RESEARCH ARTICLE

Family-Level Benthic Macroinvertebrate Communities Indicate Successful Relocation and Restoration of a Northeast Iowa Stream

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ABSTRACT

A major stream relocation and restoration project was started in 2004 near Dorchester, Iowa. The project converted riparian cropland and stream bank trees to native tallgrass prairie vegetation while relocating Brook Creek to its original streambed. The goal of this project was to restore Brook Creek to conditions comparable with South Pine Creek, a nearby reference coldwater stream that was used as a model for Brook Creek. Benthic macroinvertebrates were monitored in 2005, 2007, 2010, and 2012 in both Brook Creek and South Pine Creek. Benthic macroinvertebrate family-level taxonomic richness, Ephemeroptera/Plecoptera/Trichoptera (EPT) family richness, and family-level biotic indices (FBI) were calculated. We found that Brook Creek's FBI values were lowered and EPT richness values increased significantly from 2005 to 2012, indicating establishment of a high quality benthic macroinvertebrate community. Benthic macroinvertebrate communities in Brook Creek became increasingly similar to South Pine Creek over the course of this study as evidenced by a principle component analysis and percent similarity, from a 28.72% similarity in 2005 to 62.54% similarity in 2012. These results demonstrate the successful reestablishment of a benthic macroinvertebrate assemblage following stream reconstruction and similarity to a high-quality reference stream.

Keywords: aquatic macroinvertebrates, family-level biotic index, stream restoration

Stream restoration is often used to combat the deterioration of waterways, but follow-up monitoring to evaluate its effectiveness is often lacking (Bernhardt et al. 2005). Stream restorations are often expensive and labor intensive, with over $1 billion per year being spent since 1990 on stream restoration projects nationwide (Bernhardt et al. 2005). Alexander and Allan (2006) reported a median cost of $12,957 for 1,345 stream restoration projects in the Upper Midwest, yet only 11% of these projects were monitored for success after restoration.

When post-project monitoring is conducted, restoration efforts have frequently been shown to improve water and habitat quality (Nerbonne and Vondracek 2001, Muotka et al. 2002, Purcell et al. 2002, Moerke et al. 2004). However, many restoration efforts result in incomplete success and long-term success is often unknown (Stranko et al. 2012). Questions remain whether restoration efforts are economically viable and ecologically sound, or if different techniques should be implemented (Stranko et al. 2012). In some cases, recovery of streams without human action has been as effective in restoration as intentional anthropogenic reconstructions (Friberg et al. 1998). Restoration projects vary widely in the techniques used, and information on many restoration projects is not available or comparable, and follow-up studies are infrequent (Bernhardt et al. 2005, Alexander & Allan 2006, Miller et al. 2010). The most common goals of restorations of Midwestern U.S. streams include bank stabilization, managing riparian zones for erosion, increasing in-stream habitat, improving water quality, and increasing fish populations and passage (Alexander & Allan 2006). Post-restoration efforts are needed to compare the most effective restoration techniques while determining their value in improving water quality and aquatic biodiversity.

Benthic macroinvertebrates offer an efficient way of measuring the quality of water affected by different land uses (Herringshaw et al. 2011). They are large enough to be collected easily and have a wide range of tolerance to varying degrees of pollution (Goodnight 1973). Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) are known collectively as EPT taxa and are orders of aquatic insects with gills that depend on the presence of high levels of dissolved oxygen in the water. Their presence or lack thereof is a particularly helpful indicator of dissolved oxygen levels and health of a stream (Goodnight 1973).

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In Iowa, 92% of total land area is used for producing row crops (Herringshaw et al. 2011). Agriculturally intensive landscapes often lead to increased nutrient runoff into streams and increased plant growth, resulting in lower dissolved oxygen levels (Herringshaw et al. 2011). Currently, streams and watersheds are facing increased risks of pollution (Wittman et al. 2013) from the rapid conversion of millions of acres of grassland, shrubland, and wetlands into cropland. The high demand for biofuels is partially behind this conversion due in part to subsidies and current high crop prices in the U.S. (Faber et al. 2012). This study took place in Allamakee County, Iowa, which has one of the highest rates of habitat loss in Iowa; between 30,001 and 50,000 acres (ca. 10% of the county) were converted to cropland between 2008 and 2011 (Faber et al. 2012). The conversion of these lands, including Conservation Reserve Program (CRP) land, into cropland removes buffer zones that filter farm runoff leading to pollution of nearby rivers and lakes (Faber et al. 2012). This decline in water quality has detrimental effects on biodiversity in the streams (Polhemus 1993, Alexander & Allan 2006, Miller et al. 2010, Herringshaw et al. 2011).

The goal of this study was to assess the effects of a major stream relocation, reconstruction, and streamside vegetation planting on the benthic macroinvertebrate assemblage in a steam near Dorchester, Iowa. This stream, Brook Creek, was relocated in August 2004 back to its original streambed from a ditch initially constructed in 1949 to create a bottomland cornfield (M. Osterholm, landowner, pers. comm.). The long-term goal of this restoration project is to restore Brook Creek to a condition comparable with South Pine Creek, a high quality cold-water trout stream that contains the only remaining original population of brook trout (*Salvelinus fontinalis*) endemic to northeast Iowa. The abundance and diversity of benthic macroinvertebrates of Brook Creek was assessed in relation to South Pine Creek over an eight-year span (2005–2012). We expected that relocating Brook Creek to its original streambed and establishing a stream bank with prairie vegetation would result in a high density and diversity of benthic macroinvertebrates, especially EPTs with low pollution tolerance.

Methods

Brook Creek Reconstruction and Restoration

Brook Creek is located on private land approximately 1 km northwest of Dorchester, Iowa, in Allamakee County at 43.48° N, 91.52° W (Figure 1). Brook Creek is located at the confluence of Duck Creek and Waterloo Creek. In 1949, this spring-fed stream (Figure 1, top) was channeled into a ditch along the road and the former meandering stream bed filled in and the area converted to an agricultural field (Figure 1, middle) that was farmed until 2003. By then, the non-crop areas were dominated by reed canary grass (*Phalaris arundinacea*), wild parsnip (*Pastinaca sativa*), Canada thistle (*Cirsium arvense*), and boxelder trees (*Acer negundo*).

Using the 1940s aerial photos, the former location Brook Creek streambed was defined (Figure 2, top), and then in late summer of 2004, trees were removed and earthmoving equipment used to excavate the 362 m long original stream bed, fill in the ditch, and contour the stream banks to a gradual 6:1 slope. The stream bed was solidified with 2- to 4-inch rock (Figure 2, middle) to create the riffle-run pool pattern similar to the South Pine Creek reference stream. Stream banks were stabilized with plugs of local ecotype prairie cordgrass (*Spartina pectinata*), and 2 ha of stream bank riparian area were overseeded with five additional species of native grasses and 26 species of native forbs found in sedge meadow and wet prairie areas in Northeastern Iowa using local ecotype seed (Table A1). As these plants became established, they improved instream habitat by holding the soil and providing increased cover (Figure 2, bottom). Prescribed burns, selective application of herbicides, and mowing have been used regularly to control non-native vegetation. All tree removal, seeding, herbicide application, mowing, and prescribed burning has been performed by Driftless Land Stewardship LLC (Bagley, WI). The lower end of Brook Creek near where it dumps into Duck Creek occasionally has significant silt deposited due to flooding from Duck Creek and Waterloo Creek. Silt was removed from riffles in the lower section of Brook Creek in 2006 and 2009, and additional rock was added in 2007 to some of those riffles. All samples from Brook Creek for this study were taken upstream in areas unaffected by silt. As of 2012, the riparian areas along the length of Brook Creek have been established into native tallgrass prairie vegetation (Figure 2, bottom).

South Pine Creek Reference Stream

South Pine Creek was used as a reference stream and is located approximately 13 km southwest of Brook Creek. Located in Winneshiek County, Iowa (43.37° N, 91.66° W) on land owned by the IDNR, South Pine Creek is a coldwater stream that contains the only surviving source population of native brook trout in Northeast Iowa. South Pine Creek was used as a model of riffle-run and pool lengths, widths, and depths in the reconstruction of Brook Creek during its relocation. The temperature, fall and flow rates of Brook Creek (mean temperature of 53.9°F; slope = 0.008; mean flow rate 0.8 cfs) are similar to South Pine Creek (mean temperature of 53.1°F; slope = 0.012; mean flow rate 1.4 cfs).

Macroinvertebrate Sampling

In 2005, 2007, 2010, and 2012, sampling of benthic macroinvertebrates was performed in both Brook Creek

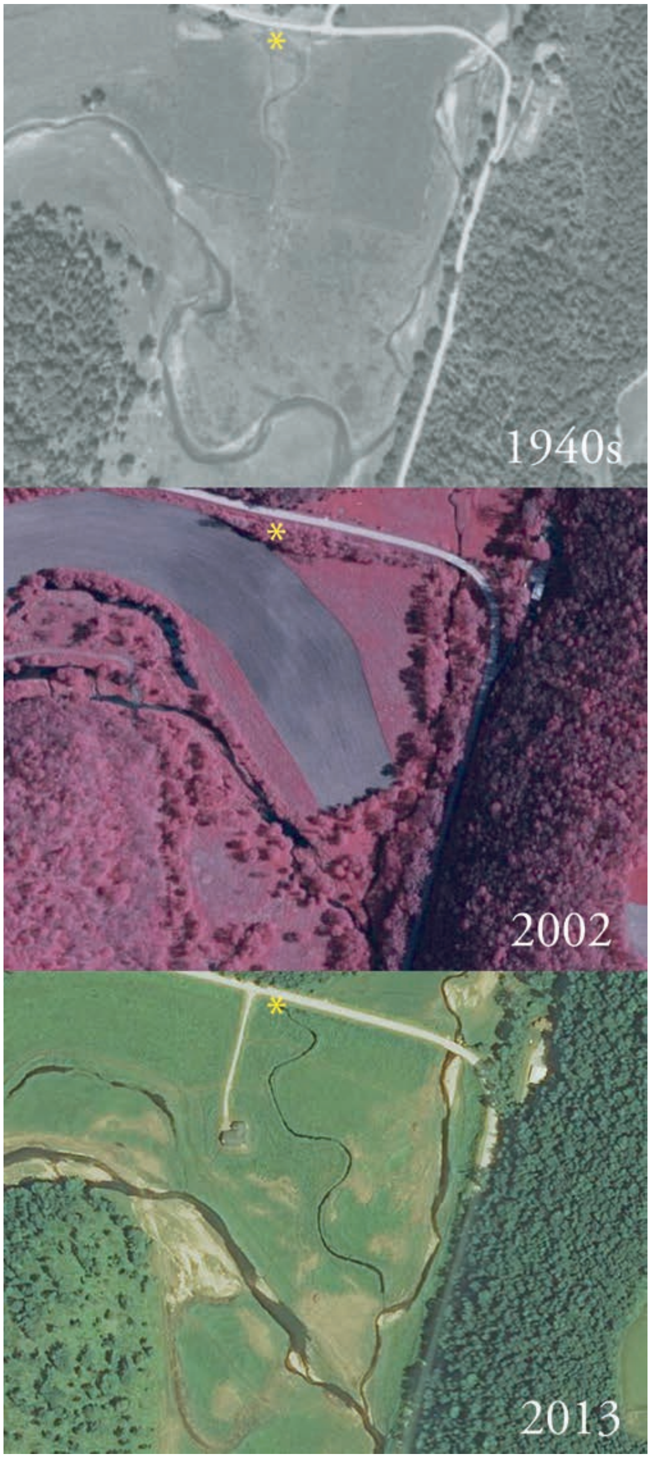

Figure 1. Aerial photos of Brook Creek in the 1940s (top), 2002 (middle), and 2013 (bottom), located between Waterloo Creek (coming from left) and Duck Creek (coming from upper right). Spring is indicated by an asterisk. Photos from Iowa Geographic Map Server (ortho.gis.iastate.edu/index.html).

Figure 2. Brook Creek in June 2003 (top) as a cornfield before restoration with creek ditched in tree line at far edge of field; after relocation (middle) and reconstruction in September 2004; and in August 2012 (bottom) lined by tallgrass prairie vegetation including prairie cord grass (*Spartina pectinata*).

and South Pine Creek using a 12 × 12-inch Surber sampler. Samples were collected from three riffle areas within each stream approximately once per month on four or five different dates each summer between late May and early September. Samples were preserved with 70% ethanol in a Ziploc® baggie and taken back to the lab where the samples were refrigerated until sorting and identification. In the lab, samples were cleaned to remove dirt and mud, were then sorted, and all benthic macroinvertebrates found in the sample were quantified and identified to order, family, and life stage using Voshell (2002), Bouchard (2004), and Merritt et al. (2008). Each specimen was identified to taxonomic family and assigned a tolerance value (TV) from Hilsenhoff (1987), Bouchard (2004), or Eyarin Jehamalar et al. (2010). A family-level biotic index (FBI) was then calculated (Hilsenhoff 1988). The FBI is a scale measuring water quality of a stream by assigning benthic macroinvertebrates a TV based on their response to organic pollution (Hilsenhoff 1988). Lower FBI values indicate higher water quality.

Statistical Analysis

Macroinvertebrate density (#/ft²), family-level taxonomic richness, and a FBI were calculated for three riffles in both Brook Creek and South Pine Creek for each year. Replicates for analysis were the combined samples from a given riffle within a year. The density and taxonomic richness of EPT taxa (Ephemeroptera, Plecoptera, and Trichoptera), were also determined. A two-way analysis of variance (ANOVA) was performed to compare taxonomic richness, EPT richness, and FBI between streams and across years, with planned contrasts between Brook Creek and South Pine Creek within each year. Shannon Diversity (H') and Pielou's Evenness (J') indices were calculated using log base 2 calculations for the overall benthic macroinvertebrate assemblage in both Brook Creek and South Pine Creek each year (Eckblad 1998). Percent similarity between streams within each year was also calculated using Eckblad (1998), while a principle components analysis (PCA) was performed using composition abundance data to summarize taxonomic similarities between stream communities and across years. All statistical analyses were performed using SPSS (2010).

Results

A total of 30,394 macroinvertebrate specimens were collected from Brook Creek and South Pine Creek in 2005, 2007, 2010, and 2012 representing 49 different taxa (Table 1). Mean density of benthic macroinvertebrates ranged from a low of 200.3/ft² in South Pine Creek in 2007 to a high of 816.1/ft² in Brook Creek, also in 2007 (Table 1).

Over the course of this study, family-level taxonomic richness in Brook Creek almost doubled, from an average of 11.7 (± 0.67 SE) taxa in 2005 to 20.7 (± 1.45 SE) taxa in 2012, while South Pine Creek taxonomic richness was generally higher but varied from 17.6 (± 1.2 SE) to 24.7 (± 3.3 SE) taxa between 2005–2012 (Table 1, Figure 3). There was a significant difference in taxonomic richness between streams ($F = 5.71$; df = 1, 16; $p = 0.03$) and among years ($F = 6.12$; df = 3, 16; $p = 0.006$), but the interaction between streams and years was not significant ($F = 1.12$; df = 3, 16; $p = 0.37$). Within year comparisons (Figure 3) revealed taxonomic richness in Brook Creek was less than South Pine Creek in 2005 ($F = 5.12$; df = 1, 16; $p = 0.038$), but comparable the other three years ($p > 0.05$).

EPT family-level taxonomic richness increased in Brook Creek from 2005 to 2012 but remained lower than EPT taxonomic richness in South Pine Creek (Figure 4). Between streams, EPT taxonomic richness was significantly greater in South Pine Creek in 2005 ($F = 11.57$; df = 1, 16; $p = 0.004$), 2007 ($F = 14.29$; df = 1, 16; $p = 0.002$), and 2010 ($F = 20.57$; df = 1, 16; $p < 0.001$) than Brook Creek. However, in 2012 ($F = 0.57$; df = 1, 16; $p = 0.46$) there was not a significant difference between the streams. There was also a significant difference in EPT taxa among years ($F = 9.46$; df = 3, 16; $p = 0.001$).

The family-level biotic index (FBI) calculations show an improved FBI in both Brook Creek and South Pine Creek from 2005 to 2012 (Figure 5). South Pine Creek had a significantly lower FBI and higher water quality than Brook Creek in 2005 ($F = 5.59$; df = 1, 16; $p = 0.031$), 2007 ($F = 15.23$; df = 1, 16; $p = 0.001$), 2010 ($F = 1.75$, df = 1, 16; $p = 0.0.37$), and 2012 ($F = 7.51$; df = 1, 16; $p = 0.015$). There was also a significant difference in FBI among years ($F = 8.04$; df = 3, 16; $p = 0.002$).

Overall, Brook Creek showed an increase in Shannon Diversity (H') from 2.54 in 2005 to 2.81 in 2012; however Pielou's Evenness Index (J') over this time indicated low evenness, suggesting that although H' diversity was increasing in Brook Creek, the number of individuals within the different taxonomic groups varied substantially (Table 1). South Pine Creek did not show an overall change in H', with values of 2.910 in 2005 to 2.905 in 2012.

Comparing percent similarity of taxa between Brook Creek and South Pine Creek each year shows that similarity increased with each subsequent sample year. In 2005 the streams were only 28.7% similar, but by 2012 percent similarity had increased to 62.5% (Table 1).

The principle components analysis (PCA) shows the Brook Creek benthic macroinvertebrate assemblage is becoming more like South Pine Creek (Figure 6) with the greatest separation distances indicating lowest similarity between the two streams in 2005 and the shortest distance between Brook Creek and South Pine Creek indicating highest similarity in 2012. The taxa that contributed the most to the first principle component were Glossosomatidae (Trichoptera) at 0.853; and Dytiscidae (Coleoptera) at −0.779.

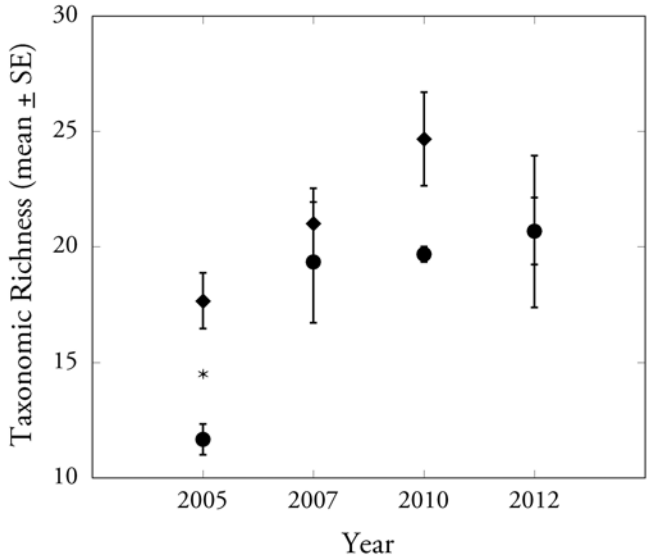

Figure 3. Family-level taxonomic richness values (mean ± standard error) for Brook Creek (•) and South Pine Creek (♦) in 2005, 2007, 2010, and 2012. * indicates a significant difference between streams with each year (planned contrasts, $p < 0.05$).

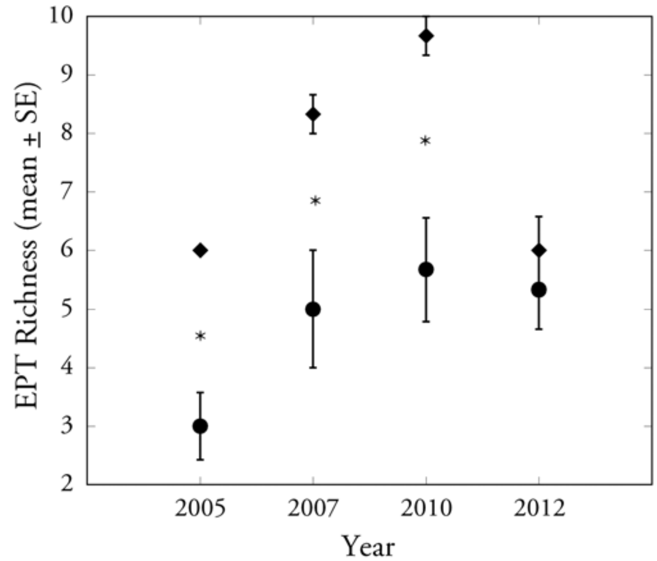

Figure 4. Ephemeroptera, Plecoptera, and Trichoptera (EPT) family-level taxonomic richness values (mean ± standard error) for Brook Creek (•) and South Pine Creek (♦) in 2005, 2007, 2010, and 2012. * indicates a significant difference between streams with each year (planned contrasts, $p < 0.05$).

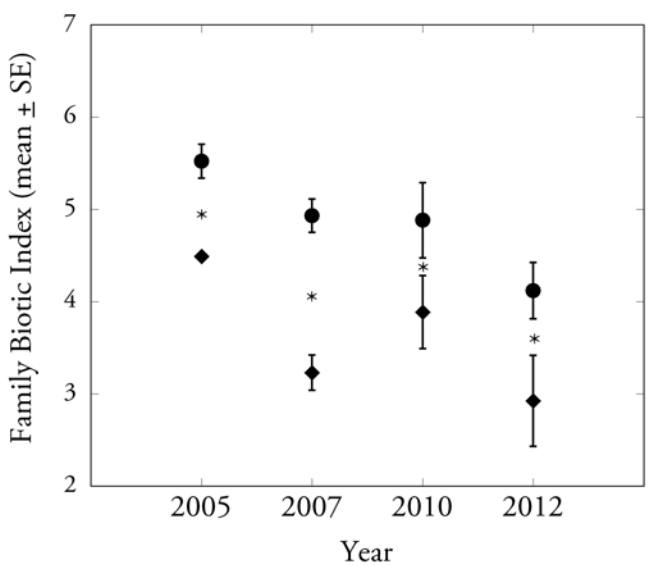

Figure 5. Family-level Biotic Index (FBI) (mean ± standard error) for Brook Creek (•) and South Pine Creek (♦) in 2005, 2007, 2010, and 2012. * indicates a significant difference between streams with each year (planned contrasts, $p < 0.05$).

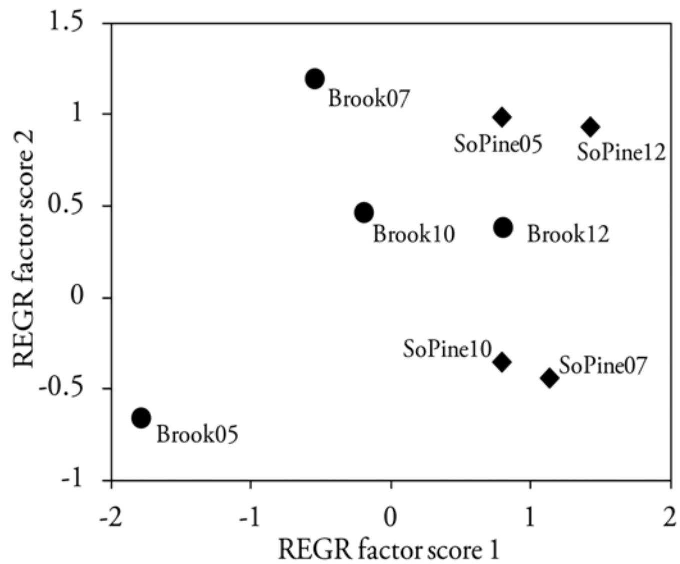

Figure 6. Principle components analysis (PCA) plot based on community diversity. The closer Brook Creek (•) and South Pine Creek (♦) within the same year are positioned on the graph indicates higher similarity in community composition between those streams.

The taxa that contributed most to the second principle component were Chironomidae (Diptera) at 0.690, Heptageniidae (Ephemeroptera) at -0.805, and Gerridae (Hemiptera) at -0.805.

Discussion

We hypothesized that the benthic macroinvertebrate community of Brook Creek would improve after habitat restoration efforts, and that these improvements would be reflected by lower FBI values, higher taxonomic richness, higher EPT richness values, and increased Shannon diversity indices. We also expected that Brook Creek would become increasing similar to the model reference stream, South Pine Creek. Brook Creek had dramatic increases in taxonomic richness from 2005 to

Table 1. Family-level taxonomy, tolerance values (TV), and counts of all benthic macroinvertebrates collected from Brook Creek and South Pine Creek in 2005, 2007, 2010, and 2012.

				2005		2007		2010		2012		
Class	**Order**	**Family**	**TV**	**Brook**	**South Pine**	**Brook**	**South Pine**	**Brook**	**South Pine**	**Brook**	**South Pine**	**Totals**
Hirudinea			10	1	7	40	4	204	3	24	4	287
Oligochaeta			8	0	2	1	59	27	17	3	0	109
Arachnida	Acariformes	Hydracarina	4	4	8	64	11	132	59	40	72	390
Bivalvia		Sphaeriidae	7	0	0	0	4	0	0	0	13	17
Crustacea	Amphipoda	Gammaridae	4	77	44	2599	62	1284	694	959	96	5815
Crustacea	Amphipoda	Hyalellidae	8	0	0	0	0	0	0	0	25	25
Crustacea	Isopoda	Asellidae	8	0	0	0	1	2	340	1	166	510
Gastropoda	Prosobranchia	Viviparidae	7	0	0	13	1	0	1	0	0	15
Gastropoda	Pulmonata	Lymnaeidae	7	0	0	0	0	0	1	10	5	16
Gastropoda	Pulmonata	Physidae	7	784	2	683	9	722	185	105	29	2519
Gastropoda	Pulmonata	Planorbidae	7	0	0	3	0	0	6	7	7	23
Insecta	Coleoptera	Dryopidae	4	0	0	0	0	0	5	0	0	5
Insecta	Coleoptera	Dytiscidae	5	69	15	73	9	6	2	16	5	195
Insecta	Coleoptera	Elmidae	5	48	24	156	44	6	21	52	82	433
Insecta	Coleoptera	Haliplidae	7	0	0	1	1	2	0	0	0	4
Insecta	Coleoptera	Hydrophilidae	5	0	1	0	0	0	1	0	0	2
Insecta	Diptera	Athericidae	2	0	0	8	8	0	4	0	2	22
Insecta	Diptera	Ceratopogonidae	6	1	3	3	0	20	0	4	1	32
Insecta	Diptera	Chironomidae	6	480	175	1006	267	977	355	608	1514	5382
Insecta	Diptera	Culicidae	8	0	0	0	0	0	0	2	0	2
Insecta	Diptera	Empididae	6	0	1	1	0	11	6	0	5	24
Insecta	Diptera	Ephydridae	6	0	0	0	0	2	3	0	4	9
Insecta	Diptera	Muscidae	6	2	5	3	0	3	6	0	24	43
Insecta	Diptera	Psychodidae	10	0	8	12	0	3	1	4	1	29
Insecta	Diptera	Ptychopteridae	7	0	0	0	0	0	0	1	0	1
Insecta	Diptera	Simuliidae	6	695	448	1091	51	8	68	24	169	2554
Insecta	Diptera	Stratiomyidae	8	0	0	21	0	1	0	1	0	23
Insecta	Diptera	Tabanidae	6	0	0	0	1	1	0	2	0	4
Insecta	Diptera	Tipulidae	3	148	28	5	1	1	0	13	1	197
Insecta	Ephemeroptera	Baetidae	4	750	1298	1250	263	57	385	69	318	4390
Insecta	Ephemeroptera	Ephemerellidae	1	0	0	7	151	0	1	0	62	221
Insecta	Ephemeroptera	Heptageniidae	4	0	0	0	3	0	0	0	0	3
Insecta	Ephemeroptera	Siphlonuridae	7	1	304	0	0	0	6	0	0	311
Insecta	Hemiptera	Corixidae	9	0	0	5	0	3	0	1	0	9
Insecta	Hemiptera	Gerridae	5	0	0	0	1	0	0	0	0	1
Insecta	Hemiptera	Veliidae	6	0	0	1	0	0	0	0	0	1

Table 1, continued.

Class	Order	Family	TV	2005		2007		2010		2012		Totals
				Brook	South Pine	Brook	South Pine	Brook	South Pine	Brook	South Pine	
Insecta	Odonata	Coenagrionidae	3	0	1	0	0	0	0	0	0	1
Insecta	Plecoptera	Perlodidae	2	0	0	0	0	0	2	0	0	2
Insecta	Trichoptera	Brachycentridae	1	22	275	220	657	350	669	375	2864	5432
Insecta	Trichoptera	Glossosomatidae	0	0	28	0	0	7	127	37	109	308
Insecta	Trichoptera	Hydropsychidae	4	3	13	23	21	8	49	15	57	189
Insecta	Trichoptera	Hydroptilidae	4	1	0	0	68	10	27	5	10	121
Insecta	Trichoptera	Limnephilidae	4	0	79	4	46	14	42	100	69	354
Insecta	Trichoptera	Odontoceridae	0	0	0	20	28	0	1	12	0	61
Insecta	Trichoptera	Polycentripodidae	6	0	0	32	32	0	5	0	0	69
Insecta	Trichoptera	Lepidostomatidae	1	0	0	0	0	0	46	0	0	46
Insecta	Trichoptera	Sericostomatidae	3	0	0	0	0	23	41	0	0	64
Adenophorea			5	0	1	0	0	0	0	38	80	119
Turbellaria			4	0	0	0	0	0	0	5	0	5
Avg Taxa Richness				11.67	17.67	19.33	21.00	19.67	24.67	20.67	20.67	
Avg EPT Richness				3.00	6.00	5.00	8.33	5.67	7.33	5.33	6.00	
FBI				5.50	4.49	4.85	3.17	5.16	4.08	4.24	3.20	
Shannon Diversity Index (H')				2.55	2.91	2.72	3.08	2.81	3.32	2.90	2.91	
Pielou Evenness Index (J')				0.64	0.66	0.57	0.66	0.55	0.66	0.58	0.60	
Percent Similarity				28.72		42.91		54.2		62.54		30394

2012 to levels comparable with South Pine Creek. EPT family-level taxonomic richness also increased in Brook Creek by 2012. While Brook Creek still had lower EPT richness values than South Pine Creek in 2012, the differences between the two streams were no longer significant. FBI values indicated an improved water quality in both Brook Creek and South Pine Creek over the course of the study, but by 2012 there was no significant difference in FBI values between the two streams. The Shannon diversity values suggest the diversity of the Brook Creek benthic macroinvertebrate community is becoming more like the diversity in South Pine Creek. In this study, restoration efforts were clearly successful as a result of habitat establishment in Brook Creek as measured by benthic macroinvertebrate communities.

Percent similarity values and PCA also both show Brook Creek becoming increasingly similar to South Pine Creek as this habitat restoration becomes established. By 2012, the streams had the most similar benthic macroinvertebrate communities with a 62.5% similarity. If this trend continues, Brook Creek will continue to become more similar in benthic macroinvertebrate composition to South Pine Creek over the next few years.

We did not expect to observe a change in FBI values for South Pine Creek. To our knowledge, South Pine Creek did not undergo any major restoration efforts during this time, yet this stream also decreased in FBI values, suggesting a change in water quality in the South Pine Creek watershed during our study. The humpless case-maker caddisfly (Trichoptera: Brachycentridae) increased dramatically in South Pine Creek from 2005 to 2012 and likely accounted for this change in the South Pine Creek FBI.

The effectiveness of stream restoration projects is often highly disputed and results of restoration efforts are mixed (Moerke et al. 2004). Stream restoration is costly and time consuming, and leaving the streams to natural recovery without human assistance can be effective (Friberg et al. 1998). Yet our study demonstrates that the relocation and reconstruction of a historical stream can restore the benthic macroinvertebrate composition to that of a high quality reference stream. In California, improved habitat and biological conditions were also found in a restored stream when compared to an unrestored control site (Purcell et al. 2002). As was observed in our study, benthic macroinvertebrate taxonomic richness at the restored stream site had become similar to a reference creek over time (Purcell et al. 2002).

Other studies have shown dramatic changes in the composition of invertebrate communities after restoration with more invertebrates with lower pollution tolerance values moving into restored sites (Muotka et al. 2002, Sarriquet et al. 2007). Muotka et al. (2002) studied the long-term recovery of benthic invertebrate communities after an instream restoration and found a relatively rapid (less than 10 years) recovery of habitat structure and associated macroinvertebrate communities. Comparably, Brook Creek showed similarly dramatic improvement in the restoration of benthic macroinvertebrate communities within this eight-year study.

Nerbonne and Vondracek (2001) studied the effects of best management practices in agriculture compared with conventional agricultural farm practices on stream biota and sediment levels. They found that stream biotic indicators were not necessarily influenced by localized restorations, but improvements in the entire watershed were necessary for changes in indicator biota such as EPT to be apparent. In this study, Brook Creek showed this apparent successful response to watershed restoration. Given the small length of this steam and small size of its "watershed" (< 2 ha), it is located entirely within a restored prairie planting area.

With the multitude of stream restoration projects under construction, further research is needed to monitor the efficacy of stream restorations. With increased monitoring of projects before and after restoration, documented success can provide support for improving habitat and water quality using stream restorations. Pre-restoration baseline benthic macroinvertebrate data from the ditched Brook Creek would have been helpful in this study, but were not available, so South Pine Creek was used as a reference model for this restoration. Although prevention of agricultural and urban impacts on streams may be the best way to preserve local stream biodiversity and maintain water quality (Stranko et al. 2012), these impacts are often uncontrollable and restoration is needed. Our study demonstrated the potential for stream restoration to be successful in improving both habitat and the biodiversity of benthic macroinvertebrates associated with high water quality.

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Table A1. List native sedge meadow and wet prairie plant species planted from local ecotype seed in the 2-ha stream riparian planting along Brook Creek, IA, USA.

Scientific Name	Common Name
Allium canadense	wild onion
Andropogon gerardii	big bluestem
Anemone canadensis	Canada anemone
Aster ericoides	heath aster
Aster laevis	smooth aster
Aster novae-angliae	New England aster
Aster oolentangiensis/azureus	sky-blue aster
Aster urophylus/sagittifolius	arrow-leaved aster
Desmodium canadense	Canada (showy) tick-trefoil
Galium boreale	northern bedstraw
Helianthus grosseseratus	sawtooth sunflower
Helianthus strumosus	pale-leaved sunflower
Heuchera richardsonii	alum-root
Liatris pycnostachya	prairie blazing star
Monarda fistulosa	wild bergamot
Panicum virgatum	switch grass
Phlox pilosa	prairie phlox
Pycnanthemum virginianum	mountainmint
Ratibida pinnata	yellow coneflower
Rosa arkansana	prairie wild rose
Rosa blanda	wild rose
Rosa carolina	pasture rose
Rudbeckia hirta	black-eyed susan
Schizachyrium scoparium	little bluestem
Silphium laciniatum	compass plant
Solidago nemoralis	oldfield goldenrod
Solidago rigida	stiff goldenrod
Sorghastrum nutans	Indian grass
Sporobolis heterolepis	prairie dropseed
Thalictrum dasycarpum	purple meadow-rue
Veronicastrum virginicum	Culver's root