SAS Institute, Inc. 2009. SAS/STAT® 9.2 User's Guide (2d ed.): Cary, N.C., SAS Institute Inc, 7,889 p.

Snedecor, G.W., and Cochran, W.G. 1982. Statistical methods. 7th edition. Iowa State Press, Ames, IA.

Sowa, S. P., Annis, G., Morey, M.E., and Diamond, D.D. 2007. A gap analysis and comprehensive conservation strategy for riverine ecosystems of Missouri. Ecological Monographs 77(3): 301–334.

Stewart, K.W., and Stark, B.P. 1993. Nymphs of North American Stonefly genera (Plecoptera), 2nd ed. University of North Texas Press, Denton.

Strayer, D.L., Beighley, R.E., Thompson, L.C., Brooks, S., and Nilsson, C. 2003. Effects of land cover on stream ecosystems: roles of empiracle models and scaling issues. Ecosystems 6: 407–423.

Suozzo, K. 2005. The use of aquatic insects and benthic macroinvertebrate communities to assess water quality upstream and downstream of the village of Stamford wastewater treatment facility. 38th Annual Report of the SUNY Oneonta Biological Field Station, Cooperstown, New York. pp141-151

Theobald, D. M. 2001. Land-Use dynamics beyond the American urban fringe. Geographical Review 91 (3): 544–564

Thorp, J. H., and Covich, A.P. 1991. Ecology and classification of North American Freshwater Invertebrates. 1st ed. Academic Press, San Diego, 930 pp.

U.S. Environmental Protection Agency. 2005. National Management Measures to Control Nonpoint Source Pollution from Urban Areas. United States Environmental Protection Agency Office of Water Washington, DC 20460 (4503F) EPA-841-B-05-004 November 2005

U.S. Environmental Protection Agency. 2007. MS4 Program Evaluation Guide. U.S. Environmental Protection Agency Office of Wastewater Management. EPA-833-R-07-003.

2007, 102p. www.epa.gov/sites/production/files/2015-11/ms4guide_withappendixa.doc

U.S. Govt. Printing Office. 2017. Stormwater Discharges. 40CFR 122.26(b)(8). https://www.ecfr.gov/cgi-bin/text-dx?type=simple;c=ecfr;cc=ecfr;rgn=div5;idno=40;q1=122.2;sid=f733bdee898692b798e007b2e50158d6;view=text;node=40%3A22.0.1.1.12#se40.24.122_126

Wallace, J.B., Grubaugh, J.W., and Whiles, M.R. 1996. Biotic indices and stream ecosystem processes: results from an experimental study.Ecol Appl. 1996;6(1):140–151. doi: 10.2307/2269560.

Walsh, C.R., Sharpe, A.K., Breen, P.F., and Sonneman, J.A. 2001. Effects of urbanization on streams of the Melbourne region, Victoria, Austrailia. I. Benthic macroinvertebrate communities, Freshwater Biology 46: 535–551.

Walsh, C.R., Roy, A.H., Feminella, J.W., Cottingham, P.D., Groffman, P.M., and Morgan, R.P. II. 2005a. The urban stream syndrome: current knowledge and a search for a cure. J. N. Am. Benthol. Soc. 24(3): 706–723

Walsh, C.R., Fletcher, T.D., and Ladson, A.R. 2005b. Stream restoration in urban catchments through re-designing stormwater systems: looking to the catchment to save the stream. J. N. Am. Benthol. Soc. 24:690–705.

Wang, L., and Kanehl, P. 2003. Influences of watershed urbanization and instream habitat on macroinvertebrates in cold water streams. J. AWRA, 39(5): 1181–1196

Wang, L, Lyons, J., and Kanehl, P. 2001. Impacts of urbanization on stream habitat and fish across multiple spatial scales. Environ. Management 28(2): 255–266

Wiggins, G.B. 1996. Larvae of the North American Caddisfly genera (Trichoptera), 2nd edition. University of Toronto Press, Toronto, Canada

Yoder, C.O., Miltner, R.J., and White, D. 1999. Assessing the status of aquatic life designated uses in urban and suburban watersheds. *In:* Everson, A. (eds). National conference on retrofit opportunities for water resource protection in urban environments, Chicago, Il. EPA/625/R-99/002