2013

Short-Term Responses of Fish Assemblages to Habitat Restoration in a Small Midwestern Stream

John Leon West
Eastern Illinois University

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SHORT-TERM RESPONSES OF FISH ASSEMBLAGES TO

HABITAT RESTORATION IN A SMALL MIDWESTERN STREAM

(TITLE)

BY

John Leon West

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

Master of Science

IN THE GRADUATE SCHOOL, EASTERN ILLINOIS UNIVERSITY
CHARLESTON, ILLINOIS

2013

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By

John Leon West

B.S. Zoology

Southern Illinois University Carbondale, 2008

A Thesis

Submitted for the Requirements for the Degree of

Master of Science

Department of Biological Sciences
Eastern Illinois University
December 2013

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ABSTRACT

Recent efforts to restore stream habitat have become a common practice, yet evaluations of biotic responses to these practices are not as common. I evaluated fish assemblage response to restoration in a reach of Kickapoo Creek, a fourth order stream southwest of Charleston, Illinois. Restoration included 446 meters of bank stabilization, pool scouring keys, and the creation of two artificial riffles. To have a representation of pre-restoration fish assemblages, I sampled four stream reaches of Kickapoo Creek twice before construction of habitat restoration: two control reaches (upstream and downstream) and two restored reaches within a 0.5 km restoration stretch (upstream and downstream). To assess the effect of instream restoration on fish assemblages, I compared fish assemblages before, during, and after habitat restoration. Additionally, to assess the impact of season on fish assemblage I compared spring and fall samples. To assess the changes in habitat as a function of restoration I estimated habitat using the Qualitative Habitat Evaluation Index (QHEI) annually. Control and restored sites were sampled twice annually (spring and fall) beginning September 2009 through September 2011 with a six person crew sampling all four sites using an AC electric seine. Then I used DC electrofishing probes in a 30 meter long pool that had become too deep to sample by the 3rd sample period. Index of Biotic Integrity scores were calculated and compared between the sites and seasons. Multidimensional scaling based on Bray-Curtis Similarity, Similar Percentages (SIMPER), and Indicator Species Analysis, were used to compare assemblages before, during, and after habitat restoration. T-tests were used to compare relative density of five fish families, tolerance levels, and habitat specialists before and after restoration. A total of 24.88 hours of sampling revealed 48,109 individuals from 45 different species from 11 different families. Most fish were from the families *Cyprinidae* (89.7%), *Percidae* (3.3%), *Centrarchidae* (2.8%), *Catostomidae* (2.1%), and *Ictaluridae* (1.6%). Fall samples were found to have significantly higher relative density (CPUE) (2262.5fish/hr) compared to spring (1237.8fish/hr) along with eleven unique species captured in the fall compared to five in the spring. Habitat changed in both the restored sites as well as the control sites after habitat restoration with the restored sites having an increased QHEI score with deeper pools and more riffle area. A significant change for *Cyprinid* species occurred after habitat restoration with most species increasing. Similarity Percentages (SIMPER) revealed changes in percentage of the 5 minnow species Bluntnose Minnow (*Pimephales notatus*), Spotfin Shiner (*Cyprinella spiloptera*), Silverjaw Minnow (*Ericymba buccatus*), Sand Shiner (*Notropis stramineus*), and Central Stoneroller (*Campostoma anomalum*) during and after habitat restoration. Indicator species analyses identified Brook Silversides (*Labidesthes sicculus*) as an indicator of change during restoration, Gizzard Shad (*Dorosoma cepedianum*) as an indicator after restoration, and Redfin Shiner (*Notropis umbratilis*) during and after restoration. Overall, I found the majority of the species providing change to the fish assemblages were generalists during and shortly after restoration.

ACKNOWLEDGEMENTS

I would like to thank Dr. Rob Colombo for giving me this opportunity to seek a Master's Degree as well as his help in starting my fisheries career at SIUC. I'd also like to thank Dr. Charles Pederson and Dr. Jeff Laursen for being members of my committee and for all I've learned from them in their classes that I've taken and assisted them with.

This study could not have been completed without the aid of the EIU faculty and graduate students, specifically those who are part of the Fisheries and Aquatic Research Team. I especially would like to thank Cassi Moody, Anthony Porreca, Sarah Huck, Manisha Pant, Vaskar Nepal, K.C., Jason Stuck, Bryan Rolfsen, Carlien Lang, Justin Dore, Candice Miller, T.J. Evans, Daniel Hiatt, and a host of undergraduates that helped both in the field and lab. Additionally, I would like to thank Trent Thomas of the Illinois Department of Natural Resources for his advice and support as well as many other employees of the IDNR, IEPA, USGS, and land owners.

Finally, I'd like to thank my parents, uncles, aunts, grandpa, siblings, and childhood friends for all of their support of my interests as a kid. And I especially want to thank my family Kate, Chandler, and Layla for their support and patience during the development of my degree and career in fisheries.

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INTRODUCTION

Anthropogenic activities such as channelization, dredging, draining, filling, changes in hydrology, polluting, and elimination of riparian zones have led to the degradation of stream ecosystems in the Midwestern United States (Berkman and Rabeni 1987, Morke and Lamberti 2003, Roni, 2003, Shields et al. 1995). As much as 85% of Midwestern streams have been disturbed by these practices (Morke and Lamberti 2003). Additionally, bank erosion and sediment loading has become a major problem for aquatic ecosystems (Berkman and Rameni 1987). Hundreds of millions of dollars are spent annually on watershed restoration yet the impacts are usually not monitored intensely enough to quantify the ecosystem's response (Roni, 2005). Although habitat degradation is a major problem in the U.S., the ecological benefits of restoration projects have yet to be fully understood (Moore and Palmer 2005).

Habitat degradation has been reported to impact several taxa in the Midwestern United States. For example, diatom diversity and abundance may be negatively impacted by man-made disturbances such as habitat fragmentation (Tawnee 2008). Mass erosion, causing a decrease in woody debris, pool habitat, and substrate stability has a negative impact on biomass production of macroinvertebrates (Shields et al. 2003). Additionally, habitat loss and fragmentation caused by agriculture and human development is a major factor in the decline of amphibians (Marks 2006). Further, negative impacts on fishes may be attributed to siltation, wetland drainage, lowered water tables, dams and impoundments, and removal of streamside vegetation (Southerland 1993). Restoring habitat has become an important role in reversing the damage caused by humans to streams (Bond and Lake 2003).

Habitat restoration for streams is often aimed at returning habitat to its original state through enhancing existing habitat, or creating new habitat (Cairns 1988). In the past, these improvements have included reconnecting isolated channels and sloughs, road removal, reductions of sedimentation, replanting of riparian area, and placement of instream structures (Tarzwell 1934; White 2002) Techniques such as placing physical structure into lotic environments to create pools, to alter channel morphology, or to provide habitat for aquatic organisms have been used for several decades (White 2002). These techniques are done by placing materials into an active stream to create pools and trap gravel as well as constructing log weirs, deflectors, and riffles to provide fish habitat (Roni, 2005). These instream physical structures are used for various purposes such as to provide spawning habitat, improve channel conditions, restore floodplains, provide refuge from high flows, and improve riffle: pool ratio (Roni 2005).

Both the quantity and quality of a stream's habitat are important to riparian and lotic biotic communities (Barbour et al 1999). As such, habitat is now commonly used as a basis for impact assessments and resource inventories (Bain and Stevenson 1999). Since the physical factors of a stream can have impacts on both the benthic macroinvertebrate and fish communities (Rankin 1989), it is important to evaluate the habitat quality of a stream. The characteristics of a stream and the surrounding land are important for qualification of a stream and assessing instream habitat is an important procedure for evaluating a stream's biotic community (Barbour et al. 1999).

Several different protocols have been used to assess habitat quality in small streams. For example, the stream habitat assessment protocol (SHAP) and the Qualitative Habitat Evaluation Index (QHEI) (Rankin 1989) often are used in stream habitat evaluation. Several attributes of the QHEI make it desirable. The QHEI is designed to provide a quantified evaluation of lotic macrohabitat characteristics (Ohio EPA 2006). Currently, the Illinois Environmental Protection Agency uses the QHEI method to assess the quality of instream habitats. A maximum score of 100 is possible with 6 different metrics: substrate, instream cover, channel morphology, riparian zone and bank erosion, pool/glide and riffle run quality, and map gradient (Ohio EPA 2006). These scores have been shown to correlate positively with both fish (Rankin 1989) and macroinvertebrate (Hammer and Linke 2003) indices of biotic integrity.

Although stream restoration is becoming common (Bond et al. 2003), relatively few studies have assessed the impact of these projects on the aquatic biota (Berhardt et al. 2005, Baldigo et al. 2008). In 2009-2012, Thomas (2012) monitored habitat restoration in a Central Illinois stream where bank stabilization, artificial riffles, and stream bank vegetation were installed. In this study, fish populations were monitored before and after habitat restoration and observed changes in the community included the arrival of new species and increased total abundance of fish within the community. In the Catskill Mountains, Baldigo et al. (2008) found fish populations and communities improved short term through natural channel design. Shields and Knight (2003) discovered habitat restoration to benefit the fish community for several years where riparian habitat increased, and large woody debris and pool depth more than doubled. Larval lamprey (*Lampetra* sp.) and salamanders increased in a restoration study by Roni (2003) after large woody debris was installed in a small stream the Pacific Northwest. Knight et al. (2003) found an increase in *Catostomid* species after large woody debris was installed into a small stream. However, fish community responses to sand bed and woody debris restoration ended in failure one year later as the woody debris structures failed (Shields et al. 2003). Given the results of stream restoration noted above, evaluating ecological indicators within streams can be extremely important (Jackson et. al 2000).

Different ways of qualifying streams include assessing the water quality, periphyton, benthic macro-invertebrates, and fish communities in the stream (Barbour et al. 1999). Though organisms such as diatoms and macroinvertebrates are good indicators of stream quality, there may be more advantages when using fishes (Karr, 1991). Diatom and macroinvertebrate identification can be difficult and may require professional expertise (Karr 1991). Fishes, on the other hand, can be fairly easy to identify. In addition, they occupy different trophic levels (i.e. insectivores, omnivores, herbivores, piscivores, and omnivores) (Karr 1991), have different tolerance levels (i.e. tolerant, intolerant, and intermediate) (Smogor 2000), and have major effects on ecosystems (Vanni 2010). Typically, the general public may relate to fish more than other biotic communities as well. Finally, community indices for stream fishes have been elucidated at both the local and regional scales (Karr et al. 1986). Thus, fish are valuable to biotic integrity and are important in evaluating streams as well as occupying a variety of habitats (Grabarkiewicz and Davis 2008).

Many fishes are habitat specialists and there is a correlation between a fish assemblage and their available habitats (Gorman and Karr 1978). For example, Harvey and Stewart (1991) found pool quality to be important in the survival of the Central Stoneroller (*Campostoma anomalum*) and Creek Chub (*Semotilus atromaculatus*) whereas Johnson et al. (2009) found *Micropterus* species distributions were associated with stream slope and velocity along with the presence of run, riffles and pools. The

Spotted Darter (*Etheostoma maculatum*) needs riffles and glides with rocky substrate in order to spawn (Osier and Welsh 2007) whereas the Johnny Darter (*Etheostoma nigrum*) needs slow moving water over a cobble or sand substrate (Propst and Carlson 1989). Some species of *Nocomis* build their nests out of pebbles (Sabaj et al. 2000) and woody debris is found be a refuge for fish evading predation (Everett and Ruiz 1993). Along with habitat preference, fishes may also have movement patterns based on their life history or change in their habitat (Bond 1996).

Many fishes have long migrations annually or seasonally (Bond 1996) and seasonal changes in fish abundances occur for some species during reproduction and spring and fall migrations (Barbour et al. 1999). Some small stream fishes are highly migratory such as the Northern Hog Sucker (Smith 1979) whereas species such as Green Sunfish, Longear Sunfish, and Rock Bass can occupy a home range of less than 61m (Gerking 1953). Seasonal movements, which are common for many fishes (Pflieger 1975), may contribute to seasonal changes in fish assemblages. For instance, Fuselier and Edds (1996) found fish assemblages were seasonally different in a small stream. These authors found a higher total number of fish in the spring compared to fall with riffle fish assemblages more seasonally variable than the pool fish. Some stream fish move to quieter habitat or larger streams in the winter (Pflieger 1975).

Kickapoo Creek is a fourth order stream in east-central Illinois (IDNR). Its headwaters are south of Mattoon, Illinois and it flows south-east approximately 15 kilometers between Mattoon and south of Charleston, Illinois before draining into the Embarras River. The drainage is a combination of agriculture, sparse forest, grassland, and human development. In 2001, a factory of the company Vesuvius was responsible for a furfural spill that killed over 200,000 fish along with other fauna in Kickapoo Creek (IDNR). A settlement was reached for the destruction and the settlement money was used to restore habitat in an area southwest of Charleston (IDNR). Habitat restoration included two artificial riffles, 446 meters of bank stabilization (rock), development of scouring keys, and planting of native grasses for bank stabilization. The Illinois Department of Natural Resources, the United States Geological Survey, Eastern Illinois University Biological Sciences, and land owners cooperated in restoring habitat and monitoring habitat, fish assemblages, and macroinvertebrate communities beginning in the fall of 2009. Habitat restoration was applied to the stream during September, 2010.

Objectives

- Evaluate habitat change before and after restoration.
- Assess seasonal differences in characteristics of fish assemblages present during spring and fall.
- Compare fish assemblage data before, during, and after habitat restoration.
- Compare fish relative density before and after restoration for control and restored sites for the five most common fish families collected during this evaluation.
- Compare fish relative density before and after restoration for control and restored sites for intolerant, tolerant, generalist, specialist, and mineral substrate spawner species collected during this evaluation.

METHODS

Study site

In order to evaluate fish assemblage response to habitat restoration in Kickapoo Creek, a study site was selected by the Illinois Department of Natural Resources approximately 6.5 kilometers southwest of Charleston, Illinois. A downstream control site (Site A: 232 m), two sites that are within the restoration reach (Site B: 254 m; Site C: 192 m), and one upstream control site (Site D: 183 m) were selected as the area of study (Figure 1). Habitat restoration was constructed and completed in September 2010, which was approximately one year after the project began. Restoration included two artificial riffles, 446 m of bank stabilization, and installation of scouring keys to the restoration reach. At each site I marked the downstream and upstream points using a handheld GPS. The two sites in the restored reach were continuous with the other. The downstream control was approximately 50 m from the restored sites. However, the upstream control was nearly 2 km from the restored sites.

Habitat and Water Quality

I evaluated stream habitat by using the Ohio EPA's Qualitative Habitat Evaluation Index (QHEI) before and after habitat restoration during summer 2010 and 2011. To assess habitat, I divided stream habitat into 10 instream habitat sections and 11 substrate sections. Instream cover was quantified by calculating percent canopy, percent run/riffle/pool, percent slack water, square feet of boulders, undercut banks, rock/clay ledge, submerged tree roots, brush debris jams, logs, aquatic vegetation, submerged terrestrial vegetation, overhanging vegetation, shallows in still waters, pools greater than 70cm, root wads, oxbows, and backwaters. I evaluated substrate at 0.6 m increments across the stream. Substrate classes were based on the QHEI substrate class index (Rankin 2006) with silt/mud <0.062mm, sand 0.062-2mm, fine gravel 2-7mm, medium gravel 7.6-15mm, coarse gravel 15mm-6.4cm, small cobble 6.4cm-12.7cm, large cobble 12.7-25.4cm, boulders >25.4cm , bedrock, claypan, plant detritus, vegetation, submerged logs, or artificial. I calculated hydraulic features as well by estimating mean water width, mean channel width, maximum depth, mean thalweg depth, and width/depth ratio. Water width was measured to the nearest centimeter and stream channel to nearest meter. Substrate was assessed in 0.6m increments across the stream. The final score was generated by adding the evaluated score of substrate, instream cover, channel morphology, bank erosion and riparian zone, pool/glide and riffle/run quality (Rankin 2006). Water quality was monitored during every sampling period using a YSI-85 water quality meter. Water temperature, specific conductivity, pH, and dissolved oxygen were taken at the beginning of each sampling day.

Fish

I sampled fish twice annually (spring and fall) beginning fall 2009 through fall 2011. At each site we placed 12 m by 1.2 m, .3 cm meshed block nets at the upstream and downstream transect ends to develop a closed site. The fish community was sampled with a six person crew using an 8 m electric seine with 12 copper electrodes spaced 0.75 m apart and powered by a 2000 watt AC generator. Following the electrofishing sample, downstream block nets were pulled and I collected all fish trapped therein. All fishes in the upstream blocking seine were released without enumeration. During spring and fall 2011 the restoration created a deep pool in the upstream restored site (Site C), forcing us to use DC electrofishing to sample 30m of the deep pool habitat and its associated riffle. With this method, 3 crew members each moved a DC anode throughout the water column while advancing upstream. These 3 crew members, as well as the rest of the crew, captured each incapacitated fish possible. Since this was a different method of collecting, these fishes were not included in statistical analysis, but these data were recorded and referenced.

All fishes over 100 mm were identified to species, measured to nearest millimeter, weighed to nearest gram, and were released back into the stream. All fish smaller than 100 mm were euthanized and returned to the EIU Fish and Aquatic Sciences Lab for enumeration and species identification. When applicable, I categorized fish as specialists, benthic invertivores, mineral substrate spawners, or tolerant/intolerant according to the Illinois Environmental Protection Agency IBI guide (Smogor 2000). I used an Index of Biotic Integrity (IBI) to qualify the community by using the Illinois Department of Natural Resources' IBI calculator (IDNR 2010). An extrapolated IBI score in Illinois is calculated by the number of native fish species, native minnow species, native sucker species, native sunfish species, benthic invertivore species, intolerant species, and the proportion of specialist benthic invertivores, generalist feeders, mineral substrate spawners, and tolerant species (Smogor 2000). Effort was calculated using catch per unit effort (CPUE) with total number of fish captured per hour.

Statistical Methods

To assess impacts of habitat restoration on relative density in restored and control sites, I calculated (CPUE fish/electrofishing hour) as an estimate of relative density. Before restoration sample periods included fall 2009 and spring 2010. After restoration sample periods included fall 2010, spring 2011, and fall 2011. Average CPUE for spring and fall were also compared by using a paired T-Test. Relative density was also compared before and after effects from habitat restoration using a 2 sample T-Test for the stream's 5 most common families: *Cyprinidae, Percidae, Centrarchidae, Catostomidae*, and *Ictaluridae*. A 2 sample T-Test was also used to compare before and after habitat restoration for IBI scores and for species that were generalists, benthic invertivore habitat specialists, and mineral substrate spawners. Due to the low number of sample periods, alpha was set to 0.1.

Changes in assemblages during (fall 2010) and after (spring and fall 2011) habitat restoration was evaluated using permutational distance-based approaches, as the relative abundances were skewed and had several zero counts. This approach can be useful for the analysis of ecological community data when they meet the assumptions of parametric tests such as MANOVA (McArdle and Anderson 2001, Anderson, 2001). Consequently, permutational multivariate analyses of community responses to environmental impacts have successfully been applied in other aquatic systems (e.g. Terlizzi et al. 2005, Watson et al 2007, Martin et al. 2012). To account for the variability in the abundance data (such as no species in some sites while thousands of individuals present in another), multivariate analyses were performed on Wisconsin and square root transformed (and standardized) relative abundance using Bray-Curtis dissimilarities (Bray and Curtis

1957). Non-Metric Multidimensional Scaling (NMDS), a permutational Multivariate Analysis of Variance (perMANOVA), Similarity Percentages (SIMPER) and an Indicator Species Analysis test was applied to the data.

Non-Metric Multidimensional Scaling (Field et. al. 1982) based on Bray Curtis dissimilarity (Bray and Curtis 1957) was used to produce two-dimensional ordination plots (stress 0.165). This displayed spatial and temporal variation in fish assemblages. Global NMDS using function metaMDS (package vegan, version 2.0.7 in R, version 2.15.3) was used to analyze the variation in assemblage structure.

To assess the differences in assemblages among the control and restored sites caused by the restoration, I divided the assemblage data into 3 groups: Unimpacted by restoration (all sites before restoration and control sites after restoration. i.e. Sites A,B,C,D for fall 2009 and Spring 2010. A and D for fall 2010, spring 2011, and fall 2011), impacted during restoration (B and C fall 2010), and impacted after restoration (B and C spring and fall 2011).

I tested the differences among the 3 groups using permutation based Multivariate Analysis of Variance (permanova; package vegan, version 2.0.7 in R, version 2.15.3), PerMANOVA (McArdle and Anderson 2001, Anderson 2001) is an alternative to both parametric MANOVA and to ordination methods for describing how variation is attributed to different experimental treatments or uncontrolled covariants. It partitions sums of squares of a multivariate data set using metric and semi-metric distance metrices. Among the 3 groups, the differences were compared by pairwise comparison tests with the alpha adjusted to 0.01667 after Bonferroni correction for multiple tests. Similarity percentage (SIMPER, Clarke 1993) performs pairwise comparisons of groups of sampling units. Also, it finds the average contributions of species to the average overall Bray-Curtis dissimilarity. The function Simper (package vegan, version 2.0.7 in R, version 2.15.3) was used to identify the most important relative contributions of species for each pair of groups. These species contribute to 70% or more of the differences between groups.

Indicator Species Analysis was used to compute the indicator values of each species within a group. It would also find significant indicator species for each group following the IndVal approach of Dufrêne and Legendre (1997). This looks for specific species (mean abundance in one group more than the others) and high fidelity (present in most of the sites in that group). Function multipatt (package indicspecies, version 1.6.7 in R, version 2.15.3) was used to identify indicator species for each group. This is based on the IndVal approach described in De Cáceres and Legendre (2009). For all multivariate analyses, the significance level was set to 0.05.

RESULTS

Habitat and Water Quality

Scores for QHEI before habitat restoration were 73 and 71.5 in the control sites compared to 64 and 69.5 in the restored sites. The following assessment, scores for QHEI after habitat restoration was 63 and 70.5 in the controls compared to 78.5 and 76.5 in the restored. Both restored sites' scores increased after habitat restoration. The downstream restored (B) site's total substrate, instream, riparian and bank erosion, pool quality, and riffle/run quality increased after habitat restoration. The upstream restored (C) site's total bank erosion and riffle quality scores increased after habitat restoration. Both downstream (A) and upstream (D) control sites had a decrease in total substrate, channel morphology, and pool quality scores during summer 2011 (Table 1). Water quality was taken at least once during each sample period. The water quality taken during the study was in the following ranges: Conductivity 371-689 uS/m, Temperature 12.1-20.9 C, and Dissolved Oxygen 7.8-10.2 mg-L-1.

Total Catch

I collected and identified 31,769 individual fish from the restored sites and 15, 746 in the control sites from fall 2009 through fall 2011 (Table 2). These were from 45 different species and 10 different families. All fishes are native to the state of Illinois. *Cyprinid* species made up the majority (89.7%) of the total catch, and 5 families, (*Cyprinidae, Ictaluridae, Catostomidae, Percidae, Centrarchidae*) made up 99.6% of the total catch. The Sand Shiner *(Notropis stramineus)* was the most numerically abundant species sampled during the sample period (13,219). The next 4 most common species were the Spotfin Shiner (*Cyprinella spiloptera*) (9,517), Silverjaw Minnow (*Ericymba buccatus*) (8,183), Bluntnose Minnow (*Pimephales notatus*) (5,102), and Central Stonerollers (*Campostoma anomalum*) (4,048) (Table 2). Of the species we sampled, 13 of the 45 species were represented by less than 10 individuals (Table 2).

A total of 23.8 hours of AC electrofishing effort was applied to the control and restored sites during the sampling period. Average CPUE was nearly the same for the control and restored sites during the initial sample period in fall 2009. Both however, had increased substantially by the last sample period in fall 2011 (Figure 2, Table 3). I found a significantly higher relative density of all total fish after the initial impact of restoration in restored ($t = 2.71$ $df = 8$ $p = 0.01$) and control sites ($t = 0.98$ $df = 8$ $p = 0.04$) (Figure 2). By fall 2011 an increasing trend in relative density was occurring in both the restored and control sites with the greatest density occurring within the restored sites (Figure 2).

Seasonal and IBI Comparisons

I found a significantly higher relative density in fall compared to spring relative density ($t=2.71$, $DF=18$, $P=0.01$) (Figure 3). I found 11 unique species that were captured only during fall: Bullhead Minnow (*Pimephales vigilax*) , Brook Silverside (*Labidesthes sicculus*), Western Mosquitofish (*Gambusia affinis*), Spotted Bass (*Micropterus punctatus*), Mississippi Silvery Minnow (*Hybognatus nuchalis*), Channel Catfish (*Ictalurus punctatus*), Redear Sunfish (*Lepomis microlophus*), Tadpole Madtom (*Noturus gyrinus*), Shorthead Redhorse (*Moxostoma macrolepidotum*), Fantail Darter (*Etheostoma flabellare*) and Fathead Minnow (*Pimphales promelas*) (Table 3). Only 5 unique species were captured only during spring: Longnose Gar (*Lepisosteus osseus*), Golden Shiner (*Notemigonus crysoleucas*), Highfin Carpsucker (*Carpiodes velifer*), Dusky Darter (*Percina sciera*), and Chestnut Lamprey (*Ichthyomyzon castaneus*) (Table 3). I found that richness during fall (40 species) was greater than that of spring (34 species) (Table 3). Index of Biotic Integrity (IBI) scores ranged from 32-41 in the fall compared to 27-37 in the spring sample periods. Differences in the IBI scores were not significant during the study period (Restored= $t = -1.66$ $df = 8$ $p = 0.14$; Control= $t = -0.27$ $df = 8$ $p = 0.79$) (Table 4).

Fish Assemblage before, during, and after habitat restoration

Non-metric multidimensional scaling based on Bray Curtis suggested that there are differences in fish assemblages between before, during, and after habitat restoration (Figure 4). Permutational MANOVA indicates a significant difference ($f = 5.4$ $df=19$ $p = 0.0016$) between before, during, and after habitat restoration (Figure 4). Pairwise comparison reveals a significant difference in the unaffected compared to the affected during restoration ($f = 4.02$ $df = 15$ $p = 0.035$), a significant difference in unaffected sites compared to affected sites after restoration ($f = 4.26$ $df = 5$ $p = 0.003$), but no significant change between affected sites during restoration and affected sites after restoration ($f = 1.87$ $df = 5$ $p = 0.257$) (Figure 4). (Table 5)

According to SIMPER, a change in assemblages occurred during restoration with contributions from the Sand Shiner (24%), Silverjaw Minnows (19%), Spotfin Shiners (18%), and Bluntnose Minnow (12%) compared to before restoration. These species had an increasing trend during this period (Figures 5, 6, 7, 8) . Between before and after restoration, percentages in the Spotfin Shiner (30%), Sand Shiner (29%), and Bluntnose Minnow (13%) changed. These three species increased after restoration (Figures 5,7,8). When I compared during and after restoration, changes occurred for the Silverjaw Minnow (23%), Spotfin Shiner (18%), Bluntnose Minnow (13%), Sand Shiner (11%), and the Central Stoneroller (11%). The Silverjaw Minnow and Central Stoneroller did not increase proportionally with the other species during this time (Figures 6 and 9). (Table 6)

Indicator species analyses revealed the Brook Silverside to be an indicator of change in the assemblage during restoration (p = 0.005). Gizzard Shad were significant indicators of assemblage change in the restored sites after restoration (p = 0.019). The Redfin Shiner was a significant indicator of change during restoration as well as after restoration in the restored sites (p = 0.011).

Relative density of the 5 most common families before and after restoration

I found *Cyprinid* species to have an increasing trend throughout the study (Figure 10). *Cyprinid* species' relative density had a significant increase in both the restored (t = 3.19 df = 8 p = 0.01) and control sites (t = 2.65 df = 8 p = 0.03) after restoration (Figure 10). Relative density of all *Percidae* species had no significant changes after habitat restoration in the restored (t = -0.26 df = 8 p = 0.80) or control sites (t = -0.48 df = 8 p = 0.65) (figure 11). The relative density of *Centrachidae* species showed no significant changes after habitat restoration in the restored (t = 0.51 df = 8 p = 0.63) or control sites (t = 0.87 df = 8 p = 0.41) (Figure 12). Throughout the study, *Catostomidae* species were most abundant in the restored sites except after the sample period immediately following habitat restoration (Figure 13). No significant change occurred in the relative density of *Catostomidae* after habitat restoration in restored (t = 0.34 df = 8 p = 0.74) or control sites (t = 0.87 df = 8 p = 0.41) (Figure 13). I found no significant change as related to before and after habitat restoration for *Ictaluridae* species in the restored (t = 1.03 df = 8 p = 0.34) and control sites (t = 1.42 df = 8 p = 0.19) (Figure 14). However, relative density of *Ictaluridae* species in the restored sites surpassed the control sites during fall 2011 (Figure 14).

Relative density of intolerant and tolerant Species before and after habitat restoration

Intolerant species (Brindled Madtom, Northern Hog Sucker, Rainbow Darter, and Highfin Carpsucker) were collected throughout the study. I found no significant changes in relative density of intolerant species in the restored (t = 1.29 df = 8 p = 0.23) or control sites (t = 0.93 df = 8 p = 0.38) after habitat restoration (Figure 15). Intolerant species had a peak in relative density after habitat restoration in the control sites in fall 2010 (figure 15). Tolerant species (Creek Chub, Green Sunfish, White Sucker, Yellow Bullhead, Golden Shiner, and Fathead Minnow) were also collected throughout the study. I found no significant changes in relative density of tolerant species' in the restored (t = 0.68 df = 8 p = 0.52) or control sites (t = 0.88 df = 8 p = 0.41) after habitat restoration (Figure 16). Tolerant species relative density peaked immediately after habitat restoration in the control sites (Figure 16).

Relative density of generalists, benthic invertivore, habitat specialists, and mineral substrate spawner species before and after habitat restoration

Generalist species (Black Bullhead, Bluegill, Bluntnose Minnow, Channel Catfish, Creek Chub, Creek Chubsucker, Fathead Minnow, Gizzard Shad, Green Sunfish, Quillback, Redfin Shiner, Sand Shiner, Silverjaw Minnow, Spotfin Shiner, Striped Shiner, Suckermouth Minnow, White Sucker, and Yellow Bullhead) showed that a significant increase ($t = 2.46$ $df = 8$ $p = 0.04$) in relative density occurred in the restored sites but not in the control ($t = 0.81$ $df = 8$ $p = 0.44$) by fall 2011 (Figure 17). Benthic invertivore habitat specialists (Brindled Madtom, Bullhead Minnow, Golden Redhorse, Greenside Darter, Johnny Darter, Logperch, Northern Hog Sucker, Orangethroat Darter, Rainbow Darter, Shorthead Redhorse, and Tadpole Madtom) showed no significance in relative density change before and after habitat restoration in the restored ($t = 0.65$ $df = 8$ $p = 0.42$) and control sites ($t = 0.37$ $df = 8$ $p = 0.71$) (Figure 18). However, the control sites immediately after restoration showed peak relative density of these species (Figure 18). Mineral substrate spawners (Central Stoneroller, Chestnut Lamprey, Creek Chubsucker, Dusky Darter, Fantail Darter, Golden Redhorse, Logperch, Northern Hog Sucker, Orangethroat Darter, Rainbow Darter, Redfin Shiner, Shorthead Redhorse, and Striped Shiner) showed the same seasonal trend in the control and restored sites throughout the study (Figure 19). There was no significance in relative density before and after habitat restoration in the restored ($t = 0.65$ $df = 8$ $p = 0.54$) or control sites ($t = 0.37$ $df = 8$ $p = 0.71$).

DC electrofishing deep water section of Upstream Restored (C) after restoration

During the spring 2011 DC electrofishing sample, a total of 20 species were sampled from the deep water and artificial riffle section of the upstream restored site (C) (Table 7). The most dominant fish relative density at this time was the Spotfin Shiner

(187.5 fish /hr) (Table 7). During the fall 2011 DC electrofishing sample, I found a total of 26 species sampled from the deep water and artificial riffle section of the upstream restored site (C) (Table 8). Again the dominant species was the Spotfin Shiner (161.05 fish/hr) (Table 8). However, Bluegill were the second most abundant species (110.53 fish/hr) (Table 8). The Sand shiner was more abundant in the Fall DC electrofishing sample (85.41 fish/hr) than in the spring (1.58 fish/hr).

DISCUSSION

Habitat Change

There are many various methods and goals to habitat restoration (Roni, 2005). The goal of the Kickapoo Creek habitat restoration project was to restore riffle habitat, create deeper pool areas, to stabilize stream banks, and prevent further erosion. I found that habitat changed in both the control and restored sites after restoration. In my study reach, I found QHEI scores to increase in the restored sites after habitat restoration whereas they decreased in the controls sites. A similar finding occurred for Shields and Knight (2003) where significant changes occurred within the rehabilitated reach of Hotophia Creek in Mississippi. They found sediment loads to decrease and pool depths to more than double.

Though the downstream control (A) and upstream control (D) were not restored, the habitat did change in these sites between fish sampling periods. A QHEI was not conducted during the 2009 sample season, but it is worth noting that both control sites had deep pools caused by logjams dammed up by large overhanging trees. During the winter and early spring (2009-2010), these pools were filled with sand and had become shallow runs instead. This habitat change in the control sites was represented in the first QHEI analysis in 2010. During the early spring of 2011, a catastrophic flood event changed the control sites dramatically. In the downstream control site (A), several trees were washed out of the shoreline causing more brush debris jams in the site. However, cobble and gravel were then covered to make sandy runs and pool areas diminished causing the pool quality scores to decrease. The upstream control site (D) was not as affected by the early spring floods, but it did change as well. One large log jam had washed away, good quality substrate was covered by sand, and a large pool area had turned into a sandy run causing pool quality scores to decrease.

The habitat construction in the restored sites in September 2010 caused the habitat makeup of the sites to change immediately as expected. However, the early spring floods caused the scouring keys to form deep pools below the artificial riffles. This is an event similar to what Thomas (2012) found in a small central Illinois stream. I found QHEI scores increased the year following habitat restoration in both restored sites. Pool and riffle quality improved from the scour holes and artificial riffle in the downstream restored site (B). The same was the case for the upstream restored site (C) even though the pool quality was already a high score before habitat restoration, since it was mostly pool before habitat restoration. The artificial riffle installation replaced some of the pool area during restoration. However, the site did end up with an area nearly 2 meters deep, much deeper than any other pool in the entire study area. Shields and Knight (2003) found this to be the case with their scour pools as well and 10 years later had pool area

2.5-3 times greater in than pre-restoration depth. Pool scouring occurred more rapidly in my study.

Total Catch

Relative density of fishes caught throughout the entire study continued to increase until reaching the highest level in the final sample period in fall 2011, more than double the first sample in fall 2009. Control sites had an increasing trend after the habitat restoration period as well, which may indicate that the overall amount of fishes was more abundant in the study sites during this period of time or that some fish were also using the restored sites as well as the nearby downstream control. However, the significant increase in relative density in the restored sites may indicate more fish utilizing the new habitat. In an Illinois stream with a series of habitat restoration evaluations, Thomas (2012) found that fish abundance increased following the restoration and one of his sample sites had fish populations increase as much as 84.6%. I found this to be the case for our study as well, especially with *Cyprinidae* species. Not only were they the most successful group, but some species such as the Spotfin Shiner, Steelcolor Shiner, Sand Shiner, and Bluntnose Minnow increased substantially after restoration. Members of the *Cyprinid* family are known to utilize many different types of habitat and make up the majority of fish fauna in many Illinois streams (Smith 1979).

Interestingly, an increase in relative density came immediately after the habitat restoration construction when we sampled only one week after earthmovers, bulldozers, and tons of rock had disturbed the ecosystem. An increase in cyprinid species such as the

Bluntnose Minnow, Creek Chub, Sand Shiner, Spotfin Shiner, Steelcolor Shiner, and Silverjaw Minnow were the cause of this increase. Not only are many *Cyprinids* highly mobile species (Smith 1979), but the Spotfin Shiner, Bluntnose Minnow, and Creek Chub are known to tolerate impacted habitat (Trautman 1981). This may have led to their increase in the restored areas. Other generalist species contributed to this increase as well. Some generalists are capable of tolerating disturbance. For example, the White Sucker (generalist) is known to tolerate disturbed conditions such as silt (Trautman 1981).

Seasonal Differences

I found significant differences in my seasonal comparisons. Normally, stream surveys are done in the mid to late summer (Barbour et al. 1999). My fall sample periods (September-October) had much higher total number of species and total CPUE than spring samples. These seasonal differences may have occurred for a variety of reasons. All of our sampling periods were done while the stream was as close to base flow as possible. However, sampling in the lowest flow possible may be difficult in the spring as flow rates are fluctuating from spring rains. Some spring sampling periods may have had more flow than the fall samples. This may have led to a higher escapement due to the higher volume of water. It is also not recommended to sample larval fishes for a fish survey (Barbour et al 1999). Sampling in the fall may have led us to collect young of year fish that were larval stage earlier in the summer. This may attribute to the more abundant fall sample sizes with more young-of-year fish. Winter mortality may also contribute to fewer fish in the spring.

The difference between seasonal sample periods may also be because fish populations tend to stay in one general area during the summer (Barbour et al 1999). It is also reported that fish populations are unlikely to be affected by catastrophic environmental events such as a flood (Barbour et al 1999) The Kickapoo Creek study area did experience flooding each winter and spring. Some motile fish such as *Cyprinids*, may have increased during these high water events. Since no mark and recapture data was taken at Kickapoo Creek, I couldn't determine where the new fish come from and the previously sampled fish go. However, most of the fish captured for this study were small and removed from the stream thus making most of the next sample a potential new community.

Five most common families' change after restoration

Cyprinid species, known to be highly mobile (Smith 1979), were the only species to have a significant increase after restoration in the restored sites. In a habitat restoration project, Thomas (2012) found a highly increasing number of *Cyprinid* species as well. However, an increase in the control sites happened in my study as well. Knight et al. (2003) expected to see a change in a cyprinid dominated community to a *Centrarchid* dominated community by restoring bank habitat woody debris but did not find this to be the case. This may have been a result of *Cyprinid* species coping with frequent flood conditions (Knight et al. 2003). Kickapoo Creek experienced multiple high water events as well and *cyprinids* continued to increase. Not only were they the most successful group, but some species such as the Spotfin Shiner, Steelcolor Shiner, Sand Shiner, and Bluntnose Minnow increased substantially after restoration. Members of the *Cyprinid* family are known to utilize many different types of habitat and make up the majority of fish fauna in many Illinois streams (Smith 1979).

None of the other common families had a significant increase after restoration but there may have been increasing trends happening. Though not significant, sunfish had an increasing trend the last 2 sample periods in the restored sites. Bluegill, Green Sunfish, and Longear Sunfish are all known to occupy pool areas in small streams (Stuper et al. 1982, Smith 1979). *Ictalurid* species may be using the stabilization rock and deeper pools causing their increasing trend after restoration. Many presumed young-of-year Northern Hog Suckers and White Suckers led to the peak density directly after restoration for *Catostomids*. Darters may not be as motile as other fishes (Pfleiger 1975) so it may have been too soon for these species to have a positive effect from the restoration.

Tolerance, generalists, specialists, and substrate spawners

Thomas (2012) found more sensitive species after habitat restoration on a small Central Illinois stream. However, in Juday and Potato Creek in Indiana, American brook lampreys were no longer collected after habitat restoration (Moerke and Lamberti, 2003). I found no significant changes in our overall relative density of intolerant species. However, after the initial habitat restoration they increased in the control sites. I think this may be due to intolerant fish moving into the control sites while the restoration construction was in progress. Though we found no significant increase, tolerant species were fairly consistent in the restored sites with the exception of right after the habitat construction where they were the most in both the control and restored sites. This may be because all the tolerant species are generalist species. Thomas (2012) found an increase in tolerant species after restoration as well (Yellow Bullhead, Green Sunfish, and White Sucker). Some species with a high tolerance such a Bluntnose Minnow can occupy habitats with disturbance, turbidity, and siltation (Trautman 1981; Becker 1983; Boschung and Mayden 2004).

Generalist species had a significant increase in relative density after restoration. Most of the *Cyprinid* species I found were generalists (Smogor 2000) and the Spotfin Shiner, Bluntnose Minnow, and Creek Chub are known to tolerate impacted habitat (Trautman 1981). This may have led to their increase in the restored area where the stream was initially disturbed and the habitat was new. Other generalist species contributed to this increase as well. Other tolerate species such as the White Sucker, is known to tolerate disturbed conditions such as siltation (Trautman 1981).

Though I found habitat specialists such as the Brindled Madtom and Northern Hog Sucker were showing increasing trends after restoration, other specialists were not. There was no significance in overall habitat specialists' relative density after restoration. There was no significance in mineral substrate spawners, though the Redfin Shiner indicated a change in the assemblage during and after restoration. However, Central Stonerollers, another mineral substrate spawner, did not increase proportionally after habitat restoration. This leads me to think that it may be too soon to see these specialists improving after habitat restoration.

Fish assemblage changes

In the restored sites during restoration, the Sand Shiner, Silverjaw Minnow, Spotfin Shiner, and Bluntnose Minnow all provided change to the assemblage. During restoration, all of these species increased compared to before restoration. All of these species are considered generalists (Smogor 2000) and some with higher tolerance such as the Bluntnose Minnow and Spotfin Shiner (Trautman 1981; Becker 1983; Boschung and Mayden 2004). This may have led to their increase in the restored area where the stream was initially disturbed and the habitat was new.

The Spotfin Shiner, Sand Shiner, and Bluntnose Minnow all provided changes in community when comparing before and after habitat restoration. All of these species are generalists and highly motile *Cyprinids,* which contributed to the change by increasing after restoration. The Sand Shiner inhabits sand and gravel runs and pools in small streams (Etnier and Starnes 1993) which is typical habitat of the Kickapoo Creek study sites. However, by the fall 2011 sample, the Spotfin shiner was the most abundant fish in the restored sites. They were the most relative abundant species in the spring DC electrofishing survey as well. Generally, the Spotfin Shiner is found in or near riffles or raceways over gravel in moderate or fast current (NatureServe *Explorer* 2005) and in pools with sand, gravel, and silt substrate (Smith 1979). These habitat descriptions mostly make up the restored sites and may be contributing to the increase in this species.

When comparing during restoration to after restoration, cumulative percentage changes came from the Silverjaw Minnow, Spotfin Shiner, and Bluntnose Minnow, Sand

Shiner, and Central Stoneroller. Once again, these fish are all generalists except for the Central Stoneroller (Smogor 2000). Here, the Silverjaw Minnow and Central Stoneroller did not increase along with the total abundance. The Spotfin Shiner, Sand Shiner, and Bluntnose Minnow continued to increase after habitat restoration. Spotfin Shiners became the most numerous fish by the last sample period.

Indicator species analysis revealed a change in abundance of the Brook Silverside during restoration sample period of the study. This was the only time the Brook Silverside appeared during the study. The Brook Silverside is considered to have intermediate tolerance and is an insectivore (Barbour 1999) and prefers water with low turbidity and clean substrate (AWAKE 2011). However, by the time the after restoration sample was collected this species was not included. They may have simply been passing through when collected. Gizzard Shad was an indicator in the restored sites after habitat restoration. This may be due to this species preferring deep pools in streams (Smith 1979) when pools had deepened after habitat restoration. The DC electrofishing method also sampled Gizzard Shad out of the deepest pool. Also, indicators of community change during restoration, was the Redfin Shiner. However, their numbers decreased after habitat restoration. Because the Redfin Shiner prefer pools in streams (Smith 1979), the decreasing trend after restoration may be due to something besides habitat usage.

Future ecological research and other potential habitat enhancement

During this study period from fall 2009 through fall 2011, the downstream control site (A) was within 100m of the downstream restored site. Some fish may have utilized both the habitat from the restored along with the nearby control site. Current research on Kickapoo Creek has the downstream control site further downstream to eliminate this conflict of potential crossover. I found multiple trends in fish response to habitat restoration but few were significant. This is due to the small amount of sample periods and the often variable control and restored sites before averaged together. Currently, each site is divided into 50 m transects to allow for more variables for statistical testing.

More time will likely need to pass for other species besides generalists to improve in the restored habitat if it is going to occur. Though this research project covers September 2009-September 2011, habitat restoration evaluation will continue. Though not as large of a sample size or frequent sampling period, the Illinois EPA and Illinois DNR have historic data in and near the Kickapoo Creek restoration site. This is extremely important to eventually having a complete understanding of the effects of habitat restoration on fish communities. Habitat restoration projects that cause change to biota may take years so ecological evaluations should continue for a decade (Kondolf 1995). I found a variety of fish population responses after the Kickapoo Creek's habitat restoration. Fish populations are subject to natural fluctuations and may take several sample periods before any noticeable trend (Kondolf 1995). For instance, Hunt (1976) found that brook trout did not hit carrying capacity until 5 years after habitat restoration. Shields and Knight (2003) found ten years after restoration that depth had more than doubled, and woody riparian veg more than doubled. Also, prior to restoration, they found 51% *Cyprinid* species and then found a more *Centrachid* dominated community (61%) (Shields and Knight 2003). Surveys may be reduced to alternate years as a habitat restoration project continues (Kondolf 1995).

Kickapoo Creek is a stream with extreme fluctuation of water levels and flow so habitat restoration may only withstand a certain amount of floods. A high percentage of habitat restoration ends in failure (Kondolf 1995) and if this becomes the case with Kickapoo Creek, it is still important data for potential habitat restoration decision making.

There is an importance of channel morphology as the primary determinant of the special and successional patterns of biological communities (Kondolf 1995). In streams, habitat improvement needs to be done to habitat factors that can be modified (Kondolf 1995). Other factors such as food availability need to be considered along with restoration as well (Hicks and Reeves 1994). This aquatic macroinvertebrate sampling is important to assessing the fish community. I also have to assume that there is a supply of fish in the surrounding area available to recolonize the restored habitat (Roper et al. 1997). Other ecological components have to be considered as well with improving fish habitat. Having a plan for ecological enhancement on upslope processes as well may further help stream habitat (Roper et al. 1997). Other detrimental factors occur in the Kickapoo Creek water shed besides erosion caused by agriculture. In the headwater, such factors are a sewer effluent, a golf course, and an interstate. All may contribute to flash flooding, nutrient loading, and pollution having a negative impact on the restoration. Improved stream basin techniques may positively have an influence on biotic communities.

Overall, response evaluations on fish assemblages shortly after restoration favored generalist and more motile species mostly from the *Cyprinid* family. As time continues, Kickapoo Creek's fish assemblage response to habitat restoration may become more apparent.

Table 1: Qualitative Habitat Evaluation Index (QHEI) scores taken in control and restored sites before restoration (summer 2010) and after restoration (summer 2011)

QHEI Metrics	Metric Component	Scoring Range	2010 (A)	2011 (A)	2010 (D)	2011 (D)	2010 (B)	2011 (B)	2010 (C)	2011 (C)
Substrate	a)type	0-21	21	15	21	15	15	15	15	15
	b)quality	-5-3	1.5	1	1.5	1	0.5	1	1.5	1
Instream Cover	a)type	0-10	10	6	9	8	6	8	10	6
	b)amount	1-11	2	5	3	7	3	7	3	7
Channel Morphology	a)sinuosity	1-4	3	3	3	2	3	3	3	2
	b)development	1-7	5	3	5	3	5	3	5	3
	c)channelization	1-6	6	6	6	6	6	6	6	6
	d)stability	1-3	2	1	2	2	2	2	1	3
Riparian Zone/Bank Erosion	a)width	0-4	2.5	3.5	2.5	3	3	3	2.5	3
	b)quality	0-3	1.5	1.5	0.5	0.5	1.5	1.5	1.5	1.5
	c)bank erosion	1-3	2	2	1.5	2	2	3	1.5	3
Pool/Glide and Riffle/Run Quality	a)max depth	0-6	4	4	6	4	4	6	6	6
	b)current	-2-4	3	1	2	1	3	1	2	1
	c)morphology	0-2	2	2	2	2	0	2	2	2
	a)riffle depth	0-2	2	1	2	1	2	2	1	2
	b)run depth	0-2	2	2	1	1	1	2	1	2
	c)substrate stability	0-2	0	0	0	0	0	2	0.5	2
	d)substrate embededness	-1-2	0	0	0	0	1	1	1	1
Gradient		0-10	6	6	6	6	6	6	6	6
Total Score			**73**	**63**	**71.5**	**66.5**	**64**	**74.5**	**69.5**	**72.5**
				Control				**Restored**		

Table 2. Total number of fishes sampled in Kickapoo Creek during the study period from Fall 2009 through Fall 2011 using AC electrofishing.

Family	Common Name	Scientific Name	Restored	Control
Cyprinidae	Sand Shiner	*Notropis stramineus*	8663	4514
Cyprinidae	Spotfin Shiner	*Cyprinella spiloptera*	6407	2918
Cyprinidae	Silverjaw Minnow	*Ericymba buccatus*	5387	2783
Cyprinidae	Bluntnose Minnow	*Pimephales notatus*	4033	1067
Cyprinidae	Central Stoneroller	*Campostoma anomalum*	2753	1286
Cyprinidae	Creek Chub	*Semotilus atromaculatus*	676	661
Cyprinidae	Steelcolor Shiner	*Cyprinella whipplei*	715	472
Ictaluridae	Brindled Madtom	*Noturus miurus*	354	233
Catostomidae	Northern Hog Sucker	*Hypentelium nigricans*	325	253
Percidae	Orangethroat Darter	*Etheostoma spectabile*	328	342
Centrarchidae	Bluegill	*Lepomis macrochirus*	337	87
Percidae	Johnny Darter	*Etheostoma nigrum*	271	187
Centrarchidae	Green Sunfish	*Lepomis cyanellus*	243	117
Centrarchidae	Longear Sunfish	*Lepomis megalotis*	381	66
Catostomidae	White Sucker	*Catostomus commersonii*	235	78
Cyprinidae	Suckermouth Minnow	*Phenacobius mirabilis*	60	214
Percidae	Greenside Darter	*Etheostoma blennioides*	93	164
Percidae	Rainbow Darter	*Etheostoma caeruleum*	121	130
Fundulidae	Blackstriped Topminnow	*Fundulus notatus*	90	38
Cyprinidae	Redfin Shiner	*Lythrurus umbratilis*	92	22
Centrarchidae	Largemouth Bass	*Micropterus salmoides*	64	14
Ictaluridae	Yellow Bullhead	*Ameiurus natalis*	19	42
Catostomidae	Golden Redhorse	*Moxostoma erythrurum*	55	9
Clupeidae	Gizzard Shad	*Dorosoma cepedianum*	36	1
Cyprinidae	Bullhead Minnow	*Pimephales vigilax*	31	17
Cyprinidae	Striped Shiner	*Luxilus chrysocephalus*	40	15
Catostomidae	Quillback	*Carpiodes cyprinus*	19	1
Atherinidae	Brook Silverside	*Labidesthes sicculus*	14	0
Catostomidae	Creek Chubsucker	*Erimyzon oblongus*	5	2
Cyprinidae	Golden Shiner	*Notemigonus crysoleucas*	3	1
Poeciliidae	Western Mosquitofish	*Gambusia affinis*	4	2
Centrarchidae	Spotted Bass	*Micropterus punctulatus*	3	1
Lepisosteidae	Longnose Gar	*Lepisosteus osseus*	3	1
Cyprinidae	Mississippi Silvery Minnow	*Hybognathus Nuchalis*	2	1
Percidae	Logperch	*Percina caprodes*	2	0
Ictaluridae	Channel Catfish	*Ictalurus punctatus*	0	3
Ictaluridae	Black Bullhead	*Ameiurus melas*	0	1
Cyprinidae	Fathead Minnow	*Pimephales promelas*	1	0
Percidae	Dusky Darter	*Percina sciera*	0	1
Percidae	Fantail Darter	*Etheostoma flabellare*	1	0
Catostomidae	Highfin Carpsucker	*Carpiodes velifer*	1	0
Catostomidae	Shorthead Redhorse	*Moxostoma macrolepidotum*	1	0
Ictaluridae	Tadpole Madtom	*Noturus gyrinus*	0	1
Petromyzontidae	Chestnut Lamprey	*Ichthyomyzon castaneus*	1	0
Total			31769	15746

Table 3: Summary of all fishes sampled by season from all site of Kickapoo Creek during fall 2009, 2010, 2011 and spring 2010, 2011 using AC electrofishing. There were 11 unique species captured in the fall and 5 unique species captured in the spring.

	Season	
Common Name	Fall	Spring
Sand Shiner	9224	3953
Spotfin Shiner	7462	1863
Silverjaw Minnow	6128	2042
Bluntnose Minnow	3946	1154
Central Stoneroller	3390	649
Creek Chub	1094	243
Steelcolor Shiner	994	193
Northern Hog Sucker	505	82
Orangethroat Darter	489	89
Brindled Madtom	469	201
Johnny Darter	418	40
Bluegill	250	174
Longear Sunfish	268	79
White Sucker	255	58
Green Sunfish	242	118
Suckermouth Minnow	250	24
Rainbow Darter	183	68
Greenside Darter	178	79
Blackstripe Topminnow	105	23
Redfin Shiner	97	17
Largemouth Bass	74	4
Bullhead Minnow	48	0
Golden Redhorse	48	16
Yellow Bullhead	40	21
Striped Shiner	41	14
Gizzard Shad	4	33
Brook Silverside	14	0
Quillback	10	10
Western Mosquitofish	6	0
Spotted Bass	4	0
Creek Chubsucker	3	4
Mississippi Silvery Minnow	3	0
Channel Catfish	3	0
Logperch	0	2
Black Bullhead	1	0
Tadpole Madtom	1	0
Shorthead Redhorse	1	0
Fantail Darter	1	0
Fathead Minnow	1	0
Golden Shiner	0	5
Longnose Gar	0	4
Highfin Carpsucker	0	1
Dusky Darter	0	1
Chestnut Lamprey	0	1
Total	36250 (40 species)	11265 (34 species)

Table 4. Seasonal Index of Biotic Integrity scores (according to the Illinois Department of Natural Resources) for the Downstream Control (A), Downstream Restored (B), Upstream Restored (C), and Upstream Control (D) sites.

Season	Downstream Control	Downstream Restored	Upstream Restored	Upstream Control
Fall 2009	38	37	38	41
Spring 2010	27	36	37	32
Fall 2010	36	37	35	38
Spring 2011	30	34	29	30
Fall 2011	32	36	36	36

Table 5. Abundance of fishes before, during, and after habitat restoration.

Species	Before A1	Before B1	Before C1	Before D1	Before A2	Before B2	Before C2	Before D2	During A3	During B3	During C3	During D3	After A4	After B4	After C4	After D4	After A5	After B5	After C5	After D5
Sand Shiner	279	311	362	296	239	399	156	42	600	1427	1340	550	234	851	1344	688	1066	1627	846	520
Spotfin Shiner	51	13	51	54	30	81	48	7	380	834	996	646	326	625	358	388	651	2042	1359	385
Silverjaw Minnow	435	580	281	171	234	594	194	3	358	1066	1077	426	188	357	290	182	327	601	347	459
Bluntnose Minnow	101	231	136	59	65	121	54	3	66	711	521	123	187	354	266	104	248	1344	295	111
Central Stoneroller	106	146	267	236	6	158	24	6	108	465	673	234	10	369	29	47	80	460	162	453
Creek Chub	73	41	32	82	32	48	23	6	144	205	195	163	41	27	35	31	15	48	22	74
Steelcolor Shiner	25	8	21	6	0	2	1	2	50	138	216	62	36	65	41	46	145	147	76	100
Northern Hog Sucker	8	27	8	11	5	14	6	1	78	100	112	102	4	33	12	7	8	42	0	9
Orangethroat Darter	25	50	21	66	18	15	10	2	38	85	44	34	3	20	4	17	8	67	9	42
Brindled Madtom	43	13	18	27	13	18	12	11	52	41	15	40	23	39	33	52	46	118	21	35
Bluegill	11	57	16	4	0	1	2	0	19	6	18	17	9	49	98	15	8	57	33	4
Johnny Darter	17	8	26	15	0	7	1	0	43	73	53	70	7	12	6	7	7	62	23	21
Green Sunfish	18	29	17	7	2	14	23	0	31	23	24	14	15	41	16	7	16	40	16	7
Longear Sunfish	19	32	31	4	1	10	11	0	12	13	7	1	14	17	24	2	8	112	24	5
White Sucker	23	25	16	5	2	7	4	0	21	60	61	19	4	22	19	0	2	12	9	2
Suckermouth Minnow	12	8	0	115	0	4	0	2	7	18	14	19	0	2	0	16	1	13	1	42
Greenside Darter	18	23	4	62	7	28	1	7	11	8	1	36	4	18	3	11	1	7	0	7
Rainbow Darter	10	18	7	38	6	24	1	3	19	28	11	25	1	21	1	11	2	10	0	15
Blackstripe Topminnow	5	8	5	0	3	13	1	0	0	5	8	2	1	3	1	1	25	42	4	1
Redfin Shiner	8	13	3	0	1	6	5	0	13	39	11	0	0	1	4	0	0	6	4	0
Largemouth Bass	8	16	9	3	0	0	0	0	1	2	4	1	0	0	4	0	1	15	14	0
Yellow Bullhead	4	8	1	4	0	2	0	0	6	0	0	4	7	2	1	9	2	2	3	6
Golden Redhorse	4	29	6	0	0	8	7	0	0	2	0	2	1	0	0	0	0	2	1	2
Gizzard Shad	0	0	0	0	0	0	0	0	0	0	0	0	1	25	7	0	0	4	0	0
Bullhead Minnow	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	15	16	1
Striped Shiner	5	8	21	1	0	5	2	5	2	0	0	1	0	1	0	1	0	3	0	0
Quillback	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	1	7	2	0
Brook Silverside	0	0	0	0	0	0	0	0	0	13	1	0	0	0	0	0	0	0	0	0
Creek Chubsucker	2	0	1	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Golden Shiner	0	0	0	0	0	0	0	0	0	0	0	0	1	3	0	1	0	0	0	0
Western Mosquitofish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4	0	0
Longnose Gar	0	0	0	0	1	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0
Spotted Bass	0	2	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
Channel Catfish	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0
Silvery Minnow	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1
Logperch	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Black Bullhead	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Redear Sunfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dusky Darter	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tadpole Madtom	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Fantail Darter	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0

Table 6. Percentage of contribution to assessment change before, during, and after habitat restoration

Species	Before vs. During	Before vs. After	During vs. After
Sand Shiner	24%	29%	11%
Silverjaw Minnow	19%	X	23%
Spotfin Shiner	18%	30%	18%
Bluntnose Minnow	12%	13%	13%
Central Stoneroller	X	X	11%

Table 7: Deep water pool and associated riffle DC electrofishing effort in upstream restored Site (C). Spring 2011.

Species	CPUE Fish/hr
Spotfin Shiner	187.50
Sand Shiner	85.41
Longear Sunfish	35.41
White Sucker	31.25
Silverjaw Minnow	27.08
Gizzard Shad	25.00
Green Sunfish	16.67
Rainbow Darter	16.67
Creek Chub	14.58
Steelcolor Shiner	12.50
Greenside Darter	12.50
Central Stoneroller	10.42
Northern Hog Sucker	10.42
Yellow Bullhead	6.25
Spotted Bass	6.25
Orangethroat Darter	2.08
Johnny Darter	2.08
Redfin Shiner	2.08
Western Mosquitofish	2.08
Black Bullhead	2.08

Table 8: Deep water pool and associated riffle DC electrofishing effort in upstream restored Site (C). Fall 2011.

Species	CPUE fish/hr
Spotfin Shiner	161.05
Bluegill	110.53
Green Sunfish	37.90
White Sucker	30.00
Steelcolor Shiner	28.42
Orangethroat Darter	28.42
Longear Sunfish	25.26
Gizzard Shad	20.53
Bullhead Minnow	17.37
Northern Hog Sucker	15.79
Brindled Madtom	12.63
Largemouth Bass	11.05
Johnny Darter	7.89
Redfin Shiner	7.89
Central Stoneroller	6.32
Yellow Bullhead	6.32
Rainbow Rarter	4.74
Golden Redhorse	4.74
Bluntnose Minnow	3.16
Creek Chub	3.16
Greenside Darter	3.16
Quillback	3.16
Redear Sunfish	3.16
Sand Shiner	1.58
Blackstripe Topminnow	1.58
Logperch	1.58

Figure 1: Ariel map of Kickapoo Creek study area southwest of Charleston, Illinois. Arrows indicate study sites.

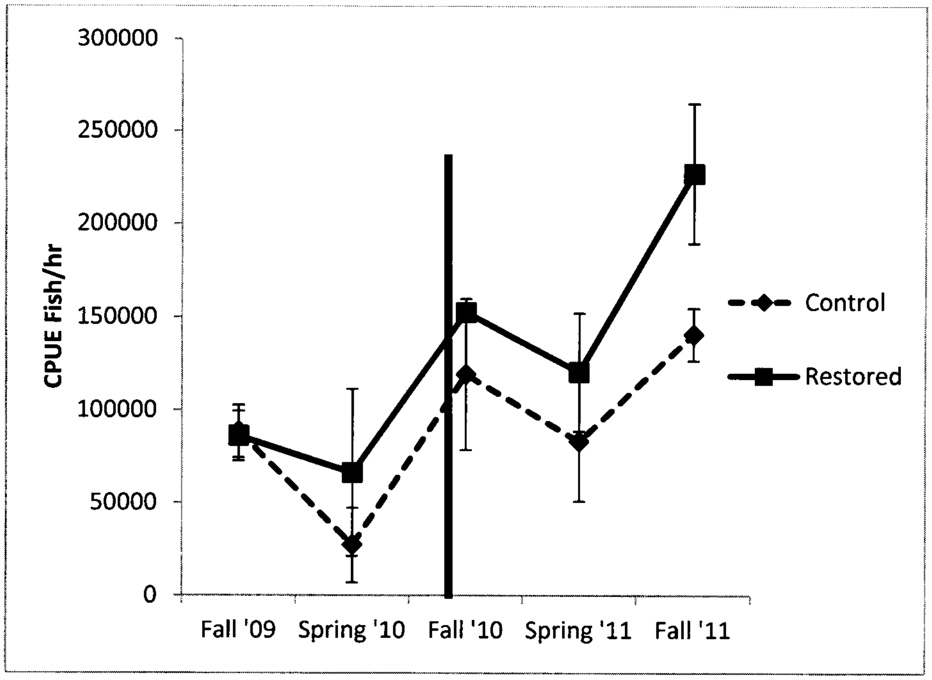

Figure 2. Relative density (CPUE) for Total Fish sampled from Kickapoo Creek during fall 2009 through fall 2011. Control includes both upstream and downstream control sites (A & D). Restored sites are downstream (B) and upstream (C). The vertical line represents approximate time of restoration. Change after restoration: Restored-t = 3.11 df = 8 P = .014.

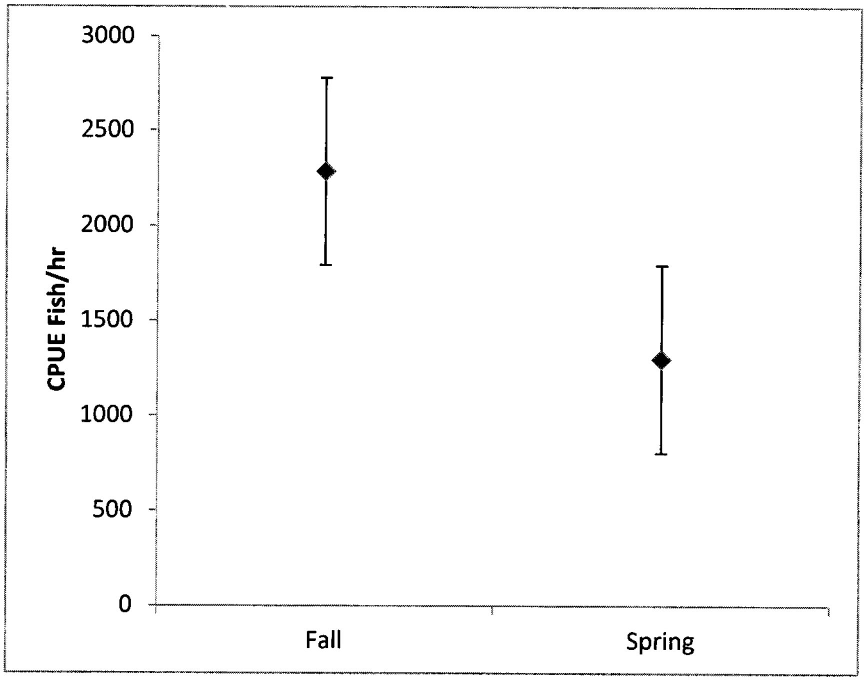

Figure 3. Season comparison of relative density (CPUE). Based on seasonal sampling T-tests, differences in mean CPUE were observed between Fall (Mean=2262.5, SE=255.1, N=12) and Spring (Mean=1237.8, SE=258.9, N=8) (t=2.71, DF=18, P=0.01).

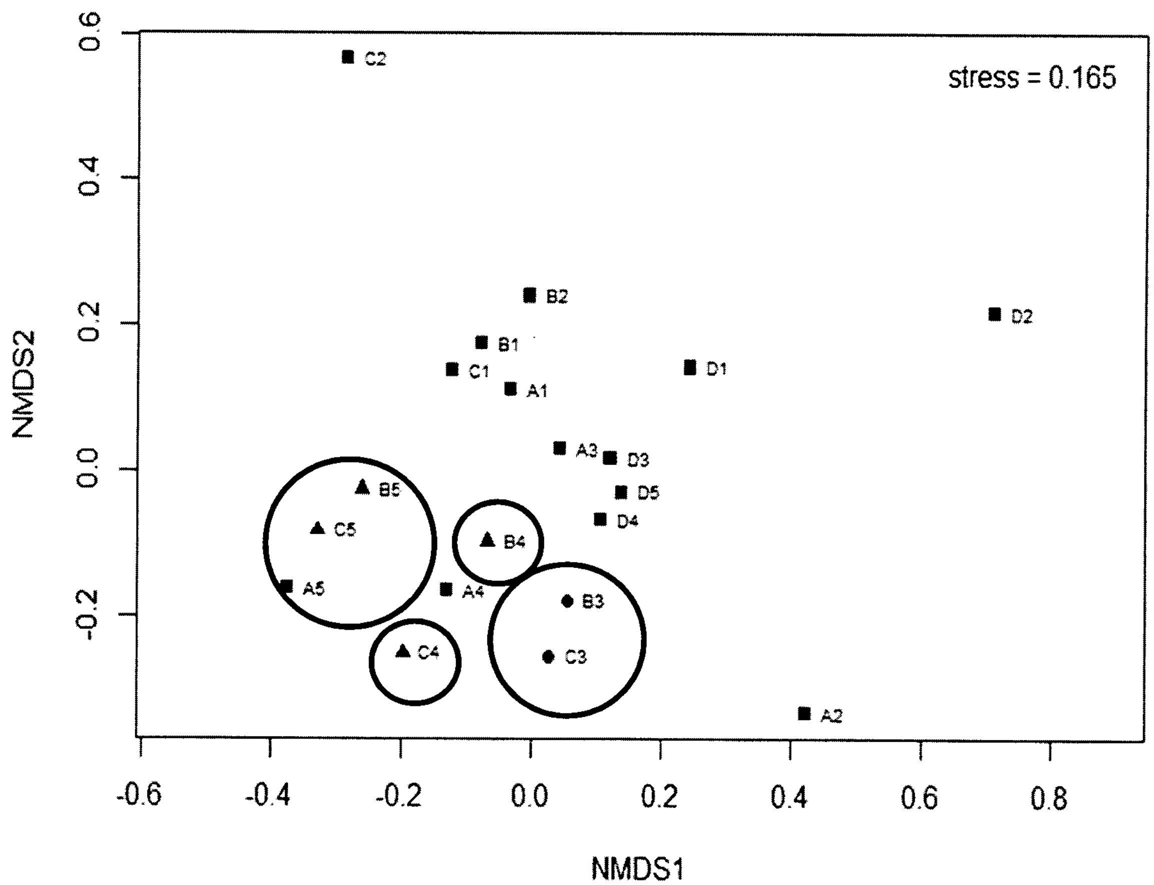

Figure 4: NMDS plot of fish assemblages sampled from Kickapoo Creek during fall 2009 through fall 2011 based on Bray-Curtis Dissimilarity. Symbols represent sampling time with squares = before restoration and unaffected by restoration (before-restored sites and controls), circles = during restoration (fall 2010), and triangles= after restoration (spring 2011 and fall 2011). perMANOVA shows difference in assemblages during the study ($f = 5.4$ $df = 19$ $p = 0.0016$). Pairwise comparison reveals a significant difference between unaffected by restoration and during restoration ($f = 4.02$ $df = 15$ $p = 0.035$) and unaffected compared to after restoration in the restored sites ($f = 4.26$ $df = 17$ $p = 0.003$). There was no significance between restoration comparing during and after restoration ($f = 1.87$ $df = 5$ $p = .257$).

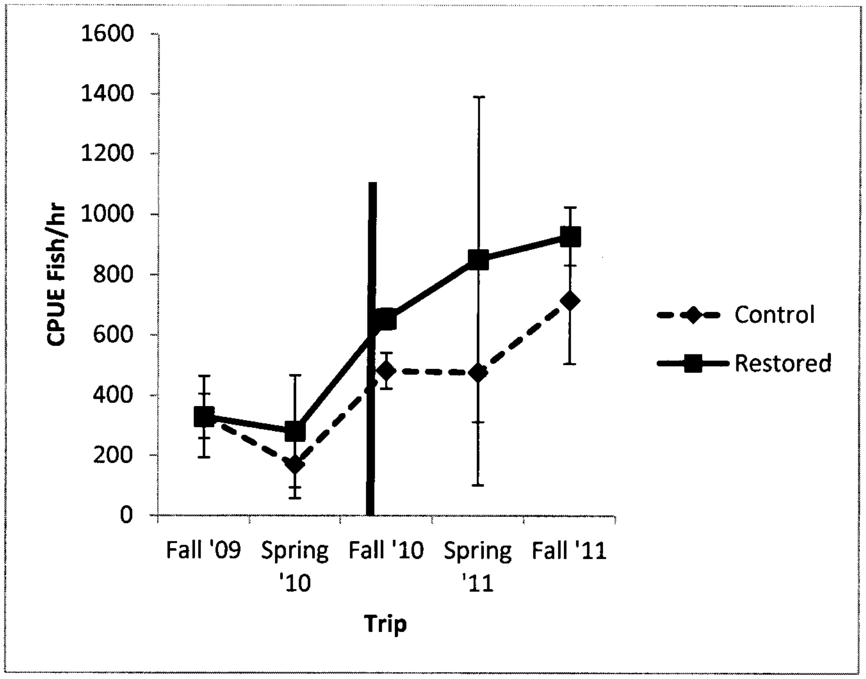

Figure 5. Relative density (CPUE) for the Sand Shiner (generalist) sampled from Kickapoo Creek during fall 2009 through fall 2011. Control includes both upstream and downstream control sites (A & D). Restored sites are downstream (B) and upstream (C). The vertical line represents approximate time of restoration. SIMPER reveals this species a contributor of change in assemblage during and after restoration.

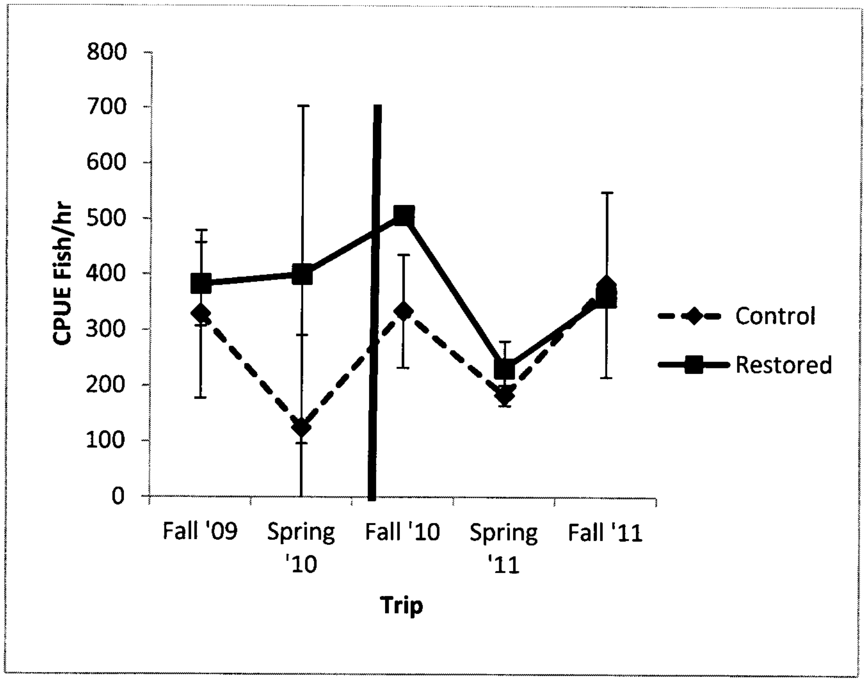

Figure 6. Relative density (CPUE) for the Silverjaw Minnow (generalist) sampled from Kickapoo Creek during fall 2009 through fall 2011. Control includes both upstream and downstream control sites (A & D). Restored sites are downstream (B) and upstream (C). The vertical line represents approximate time of restoration. SIMPER reveals this species a contributor of change in assemblage during and after restoration.

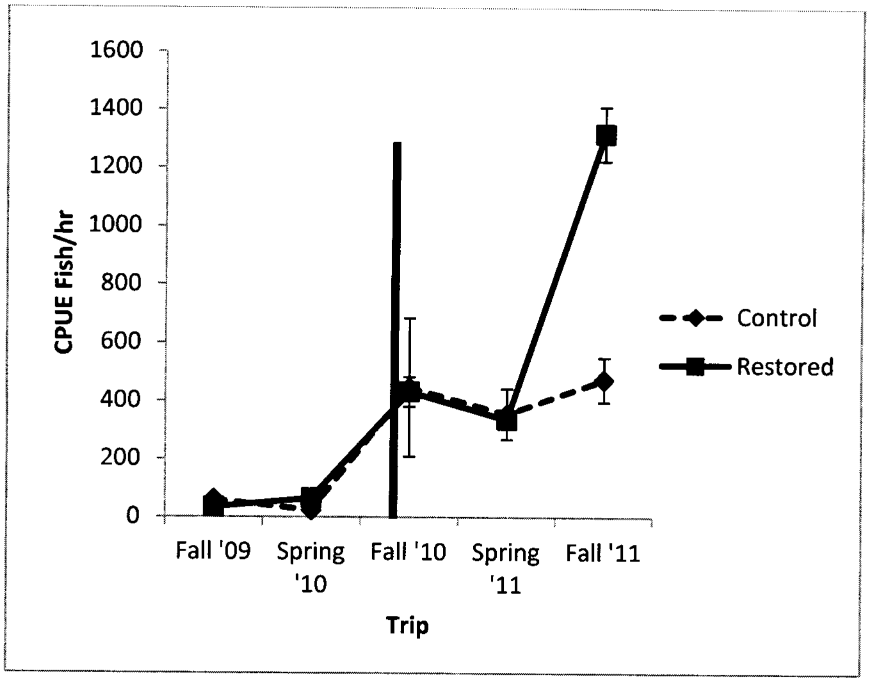

Figure 7. Relative density for the Spotfin Shiner (generalist) sampled from Kickapoo Creek during fall 2009 through fall 2011. Control includes both upstream and downstream control sites (A & D). Restored sites are downstream (B) and upstream (C). The vertical line represents approximate time of restoration. SIMPER reveals this species a contributor of change in assemblage during and after restoration.

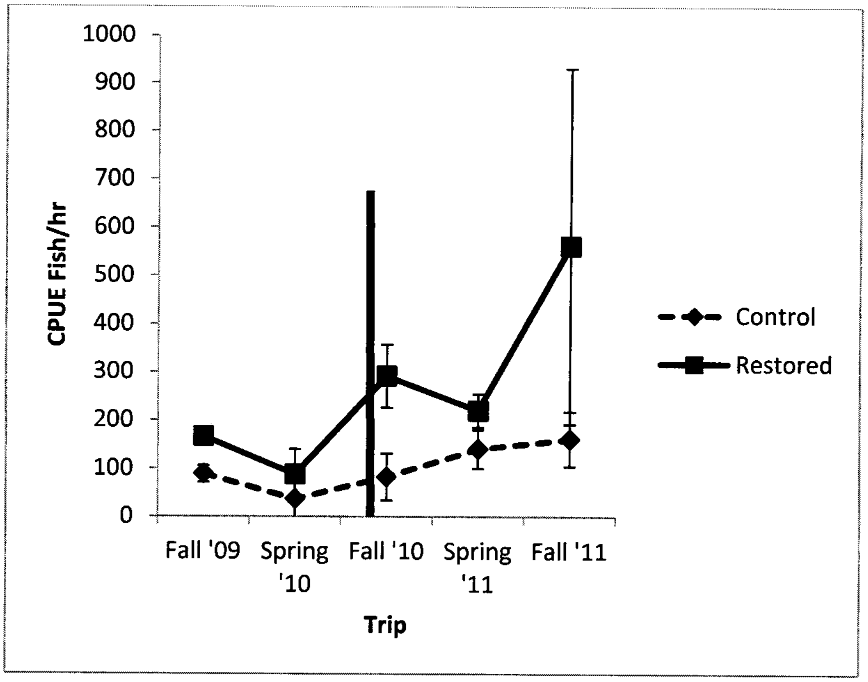

Figure 8. Relative density (CPUE) for the Bluntnose Minnow (generalist) sampled from Kickapoo Creek during fall 2009 through fall 2011. Control includes both upstream and downstream control sites (A & D). Restored sites are downstream (B) and upstream (C). The vertical line represents approximate time of restoration. SIMPER reveals this species a contributor of change in assemblage during and after restoration.

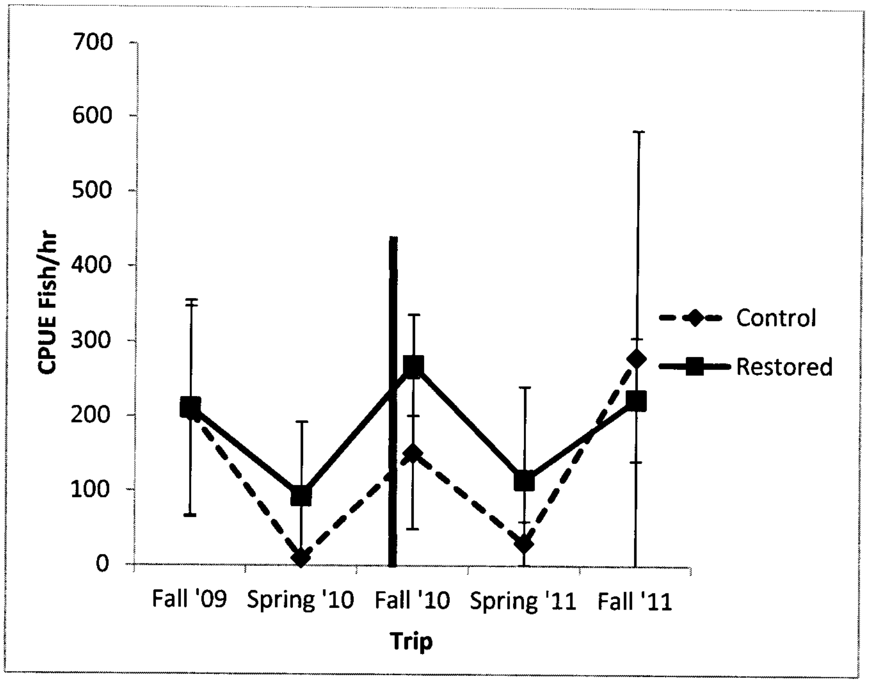

Figure 9. Relative density (CPUE) for the Central Stoneroller (mineral substrate spawner) sampled from Kickapoo Creek during fall 2009 through fall 2011. Control includes both upstream and downstream control sites (A & D). Restored sites are downstream (B) and upstream (C). The vertical line represents approximate time of restoration. SIMPER reveals this species a contributor of change in assemblage after restoration.

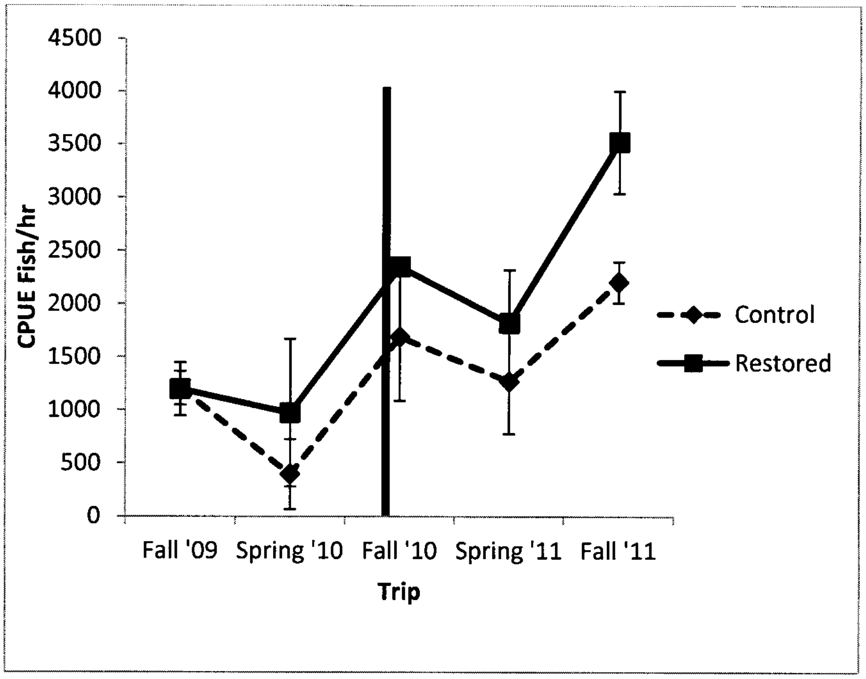

Figure 10. Relative density (CPUE) for *Cyprinidae* species sampled from Kickapoo Creek during fall 2009 through fall 2011. Control includes both upstream and downstream control sites (A & D). Restored sites are downstream (B) and upstream (C). The vertical line represents approximate time of restoration. Change after restoration: Restored: t=3.19 DF=8 P=0.01 Control: t=2.65 DF=8 P=0.03.

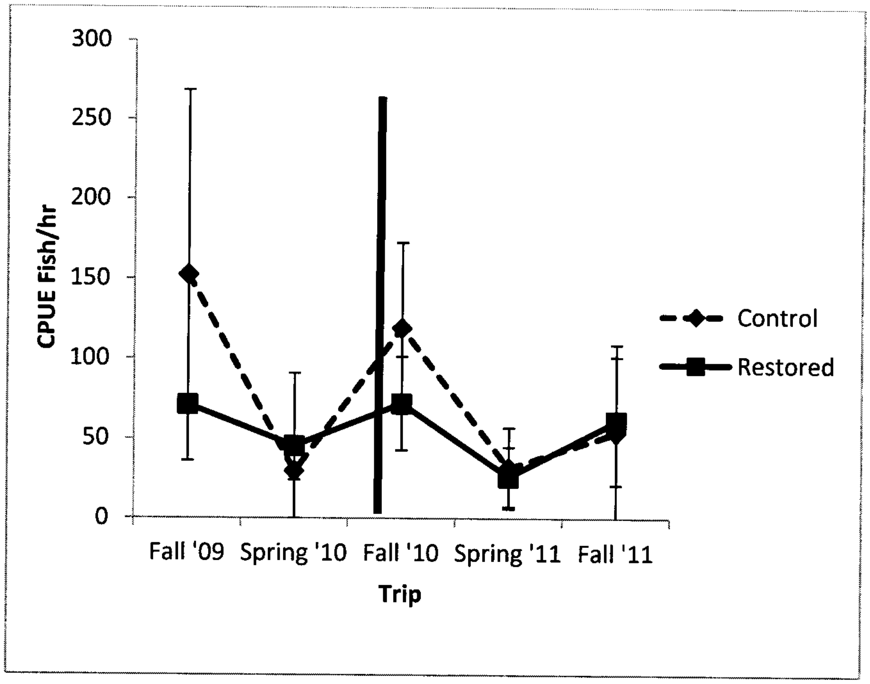

Figure 11. Relative density CPUE for *Percidae* species sampled from Kickapoo Creek during fall 2009 through fall 2011. Control includes both upstream and downstream control sites (A & D). Restored sites are downstream (B) and upstream (C). The vertical line represents approximate time of restoration.

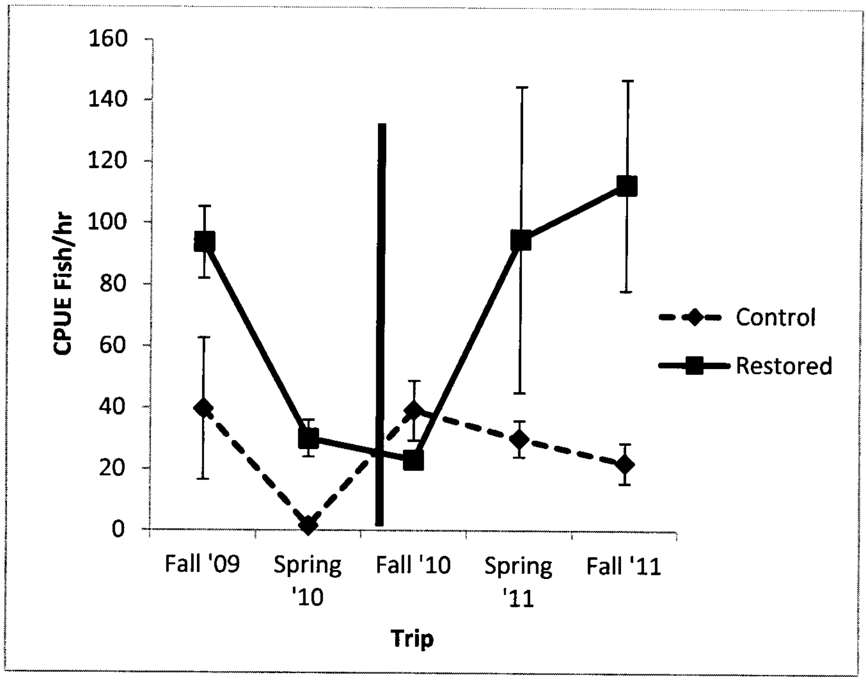

Figure 12. Relative density for *Centrarchidae* species sampled from Kickapoo Creek during fall 2009 through fall 2011. Control includes both upstream and downstream control sites (A & D) Restored sites are downstream (B) and upstream (C). The vertical line represents approximate time of restoration.

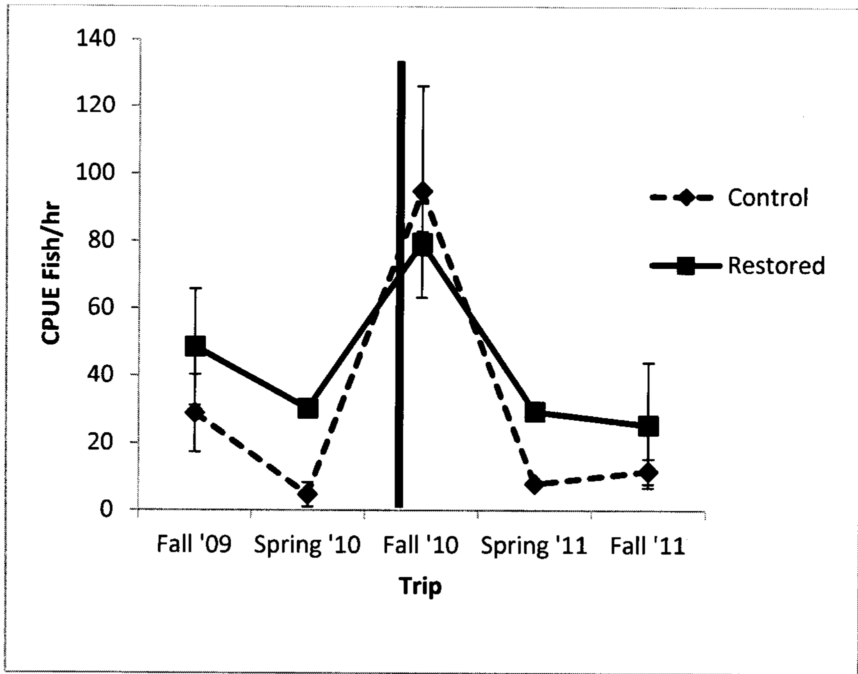

Figure 13. Relative density (CPUE) for *Catostomidae* species sampled from Kickapoo Creek during fall 2009 through fall 2011. Control includes both upstream and downstream control sites (A & D) Restored sites are downstream (B) and upstream (C). The vertical line represents approximate time of restoration.

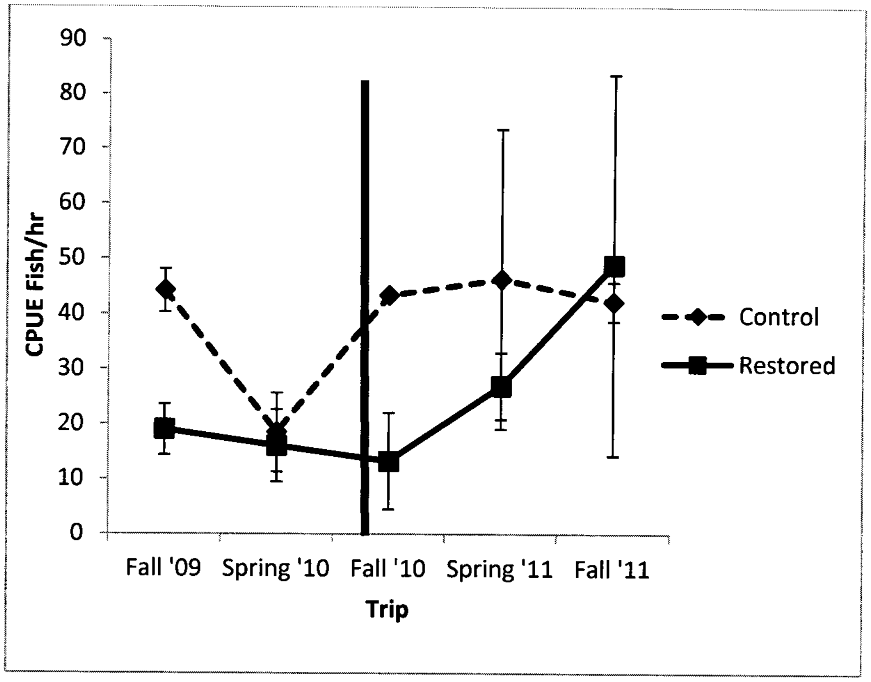

Figure 14. Relative density for *Ictaluridae* species sampled from Kickapoo Creek during fall 2009 through fall 2011. Control includes both upstream and downstream control sites (A & D). Restored sites are downstream (B) and upstream (C). The vertical line represents approximate time of restoration.

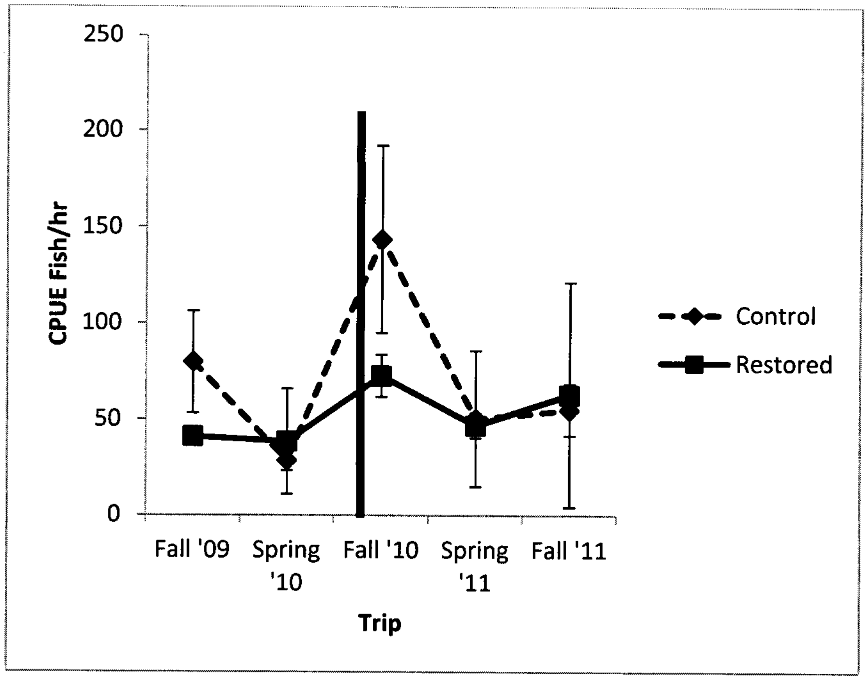

Figure 15. Relative density (CPUE) for intolerant fish species (Brindled Madtom, Northern Hogsucker, Rainbow Darter, Highfin Carpsucker) sampled from Kickapoo Creek during fall 2009 through fall 2011. Control includes both upstream and downstream control sites (A & D). Restored sites are downstream (B) and upstream (C). The vertical line represents approximate time of restoration.

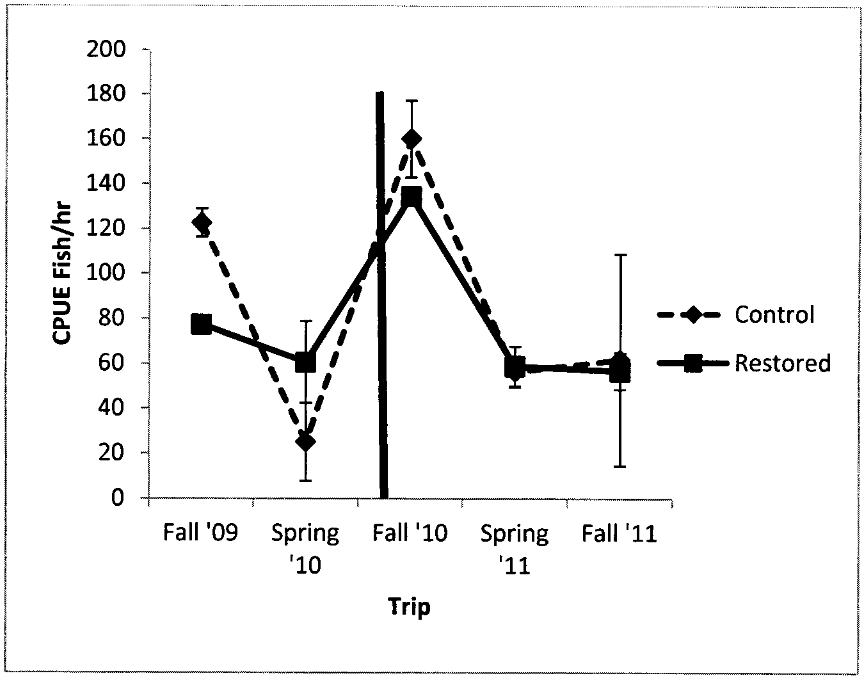

Figure 16. Relative density (CPUE) for tolerant fish species (Creek chub, Green Sunfish, White Sucker, Yellow Bullhead, Golden Shiner, Fathead Minnow) sampled from Kickapoo Creek during fall 2009 through fall 2011. Control includes both upstream and downstream control sites (A & D). Restored sites are downstream (B) and upstream (C). The vertical line represents approximate time of restoration.

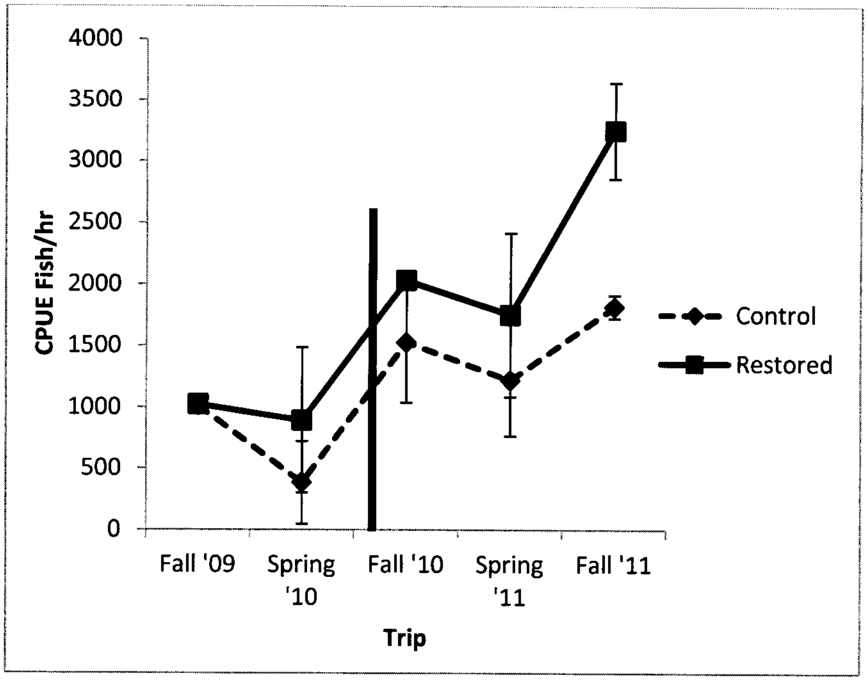

Figure 17. Relative density (CPUE) for generalist species (Black Bullhead, Bluegill, Bluntnose Minnow, Channel Catfish, Creek Chub, Creek Chubsucker, Fathead minnow, Gizzard Shad, Green Sunfish, Quillback, Redfin Shiner, Sand Shiner, Silverjaw Minnow, Spotfin Shiner, Striped Shiner, Suckermouth Minnow, White Sucker, and Yellow Bullhead) sampled from Kickapoo Creek during fall 2009 through fall 2011. Control includes both upstream and downstream control sites (A & D). Restored sites are downstream (B) and upstream (C). The vertical line represents approximate time of restoration. A significant increase occurred in the restored sites after restoration ($t = 0.42$ $df = 8$ $p=.04$)

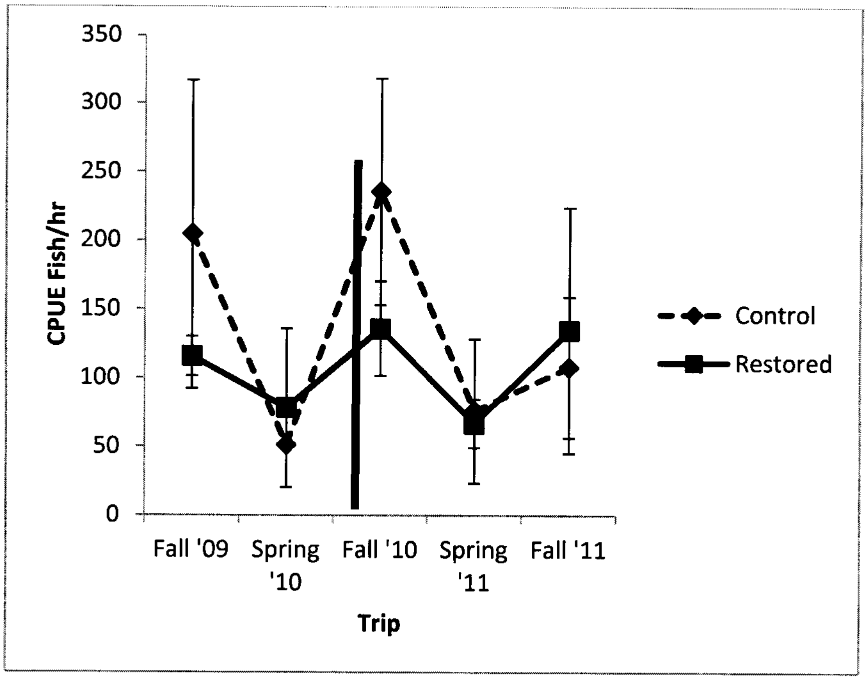

Figure 18. Relative density (CPUE) for specialist benthic invertivore species (Brindled Madtom, Bullhead Minnow, Golden Redhorse, Greenside Darter, Johnny Darter, Logperch, Northern Hog Sucker, Orangethroat Darter, Rainbow Darter, Shorthead Redhorse, and Tadpole Madtom) sampled from Kickapoo Creek during fall 2009 through fall 2011. Control includes both upstream and downstream control sites (A & D). Restored sites are downstream (B) and upstream (C). The vertical line represents approximate time of restoration.

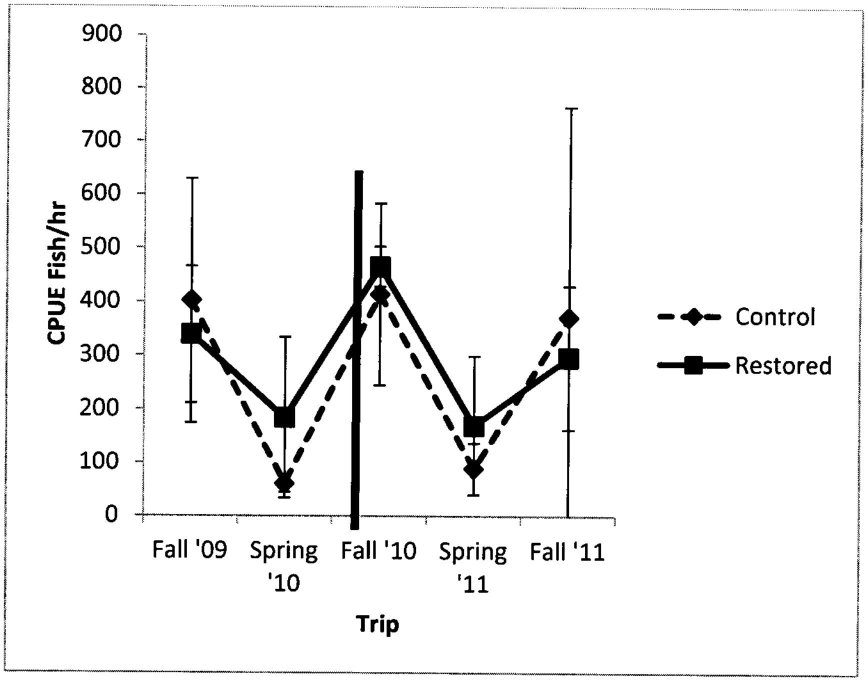

Figure 19. Relative density (CPUE) for mineral substrate spawners invertivore species (Central Stoneroller, Chestnut Lamprey, Creek Chubsucker, Dusky Darter, Fantail Darter, Golden Redhorse, Logperch, Northern Hog Sucker, Orangethroat Darter, Rainbow Darter, Redfin Shiner, Shorthead Redhorse, and Striped Shiner) sampled from Kickapoo Creek during fall 2009 through fall 2011. Control includes both upstream and downstream control sites (A & D). Restored sites are downstream (B) and upstream (C). The vertical line represents approximate time of restoration.

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