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A step in the right direction: streambank restoration efforts at the Botanical Garden of the Ozarks

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Abstract

The Botanical Garden of the Ozarks (BGO) is a unique destination in Northwest Arkansas that draws more than 80,000 visitors a year. While the BGO manages low-input practices, run-off from pesticide application and synthetic fertilizers containing phosphorus and nitrogen are of concern to water quality, habitat, and overall ecological interactions of the BGO streambanks and adjacent Hilton Creek, which flows directly into Lake Fayetteville. One way to reduce pollution to waterbodies is through the use of riparian buffers. This project sought to establish a riparian buffer immediately adjacent to a portion of Hilton Creek in an effort to improve ecological functions and water quality. The hypothesis of this study is that the streambank restoration will increase plant abundance and diversity and improve riparian habitat quality, thus enhancing ecological functions of the Hilton Creek streambank. Pre- and post-restoration assessments were conducted to test this hypothesis. A streambank riparian habitat quality assessment was adapted from the Qualitat del Bosc de Ribera' (in English, 'Riparian Habitat Quality', (QBR)) index and species diversity values based from on-site plant species inventories were analyzed using a Shannon–Wiener Index of diversity. Overall, the pre-restoration QBR index value was calculated as 55 out of 100 and post-restoration QBR index value was calculated as 65 out of 100, suggesting an immediate improvement in riparian habitat quality. Inventoried plant species equated to a pre-restoration Shannon–Wiener Index of diversity value of 2.13, while the post-restoration Shannon–Wiener Index of diversity equaled 2.91, indicating an increase in species diversity. Water quality parameters were recorded to establish baseline values for Hilton Creek to encourage future monitoring of the project site as the streambank restoration matures.

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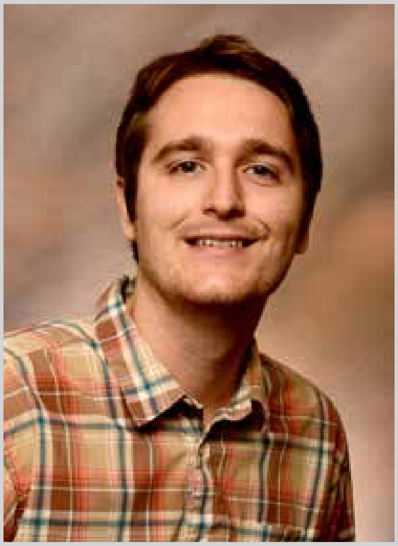
Meet the Student-Authors



Dylan Milholen

I grew up in Hot Springs, Arkansas and graduated from Lakeside High School in 2011. I have since graduated from the University of Arkansas in May 2016 with a B.S. in Environmental, Soil and Water Science, and a minor in Sustainabilty. During the summer of 2015, I received a Bumpers College travel award to conduct research in Pelotas, Brazil at Universidade Federal de Pelotas in an analytical biochemistry lab. I served as the Dale Bumpers College Ambassador for the Department of Crop, Soil, and Environmental Sciences, 2015-2016. I am highly interested in the transport and the transformation of chemicals and pollutants in the environment and their interactions in soil and water interfaces. I am thankful for guidance from Lisa S. Wood throughout my academic career and with this project. I am indebted to the several other professors I have worked with and learned from throughout my academic career, but a special thank you is owed to David Miller, Nilda Burgos, Esten Mason, all University of Arkansas Professors and Fabio Chaves, UFPel Professor, for their central facilitation in my intellectual growth as a student.

I was born in Dallas, Texas and graduated with honors from Plano West Senior High School. I began my time as an Environmental, Soil, and Water Science student at the University of Arkansas in the fall of 2013. I am currently the president of the Undergraduate Crop, Soil, and Environmental Science (CSES) club as well as a member of the Bumpers College Honors Program. In the summer of 2015 I participated in a four-week ecology program in Edinburgh, Scotland that allowed me to gain experience in field research and environmental policy. It was during this time abroad that I decided to pursue a career in environmental law. I have always felt passionately about the environment and I am thankful that the University of Arkansas has given me the opportunity to gain the knowledge and skills necessary for me to be a steward of this earth. I thank Dr. Wood for all of her support and guidance throughout this project. Dr. Wood has been an immensely wonderful presence throughout my undergraduate years as she has also served as my honors mentor, professor, and CSES club advisor.

Madison Brown

Introduction

The Botanical Garden of the Ozarks (BGO) is a unique destination in Northwest Arkansas that draws more than 80,000 visitors a year (BGO, 2015). According to BGO, the site includes over 40 acres with 12 themed gardens and borders Hilton Creek, which flows directly into Lake Fayetteville. While the BGO manages low-input practices by applying as little fertilizers and pesticides as possible to sustain healthy plant growth, run-off from pesticide application and synthetic fertilizers containing phosphorus and nitrogen are of concern to water quality, habitat, and overall ecology of the site. Excess nitrogen and phosphorus from fertilizers, and pollutants from pesticides frequently bond to soil particles that are deposited in nearby waterbodies from surface runoff (Hawes and Smith, 2005). One way to reduce pollution to waterbodies is through the use of riparian buffers (Cunningham et al., 2009).

A streambank restoration consisting of multiple vegetative species was designed to implement a functioning riparian buffer at the BGO. Riparian vegetation slows sediment-rich runoff and, depending upon buffer width and vegetative complexity, may absorb 50% to 100% of sediments as well as the nutrients and pollutants attached to them (CRJC, 2005). The literature suggests that fairly narrow riparian buffers (i.e., <30 m) can adequately provide multiple ecological functions (USACE, 1991). Ecological functions such as promotion of aquatic life, stream temperature control, and terrestrial wildlife habitat from vegetative diversity are central benefits of riparian buffers (Wenger, 1999).

This project sought to establish a riparian buffer immediately adjacent to a portion of Hilton Creek in an effort to improve ecological functions and water quality. The hypothesis of this study is that the streambank restoration will increase plant abundance and diversity and improve riparian habitat quality, thus enhancing ecological functions of the Hilton Creek streambank. The Qualitat del Bosc de Ribera' (QBR) index (in English, 'Riparian Habitat Quality') serves the purpose of providing a simple method to evaluate riparian habitat quality (Munné et al., 2003). A larger QBR index indicates greater riparian habitat quality. It is necessary to catalog streambank vegetative species pre- and post-restoration to test the hypothesis that the streambank restoration will increase plant abundance and diversity of the site. The Shannon–Wiener Index of diversity is a widely used index for comparing species diversity between habitats (Clarke and Warwick, 2001). A greater Shannon–Wiener Index of diversity indicates greater species diversity.

The objectives for this project were 1) to assess the streambank riparian habitat quality by comparing a pre-assessment QBR index (Munné et al., 2003) and a post-assessment QBR index, 2) catalog streambank vegetative species diversity using a Shannon–Wiener Index of diversity (Krebs, 1989), and 3) to measure baseline water quality parameters including temperature, dissolved oxygen, specific conductance, and pH for Hilton Creek adjacent to the streambank restoration site. It is essential to assess streambank riparian habitat quality in order to test the hypothesis that the streambank restoration will improve riparian habitat quality.

Materials and Methods

Initial Assessment

The streambank restoration area was divided into three zones perpendicular to the stream: Zone A (1.3 wide × 10.7-m long, variable slope of 0-2%) was located at the top of the streambank; Zone B (2.7 wide × 10.7-m long, variable slope of 40-45%) was located along the steep sideslope of the streambank; and Zone C (1.3 wide × 10.7-m long, variable slope of 0-2%) was located immediately adjacent to the stream. LaMotte soil test kits Code 5930-01 and Code 5931-01 (LaMotte Company® STH, USA) were used to measure total nitrogen and phosphorus levels, respectively. Soil pH was measured using the LaMotte kit, Code 5935-01. Measurements were taken from a discreet soil sample collected prior to restoration to better understand the soils present at the riparian site and any factors limiting vegetative growth. Two grams of soil collected with the test kit spoon from the top 10 cm of soil at the geographical center of Zone C was used as the discreet sample.

The QBR Index

The streambank riparian habitat quality assessment was adapted from the QBR index (Munné et al., 2003). A QBR index comparison was conducted pre- and post-restoration (18 March and 16 April 2016). The QBR index is based on four components of riparian habitat: 1) total riparian vegetation cover, 2) cover structure, 3) cover quality and 4) channel alterations, each given a score from 0 to 25 which are added to give a total score that varies between 0% and 100% potentially assigned corresponding to total percent riparian habitat quality.

A line-transect sampling method adapted from Thomas et al. (2002) was used to calculate total percent riparian vegetation cover and cover structure. For the line-transect sampling method used for components 1 and 2, a measuring tape was placed parallel to Hilton Creek running along the middle of each zone (A, B, and C). At each 0.107 m it was noted if vegetation touched the measuring tape (touching) or not (not touching). Equation 1 was used to find the percent cover for zones A, B, and C which were then averaged to show total riparian vegetation cover and total tree cover.

$$\% \text{ cover} = \left(\frac{\text{touching}}{\text{total marks}}\right) * 100 \qquad \text{Eq. (1)}$$

The total riparian vegetation cover was scored: 25 if >80% of vegetative riparian cover was present at the riparian site, 10 if 50–80% of riparian cover was present, 5 if 10–50% riparian cover was present, and 0 if <10% of riparian cover was present at the riparian site. Cover structure was scored: 25 if >75% tree cover was present, 10 if 50–75% tree cover or 25–50% tree cover with 25% of riparian area covered by shrubs, 5 if tree cover was lower than 50% but shrub cover was at least between 10% and 25%, and 0 if <10% of either tree or shrub cover was present at the riparian site. Again, the percentage cover was totaled from only tree and shrub vegetation touching the measuring tape as previously described.

Components 3 and 4 were calculated based on visual site appearance and matched with the corresponding four scores (0, 5, 10, and 25). For component 3, the size of the riparian area was first noted based on its closest compatibility with three given selection types listed in Munné et al. (2003)—type 1, type 2, and type 3. Type 1 is described as a small riparian habitat (i.e., 25-900 m^2). Type 2 is described as a mid-range riparian habitat (i.e. 901-3600 m^2) and Type 3 is described as a large riparian habitat (i.e., >3600 m^2). After selecting the closest corresponding type of the riparian area, the cover quality (component 3) was scored. Cover quality was scored: 25 if the number of native tree species for type 1 was >1, for type 2 was >2, and for type 3 was >3; 10 if the number of native tree species for type 1 was = 1, for type 2 was = 2, and type 3 was = 3; 5 if the number of native tree species for type 1 was = 0, for type 2 was = 1, and type 3 was = 1 to 2; and 0 if there was an absence of native trees at the riparian site for all types

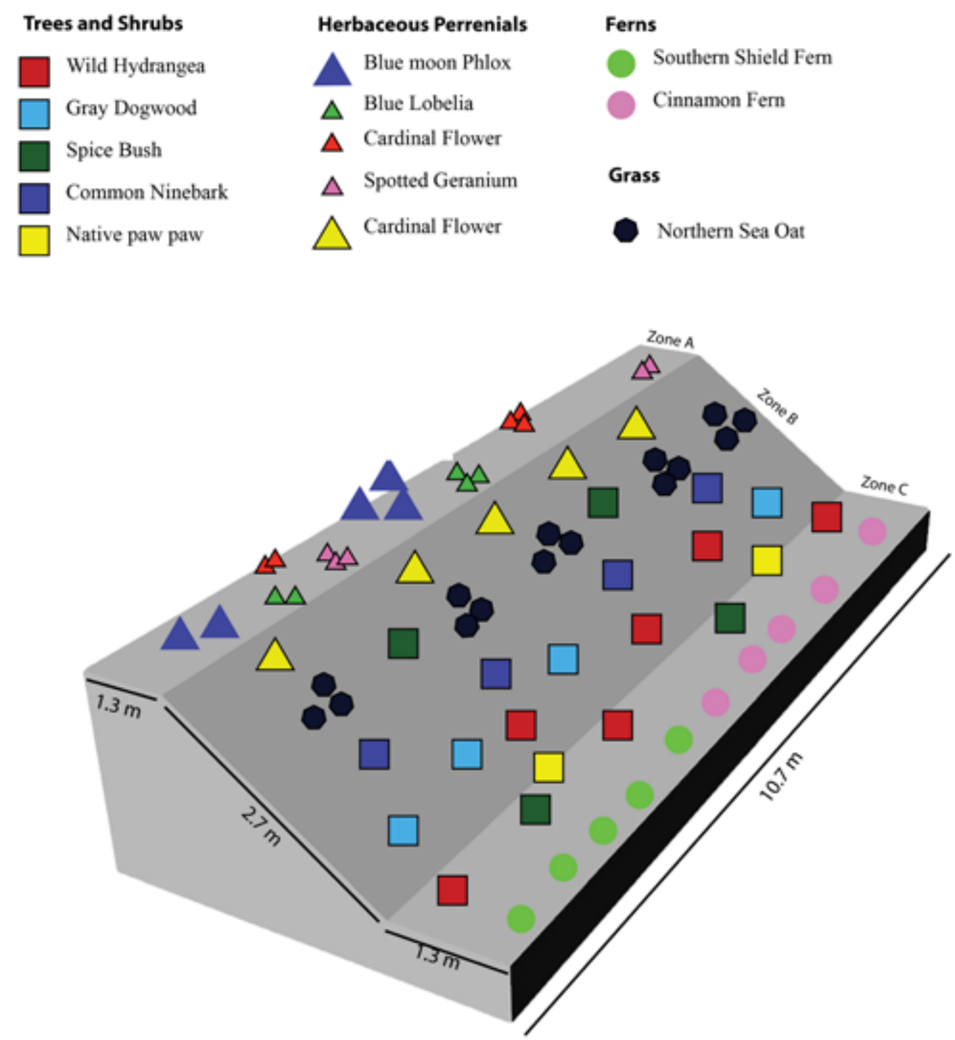


Fig. 1. Three-dimensional streambank restoration planting design using Rhinoceros® 5 and Adobe® Illustrator.

(1, 2, and 3). Channel alterations (component 4) were scored: 25 if an unmodified river channel existed, 10 if fluvial terraces were modified and constraining the river channel, 5 if the channel was modified by rigid structures along the margins, and 0 if it was a channelized stream. After scoring each of the four components, scores are added together to get a total score out of 100.

The Shannon–Wiener Index of Diversity

On-site plant species inventories were recorded (18 March and 5 April 2016) with the help of the BGO staff horticulturist. From these inventories, Shannon–Wiener Indices of diversity were calculated. The Shannon–Wiener Index of diversity (Eq. 2) represents the plant species diversity within the streambank restoration area. The index was calculated by determining the proportion each species contributes to the total population. If *S* is the total number of species in the sample, diversity is:

$$H = -\sum_{n=1}^{s} (P_i)\left|\ln P_i\right| \qquad \text{Eq. (2)}$$

where the summation sign Σ indicates that the product ($P_i \ln P_i$) is calculated for each species in turn and these products are summed together. The P_i is the proportion of individuals of each species relative to the number of individuals in the whole population. The number of plant species, *S*, and number of individuals per species were recorded 18 March and 5 April 2016 for the entire streambank restoration area (irrespective of zones) and quantified compared to the total individuals for the entire streambank restoration area, P_i. Native plant species purchased from White River Nursery and obtained from the BGO property were planted on 5 April 2016 in accordance with the design shown on Fig. 1. The recent plantings were included in the 5 April plant species inventory.

Baseline Water Quality Parameters

The methods used to measure water quality parameters in Hilton Creek, adjacent to the restoration site were adapted from the Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers (Barbour et al., 1999). In-stream measurements of dissolved oxygen, pH, specific conductance, and temperature (°C) were taken three times during the project, (7 Feb. 18 March and 16 April 2016) using a Sonde (YSI 600XLM®, USA) in accordance with Form 1: Physical Characterization/Water Quality Field Data Sheet, from APPENDIX A-1: Habitat Assessment and Physicochemical Characterization Field Data Sheet A-6 (Barbour et al., 1999). Each of the measurements was taken in replicates of three at three locations within Hilton Creek, representative of upstream (35 m upstream of the center of Zone C), midstream (center of Zone C), and downstream (35 m downstream of the center of Zone C) locations and then averaged. One-way analysis of variance (ANOVA) was run to analyze main effects of sampling time averaged across locations and location averaging the values across sampling time using JMP® Pro.

Fig. 2. Hilton Creek streambank at the Botanical Gardens of the Ozarks, Fayetteville, Arkansas shown pre-restoration, 7 Feb. 2016.

Results and Discussion

Initial Assessment

The Hilton Creek streambank pre-restoration site was devoid of vegetation with exposed soil, susceptible to erosion (Fig. 2). Post-restoration holds a diversity of native vegetation providing significant ground cover to minimize erosion (Fig. 3). Soil test results from one discreet sample from the geographical center of Zone C indicated the soil contained approximately 81.82 and 84.07 (kg/ha) of nitrate and phosphorus respectively, and had a pH of 6.9. Soil test values confirmed the site was suitable for planting desired native trees, shrubs, herbaceous perennials, ferns, and grasses arranged in the design (Fig. 1).

The QBR Index

Pre-restoration QBR index value for component 1) total riparian cover was calculated as 14% riparian cover resulting in 5 points out of a possible 25. Pre-restoration QBR index value for component 2) cover structure was calculated as 2% tree and 1% shrub cover resulting in 0 points out of a possible 25. Pre-restoration QBR index value for component 3) cover quality was scored 25 points out of 25 possible as greater than one native tree species (n = 2) was present, after matching the streambank restoration area to a type 1. Pre-restoration QBR index value for component 4) channel alteration was scored 25 points out of 25 since the stream channel boundaries appeared unmodified by human alterations.

Post-restoration QBR index value for component 1) was calculated as 64% riparian cover granting 10 points. Post-restoration QBR index value for component 2) was scored 5 points as calculations of tree cover equaled 2% and shrub cover equaled 14%. Post-restoration QBR index value for component 3) was scored 25 points, as greater than one native tree species (n = 2) of various types were present. Post-restoration QBR index value for component 4) was scored 25 points, as the stream channel boundaries remain unmodified by human alterations. Overall, the pre-restoration QBR index value was calculated as 55 out of 100 and post-restoration QBR index value was calculated as 65 out of 100, suggesting an immediate improvement in riparian habitat quality simply as a result of planting additional native species.

The Shannon–Wiener Index of Diversity

Inventoried plant species pre-restoration held a value of 10 total species and 21 total individuals from those species, while post-restoration plant species held a value of 22 total species and 94 total individuals from those species (Table 1). An addition of 12 new species and 73 individual plants from those species equated to an increased Shannon–Wiener Index of diversity value post-restoration. The pre-restoration Shannon–Wiener Index of diversity value equaled 2.13, while the post-restoration Shannon–Wiener Index of diversity equaled 2.91, indicating an increase in species diversity. Results show quantitative differences post-restoration through increased plant diversity and abundance, as well as improved riparian habitat quality.

Fig. 3. Hilton Creek streambank at the Botanical Gardens of the Ozarks, Fayetteville, Arkansas shown 5 April 2016 post-restoration, after the 3 April 2016 planting day.

Baseline Water Quality Parameters

Water temperature in the Hilton Creek in April was statistically greater than March and February, which were similar, ($P < 0.0001$; Fig. 4). Temperature averaged over time showed no statistical difference among stream sampling locations, ranging from 10.4 °C for upstream values to 11.7 °C for downstream values ($P = 0.6067$, data not shown). Dissolved oxygen declined in April compared to February and March, which were similar in concentration ($P = 0.0315$; Fig. 5). Dissolved oxygen concentration averaged over time showed no statistical difference between midstream and downstream sampling locations ranging from 9.2 mg/L downstream to 9.6 mg/L midstream, although it was statistically greater upstream from the restoration site at 11.3 mg/L ($P = 0.0007$; data not shown). Specific conductance varied over time and location with sampling dates all being statistically different ranging from 209.9 µS/cm to 369.1 µS/cm, February to April ($P < 0.0001$) and location showing no statistical difference ranging from 263.8 µS/cm to 318.8 µS/cm, upstream to downstream ($P = 0.2755$). The pH levels varied over time and location with sampling dates all being statistically different averaged at 7.1 in February, 7.9 in March, and 6.3 in April ($P < 0.0001$). The pH levels upstream averaged at 7.5 and downstream averaged at 6.7 were statistically different from each other although both were not statistically different from midstream values averaged at 7.1 ($P = 0.0884$).

Discussion

Results of increased species diversity and QBR index value indicate the streambank restoration improved riparian habitat quality, thus enhancing ecological functions of the Hilton Creek streambank. Recent experiments have provided evidence of the functional importance of biodiversity to ecosystem processes and properties (Giller et al., 2004). A study by Zedler (2000) showed that more species-rich areas achieved greater canopy complexity; thus, diversity enhanced the potential for wildlife support. Two particular plant species added in this project for wildlife support were the *Lindera benzoin* and the *Hydrangea arborescens*, commonly referred to as the Spicebush and the Wild hydrangea, respectively. The Spicebush is regarded as a sanctuary for caterpillars and the Wild Hydrangea commonly supports pollinators (Couto and Averill, 2016; Hayden, 2006). While restoration is important to restore lost biodiversity, it also provides functional landscape services, such as flood-peak reduction and water quality improvement (Zedler, 2000).

Water quality parameters were recorded to establish baseline values for the site, encouraging future monitoring of the project site as the streambank restoration matures. Dissolved oxygen is expected to be inversely related to temperature (Behar, 1997; Manasrah et al., 2006; USGS, 2016). As temperature increased in the stream in April, dissolved oxygen levels decreased in part because oxygen is less soluble in warm water than in cool water.

Table 1. Pre- and post-restoration plant species inventory recorded 18 March and 5 April 2016.

Pre-restoration[a] existing vegetation	Scientific name	Number of individuals[b]	Post-restoration[c] added vegetation	Scientific name	Number of individuals[d]
Sedge grass	*Carex spp.*	5	Northern sea oat	*Chasmanthium latifolium*	15
Chick weed	*Stellaria media*	3	Wild hydrangea	*Hydrangea arborescens*	6
Native paw paw	*Asimina triloba*	3	Cardinal flower	*Lobelia cardinalis*	8
Wild violet	*Viola spp.*	3	Blue lobelia	*Lobelia siphilitica*	5
Wild carrot	*Daucus carota*	2	Blue phlox	*Phlox divaricata*	5
Elderberry	*Sambucus spp.*	1	Red columbine	*Aquilegia Canadensis*	5
Horn beam	*Carpinus spp.*	1	Spotted geranium	*Geranium maculatum*	5
Red buckeye	*Aesculus pavia*	1	Southern shield fern	*Dryopteris ludoviciana*	5
Silky dogwood	*Cornus amomum*	1	Cinnamon fern	*Osmunda cinnamomea*	5
Wild onion	*Allium spp.*	1	Common ninebark	*Physocarpus opulifolius*	4
			Gray dogwood	*Cornus foemina*	4
			Spicebush	*Lindera benzoin*	4
			Native paw paw	*Asimina triloba*	2

[a] Pre-restoration: Species Total = 10. Note: All pre-restoration species were found again in the April assessment.
[b] Total Individuals = 21.
[c] Post-restoration: Species Total = 22.
[d] Total Individuals = 94.

Dissolved oxygen values from this study were compared to findings from Behar (1997) which suggested that even the lowest collected value of 8.9 mg/L in April was safe for most stream fish. Decreases in dissolved oxygen are important to monitor because dissolved oxygen is the oxygen that aquatic organisms use for respiration, and if it drops too low then aquatic organisms can suffocate. Freshwater streams ideally should have a conductivity between 150 to 500 µS/cm to support diverse aquatic life (Behar, 1997). Overall specific conductance measurements from the months of February to April were at desirable levels (150 to 500 µS/cm) to support aquatic life. The pH levels of the stream also varied between desirable levels from 6.1 to 8.3. It is recommended that baseline values for water quality parameters continue to be measured to better understand Hilton Creek and its interactions with the BGO streambank areas. One of the difficulties of restoration projects is the lack of baseline and reference data. This project allows others to know to what degree restoration has altered form and function by providing starting data.

Continued monitoring and adaptive management of this restoration site will play a crucial role in its overall long-term success. Adaptive management is the integration of design, management, and monitoring to systematically test assumptions in order to adapt and learn (Salafsky et al. 2001). It is assumed that a continued increase in plant species diversity will follow post-restoration, but adaptive management and continued monitoring are necessary to test and verify that assumption. Multiple studies show the importance of long-term monitoring in restoration projects and ecological studies (e.g., Franklin, 1989; Klein et al., 2007). Franklin (1989) shows that many ecological processes (i.e., plant succession, vegetative development, soil formation, biogeochemical interactions) take place over relatively long periods of time compared to grant funding time periods, making it hard to adequately account for the impact of a project with out long-term monitoring. Initial results of Klein et al. (2007), a study over a long-term monitoring program for the Lower Red River Meadow Restoration Project in north-central Idaho, U.S.A., has observed ecosystem im-

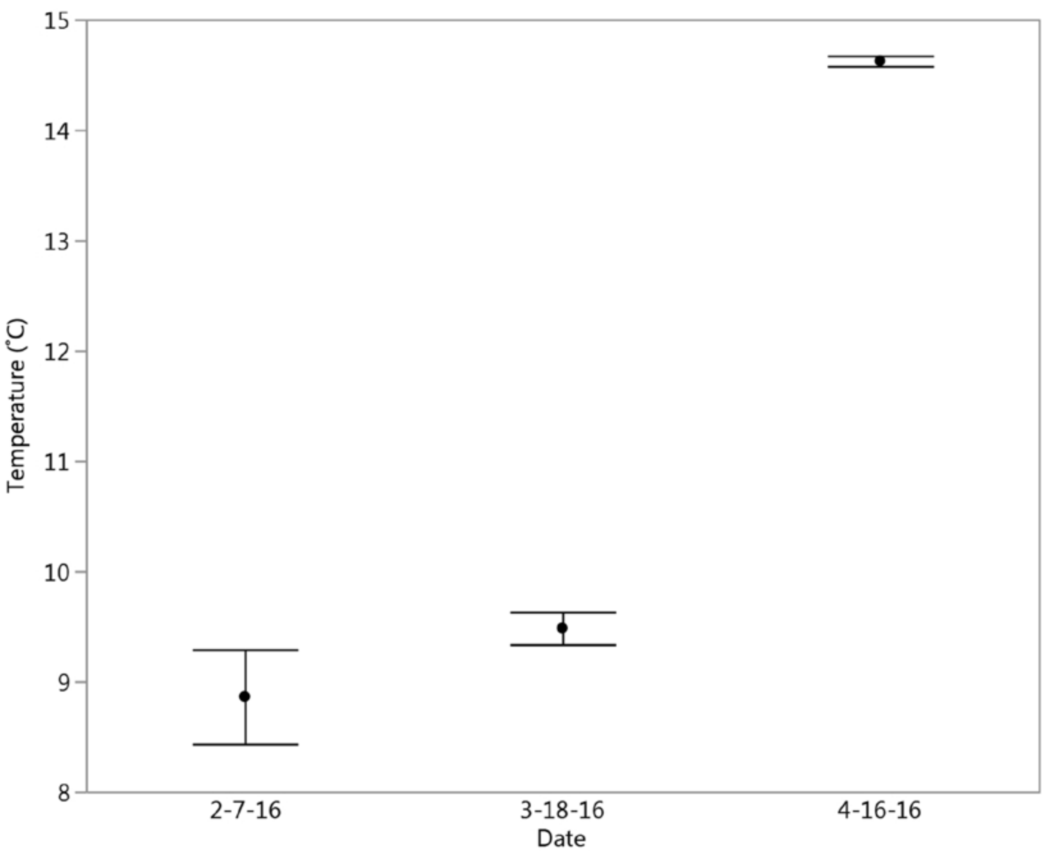


Fig. 4. Temperature (˚C) measured at three different dates, averaged across three locations adjacent to the restoration site along the Hilton Creek streambank at the Botanical Gardens of the Ozarks, Fayetteville, Arkansas, 2016. Error bars represent standard error of the mean (n = 3).

provements compared to pre-restoration conditions in channel sinuosity, slope, depth, and water surface elevation; quantity, quality, and diversity of in-stream habitat and spawning substrate; and bird population numbers and diversity. This project has provided a foundation for future study of Hilton Creek and streambanks of the BGO. An early May site visit appeared to show an even greater increase in plant species diversity and it is recommended that another species inventory be conducted during the summer months to account for vegetation that had not germinated prior to the early April inventory. There are perhaps greater benefits to be accrued from the restoration through time as later assessments could capture full germination and establishment in the restored area. Numerous studies support this hypothesis by showing increases in plant diversity from restoration efforts (Bullock et al., 2011; Le et al., 2012; Parkes et al., 2012; Rey-Benayas et al., 2009). The April assessment was limited in that there were only two and a half weeks between the time of planting and the final inventory.

A secondary outcome of this study is the opportunity for the BGO to use the site as an educational tool to teach visitors of the importance of riparian buffers and restoration efforts. In an effort to showcase the project and increase awareness, an educational sign is to be displayed near the riparian zone that recognizes some of the benefits of riparian zones. With over 80,000 visitors to the BGO annually, this project has the continued potential to educate a much broader community.

Conclusions

The BGO is a popular destination in the Northwest Arkansas community. This project demonstrated improvement in a section of the Hilton Creek streambank at the BGO and provided a foundation for further study of the site. Baseline water quality assessments of dissolved oxygen, temperature, specific conductance, and pH suggest that the Hilton Creek stream is suitable for aquatic life. Restoration efforts successfully added various veg-

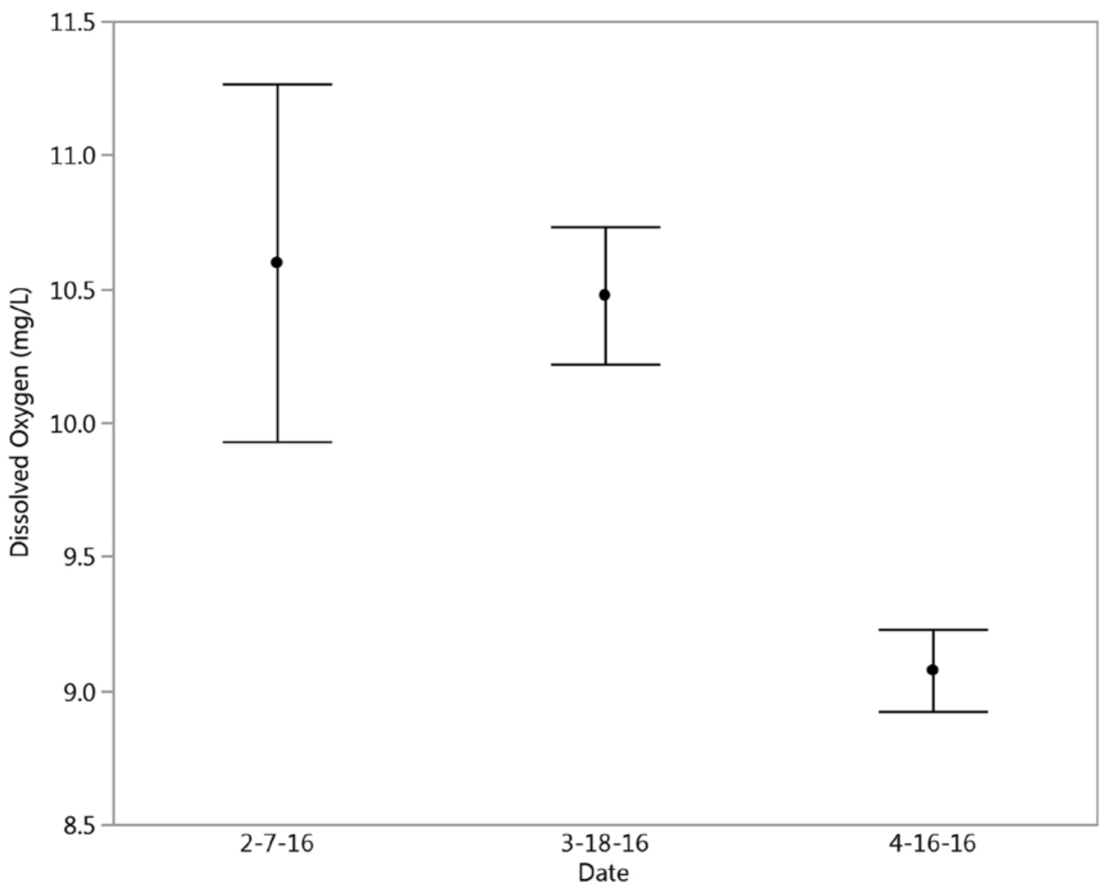


Fig. 5. Dissolved oxygen (mg/L) measured at three different dates and averaged across three locations adjacent to the restoration site along the Hilton Creek streambank, 2016. Error bars represent standard error of the mean (n = 3).

etative plant species to the streambank, supporting the hypothesis that restoration will increase plant abundance and diversity and improve riparian habitat quality, thus enhancing ecological functions of the Hilton Creek streambank. While long-term assessment is recommended to gauge the full extent of the benefits resulting from the restoration, progressing germination is expected to yield improved results. The restoration project will not only benefit the Hilton Creek streambank, but will also provide a platform to educate the BGO visitors on the significance of the chosen vegetation, riparian buffers, and restoration efforts.

Acknowledgments

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