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ROAD CULVERT IMPACTS ON STREAM FISH COMMUNITY STRUCTURE IN EASTERN OKLAHOMA

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 $\mathbf{B}\mathbf{Y}$

Dr. Thomas M. Neeson, Chair

Dr. Bruce Hoagland

Dr. Rebecca Loraamm

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Abstract

Road culverts threaten the Ozarks and Ouachita Mountains regions of Oklahoma with habitat fragmentation and loss of aquatic biodiversity. This region of Oklahoma is understudied when it comes to this issue. Fishes within the pelagic spawning reproductive guild are highly impacted by fragmentation because they need long segments of free-flowing river to reproduce. Here, we explore how stream fish community composition varies with the presence of a stream crossing structure such as a culvert. We sampled 29 sites that contained a physical structure and 39 random sites that did not contain a physical structure. At each site, we measured a suite of physical and hydrological attributes of the stream system and sampled the fish community; in sites with a road-stream crossing, we also measured a suite of physical attributes of the structure, and sampled the fish community upstream and downstream of the structure. The presence of a stream crossing structure resulted in significant differences in species richness and abundance compared to unfragmented sites. We also discovered that vertical outlet drops negatively affect species richness and abundance from the upstream to downstream stream segments. Exploring the Bray-Curtis Dissimilarity, we saw that at our fragmented sites there had large differences in stream fish community composition. We also encountered Species of Greatest Conservation Need: Wedgespot Shiner (Notropis greenei), Cardinal Shiner (Luxilus cardinalis), and Black Buffalo (Ictiobus niger). This study presents new data on the effects of fragmentation on stream fishes in this region of Oklahoma. This data could be used to create a framework for conservation of stream fishes in this region and the methodology to undertake projects such as this. With many Ozark and Ouachita Mountain streams fragmented by stream crossing structures, the need for renovation of these structures to ones more suitable for fish passage would be a first step in conservation of these stream fishes

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Literature Review

Freshwater ecosystems are highly imperiled worldwide and are experiencing biodiversity loss at a faster rate than terrestrial systems (Dudgeon et al., 2006). Stressors such as pollution, alteration of natural flow regimes, dewatering, and habitat change are some of the reasons for declining freshwater biodiversity (Palmer et al., 2007; Perkin et al., 2015). But attention has recently focused on the fragmentation of riverine ecosystems and biodiversity loss. Fragmentation occurs when a human-made structure disrupts ecological processes, blocks movement of aquatic organisms, and isolates stream segments from one another (Lindenmayer and Fischer, 2006; Gido et al., 2010; Hoagstrom et al., 2011). The restoration of ecological connectivity among river and stream segments is widely recognized as a key step in the conservation of these ecosystems (Power et al., 1996).

Certain physical characteristics of road culverts tend to make them impassable to aquatic organisms. When culverts are undersized relative to the stream width, water flows are concentrated into a smaller cross-sectional area, increasing the velocity of the water within the culvert. As a result, undersized culverts often constitute a flow velocity barrier for native fishes (Schaefer et al., 2003). Outlet drops where the water level at the plunge pool is unequal to the downstream ends of culverts impede species' distributions because stream fish in the Great Plains are generally weak leapers and are often unable to traverse a vertical outlet drop. As a result, community composition often differs between the upstream and downstream sides of a road-stream crossing (Ficke, Myrick, and Jud, 2011; Mueller et al., 2008). Longer culverts also tend to have lower passability for stream fishes because they force stream fishes to swim at higher speeds for longer distances in order to pass underneath the roadway (Bouska and Paukert, 2010).

River restoration projects that restore connectivity by removal of aging dams and retrofitting impassable road-stream crossings is a challenge for conservation (Perkin et al., 2015; Worthington et al., 2017). These restoration projects have the potential to enhance connectivity and boost freshwater biodiversity, as long as there are no other stressors that constrain ecosystem responses to connectivity restoration projects (Palmer et al., 2005). The main restoration strategy is to replace culverts with ones more suitable for connectivity and fish passage and that provides conditions that resemble natural flow velocity and that natural stream bed conditions (Warren and Pardew, 1998; Bouska and Paukert, 2010).

Because conservation practitioners lack the resources to retrofit all impassable road culverts, they rely on prioritization approaches for choosing among the thousands of candidate projects that exist in most river networks. Most prioritization approaches consistent of a cost-benefit analysis or return on investment analysis, in which conservation practitioners aim to identify projects that would result in a large increase in length of habitat reconnected per dollar spent (O'Hanley and Tomberlin, 2005; Januchowski-Hartley et al., 2014; Worthington et al., 2017; Moody et al., 2017). One of the challenges of applying prioritization approaches to a specific region is the general lack of location data for stream crossings and measures of their passability (Sleight and Neeson, 2018). In many regions, there is also a lack region-specific of data on the effects of these structures on stream fish communities. By combining stream fish composition data and analyzing the passability of culverts, conservation practitioners and construction engineers may be able to better prioritize which crossings should be replaced or renovated.

Despite the growing understanding of the effects of road culverts on stream fishes, the location and effects of physical structures in eastern Oklahoma remains poorly understood. Many of the stream ecosystems in this region are ranked as of high conservation value: small river systems in the Ozarks and Ouachita Mountains regions in Oklahoma are considered "very high conservation priority" by the Oklahoma Comprehensive Wildlife Conservation Strategy (OCWCS, 2016). In this thesis, we explore the effects of road culverts and other stream crossing structures on fish community composition in eastern Oklahoma. We also provide an updated inventory of stream fish community structure in the region, with an emphasis on quantifying the population status of species identified by the Oklahoma Department of Wildlife Conservation as Species of Greatest Conservation Need (ODWC). During the summer of 2018, we sampled 29 sites that possessed a structure that could potentially block fish movement, as well as 39 control sites that did not contain a physical structure. At each site, attributes measured fell in to three categories: physical characteristics of the stream, physical characteristics of the structure, and stream fish community composition. Statistical analysis addressed questions of stream fish richness and abundance regarding position upstream of the structure, downstream of the structure, and unfragmented sites. Next, we analyzed how species richness and abundance might be affected by physical and hydrological attributes of the stream crossing structures. Lastly, Bray-Curtis Dissimilarity Index was used to determine how stream fish community composition differs between the upstream and downstream segments of fragmented sites. The intent of this study is to enhance the understating of the effects of road culverts in stream fishes in eastern Oklahoma, and provide conservation practitioners with an updated understanding of the population status of Species of Greatest Conservation Need (OCWCS, 2016).

Effects of Road Culverts on Stream Fish Community Structure

Introduction

Anthropogenic effects are accelerating biodiversity loss in freshwater environments more rapidly than in terrestrial systems (Dudgeon et al. 2006). Loss of biodiversity is being driven by a wide range of stressors, including pollution, flow changes, dewatering, habitat change, and fragmentation (Palmer et al., 2007, Perkin et al., 2015). Fragmentation is when the presence of a man-made or natural structure alters natural flow regime, disrupts ecological processes, potentially blocks fish movement, and isolates formerly connected stream segments (Lindenmayer and Fischer, 2006; Gido et al., 2010; Hoagstrom et al., 2011). Fragmentation affects the persistence of species and the ecosystem services they provide (Perkin and Gido, 2012). With loss of free-flowing riverine habitat, there is increased extinction, and loss of genetic diversity (Jager et al., 2001). Compounding this issue, freshwater fish species as a group are the most affected by climate change and anthropogenic stressors. (Branco et al., 2016).

Habitat fragmentation in the Great Plains has had drastic effects on stream fishes in this region. With over 19,000 anthropogenic structures in this region affecting flow regimes, there are large effects of fragmentation on stream fish community structure (Costigan and Daniels, 2012; Perkin et al., 2015). Alteration of the habitats surrounding stream systems in this region from native grasslands to row crops that have more dependence on groundwater have had significant effects on stream fish populations (Perkin et al., 2015).

In the Great Plains region of North America streams are primarily affected by water depletion and fragmentation (Perkin et al., 2015). Streams in this region are heavily dominated by pelagic spawning cyprinids. These cyprinids spawn within the water column and depend on flow to carry

male and female genetic material downstream so it may fertilize (Perkin and Gido, 2011). Genetic material that flows downstream outside of the parent stream segment in a disturbed stream will create spawn that are unable to return dwindling population size of these pelagicspawning cyprinids and shrinking their native range and habitats (Perkin et al. 2015). Pelagic spawning cyprinids need long uninterrupted stream reaches ranging from 80km to 217km to be reproductively successful (Perkin and Gido, 2011). But structures downstream inhibit fish from full development while drifting downstream, while structures upstream prevent migration of adults (Perkin and Gido, 2011). Structures also reduce diversity by blocking dispersal between fragments (Perkin et al., 2015). During winters months or drought conditions where the chance to recolonize upstream stream reaches would be more difficult extinction and extirpation would be the results (Worthington et al., 2017). Fish abundance is generally lowest in stream reaches that are artificially constrained channels due to habitat homogenization and/or reduced stream flow (Worthington et al., 2017). The alteration of flow can disrupt the spawning cycles of these pelagic broadcast spawners (Worthington et al., 2017), which usually happens when there is an increase in discharge even though some individuals will spawn no matter the abiotic factors (Worthington et al., 2017).

The interactive effects of declining water availability and habitat fragmentation create an ecological ratchet effect (Perkin et al., 2015). The ratchet concept states that a change in each response variable through space or time in response to natural or human disturbances decreases reciprocal movement, thus creating a negative feedback loop. During periods of drought in the Great Plains as well as the Ozarks and Ouachita's there is less flow in these stream systems. With climate change, human water use, fragmentation, and dewatering affecting connectivity the fish that depend on flow for survival are facing range shrinkage and extinction. The response

variable in this framework would be the ability for pelagic spawning fishes to migrate upstream and spawn. Because passage is blocked, we start to see more extirpation of pelagic spawning fishes occurring during periods of drought and when flows return these fish are gone from their previous stream reaches due to fragmentation (Perkin et al., 2015). Climate change is project to cause decreased water flow in prairie streams with reoccurring summer droughts, and therefore pelagic spawning cyprinids will be further hindered from traversing structures to spawn and/or isolated in stream segments they cannot be reproductively successful in or extirpated from stream segments (Perkin et al., 2015; Worthington et al., 2017).

Alteration of flow in culverts is one of the proposed reasons fish are unable to migrate upstream to spawn (Warren and Pardew, 1998). Road crossings and other structures are constructed to concentrate the discharge and narrow the overall cross section of the stream that fish would normally be able to move or migrate in (Schaefer at al., 2003). Most structures are considered semi-permeable and at full flow and may be less effective as impediments to fish movement (Perkin and Gido, 2011). Fish community composition depends on abiotic and biotic factors of the stream environment, but connectivity issues are an abiotic constraint that drives community compositions (Labonne et al., 2008). Low or intermittent flow forces pelagic broadcast spawning species into isolated stream segments (Worthington et al., 2017). When there are no pelagic spawning species in an isolated stream segment the effects of structures aren't as heightened (Worthington et al., 2017).

Outlet drop is a factor hindering fish movement. Native fishes are weak leapers, so vertical outlet drops block their movements. Over time, this can lead to differences in species richness and abundance between upstream vs downstream sides of structures. (Mueller et al., 2008; Ficke, Myrick, and Jud, 2011). Culvert length is also known to have an effect on fish passage, as culvert

length increases so does the length the fish has to swim against higher water velocities, dependent on the construction of the culvert (Schaefer et al., 2003; Bouska and Paukert, 2010). Deeper plunge pools below the culverts will also hold more species richness and abundance than upstream segments due to deeper water and more habitat throughout the year (MacPherson et al., 2012).

Understanding the effects of stream crossing structures and their spatial impacts on stream fish populations is imperative for conservation of Great Plains minnows. With drastic impacts on native fish diversity, including 41 regional endemic species (which is 84% of all endemic fish in this region) there should be more research on the conservation of these species (Hoagstrom et al. 2011).

We conducted a regional field survey of streams with structures (pipe culverts, box culverts, low-water fords, arch culverts) that could potentially hinder longitudinal connectivity for upstream and downstream fish populations. We surveyed physical and hydrological aspects of the structures to determine if measured variables could identify the degree of obstruction to fish movements. A total of 68 sites surveyed; 29 with structures that could potentially block fish movement and 39 were without. To determine how road-stream crossing structures might affect fish community structure we sampled fish by seining the adjacent upstream and downstream segments surrounding these structures and took a suite of physical and hydrological attributes of the stream environment and road-stream crossing structures. We also used VIE (Visible Implant Elastomer) at five sites to potentially see fish movement upon recapture at a later date. Lastly, we did a fish community analysis showing how fish communities differ based upon their proximity to a physical barrier and what physical attributes of the structure produce these differences. We hypothesize that we will see similar effects of fragmentation on fish community structures in the

Ozarks and Ouachita regions as there are in the Great Plains. We hypothesize that species richness and abundance at each of fragmented sites would be subject to the same confounding factors. With little literature and data on fragmentation on stream fish communities in the Ozark and Ouachita region of Oklahoma, this study will give us insight on how physical characteristics of structures affect stream fish communities in this region. This project could potentially be a framework for further knowledge on the issue of fragmentation in this region and could potentially lead to more studies and conservation planning for Species of Greatest Conservation Need and culvert restoration in this region.

Methods

Data collection

During the summer of 2018, field surveys were conducted at a total of 68 across the Ouachita and Ozark Mountain regions of eastern Oklahoma. We examined 29 sites with physical structure (road culvert, low-water ford, etc.) that potentially block fish movements, and 39 unfragmented stream segments that contained no physical structure (Fig. 2). For each location, we recorded physical and hydrological measurements of the stream upstream and downstream of the physical structure, and measured physical characteristics of the structures themselves. We then sampled the fish community upstream and downstream of the structures to assess the fish community structure on either side of the barrier.

Culvert measurements

We measured the physical and hydrological characteristics of the structures using a small barrier assessment data sheet from Bain and Stevenson (1999). Specifically, we measured the outlet drop height (i.e., distance from the bottom of the structure outlet to the water surface below the

structure), structure length, width, type of structure, structure condition, road condition, average velocity of water going through the structure (cm/s), pool depth (cm), and structure height (Bouska and Paukert, 2010). We used a Hach FH 950 flow meter to determine average velocity of the water flowing through the culverts.

Stream measurements

Following Bain and Stevenson (1999), we measured a suite of physical and hydrological stream variables. Using a flow meter, the cross sectional width of the stream (defined the bank full width) was divided into 20 equal intervals. At each interval, the flow meter was set at 60% of the stream depth. Other physical characteristics record from the stream were water temperature, percentage canopy cover, percentage of certain substrates (bedrock, gravel, mud, sand, cobble), stream width, stream depth at thalweg, flow velocity, and discharge (Bouska and Paukert, 2010; Zbinden and Matthews, 2017). We replicated these measurements for our control (unfragmented) sites, upstream segments of our fragmented sites, and downstream segments of our fragmented sites.

Fish collection

At each study site, we used seine nets to sample the fish community. Following the approach using in Perkin et al. (2015), a team of two people would seine the available habitat within the stream reach. Once sampling the reach, we would sometimes make another pass to ensure we sampled the most we possibly could. Fish were collected and stored in a Frabill three-gallon minnow bucket with an aerator attached. Sampling time ranged from approximately 40-100 minutes depending on the size of the reach and how many fish were being collected (Zhibden and Matthews, 2017). After our seining efforts, we identified individuals to the species level and

recorded their length. All fish were released back into the stream segment they were sampled in as quickly as possibly once identified, counted, and measured; as a result, mortality was minimal and typically less than 10 individuals per site. This process was replicated in the upstream, downstream, and control segments. Effort-time differed between our sites, control sites were seined once, while upstream and downstream sites were seined once as well. We spent more effort-time at our fragmented sites than our control sites.

Mark-recapture

Visible Implant Elastomer (VIE) tags were used to test whether physical structures hindered fish movement. For our first five sites with physical structures we marked all fish captured on both sides of the structure. We used two different VIE tag colors to differentiate which side of the barrier the fish were captured (Bouska and Paukert, 2015). We injected the elastomer close to the dorsal fin. Streams were resampled monthly. Recaptured fish were again tagged and previously non-tagged fish were marked with a color noting it was captured the second round of sampling. The third field visit was the final sample and no fish caught were marked or remarked.

Data analysis

To assess whether and how stream structures affect stream fishes in our study sites, we performed a series of statistical analyses on community structure and barrier attributes. All statistical tests were conducted using R.

To test whether mean species richness and abundance differed among upstream, downstream, and control (i.e., unfragmented) sites, we performed one-way ANOVA's. We then ran paired ttests to determine whether mean abundance and richness differed between upstream and downstream segments. We chose to use a paired t-test because we hypothesized that abundance and richness at each paired site would be subject to the same set of confounding factors.

Tests were then performed to determine how differences in species richness and abundance between fragmented vs. unfragmented sites might be related to physical and hydrological characteristics of the barriers and stream sites. First, we hypothesized that differences in species richness and abundance upstream vs. downstream of a structure would be greater in locations where the structure contained a sufficient vertical drop that would block fish movements, those without drops would have similar species richness and abundance (Mueller et al., 2008). To test this hypothesis, we first calculated the difference in species richness upstream vs. downstream of each structure. We then performed a paired t-test to compare mean difference in species richness between sites with a vertical outlet drop vs. sites without a vertical outlet drop. To test whether differences in species richness and abundance were related to the type of structure, we first separated our sites with structures into two groups: those with a pipe culvert (n = 11 sites) and those with any other type of structure (n = 18 sites; structures included box culverts, arch culverts, and low water dams). We then conducted separate paired t-tests for each of those groups (sites w/ pipe culverts, and sites without) to determine whether species richness and total abundance differed between upstream and downstream stream segments.

We then fit two linear regression models to determine how the difference in species richness between upstream and downstream stream reaches, and the differences in abundance between upstream vs. downstream reaches, might be related to four physical dimensions of the structure: vertical drop height, structure length, plunge pool depth, and structure condition (how deteriorated it is). We included vertical drop height in this model because it is known to hinder fish movement and therefore should drive differences in abundance and richness between

upstream and downstream segments (Mueller et al., 2008). We included culvert length in this model because there is evidence that the length of the culvert can impede fish movement (Bouska and Paukert, 2010). Plunge pool depth was also included because the deeper the plunge pool the more species richness and abundance it can hold but also has the most dissolved oxygen in the deepest parts (MacPherson et al., 2012). Lastly, structure condition was included because if the interior condition of the structure contains debris or broken road material it could hinder fish movement (Cahoon, 2002; Sleight and Neeson, 2018).

Finally, The Bray-Curtis Dissimilarity Index was for two analyses to determine how stream barriers might affect fish community structure. First, we calculated the Bray-Curtis Dissimilarity index for all possible pairs of upstream sites; all possible pairs of downstream sites; and for all possible pairs of control sites. The Bray-Curtis Dissimilarity Index depicts how dissimilar a species community composition (species richness and abundance) is between a pair of sites. A value between zero and one is calculated for each pair, zero being complete similarity and one complete dissimilarity (Brown et al., 2007). In this analysis, our objective was to determine how similar community structure was among all upstream sites; among all downstream sites; and among all control sites.

Our second community structure analysis was to assess community dissimilarity between upstream vs. downstream sites; and between upstream and control, and downstream and control sites. To do this, we first created pairs of fragmented and control sites by identifying pairs of sites that were as similar as possible to each other in terms of physical characteristics of the stream (e.g., flow, depth, and width). We then calculated the BCI between each pair of sites and used an ANOVA to compare mean community dissimilarity among upstream vs. downstream pairs; upstream vs. control pairs; and downstream vs. control pairs. All Bray-Curtis analysis were used with the vegan package in R.

Results

We recorded 8,370 individuals across 55 species (Table 1). We collected 1,570 fish in stream segments above physical structure, 2,731 fish in stream segments below physical structures, and 4,069 fish throughout our control sites. All sites were wadeable streams with velocities ranging from 0 to 33.13 cm/s.

We found that both mean species richness and mean abundance differed between control sites, upstream of the physical structure at fragmented sites, and downstream of the physical structure at fragmented sites. We observed large and statistically significant differences in abundance between upstream segments (mean = 54.14 individuals, n = 29 sites), downstream segments (mean = 94.17, n = 29), and control segments (mean = 104.33, n = 39) as determined by our ANOVA (p < 0.05; Fig. 3). We also saw differences in mean species richness among upstream segments (mean = 4.79 species), downstream segments (mean = 5.86 species), and control segments (mean = 6.36 species). Even though we did not see significance, our ANOVA approached it (p = 0.07; Fig. 4). We also found statistically significant differences in upstream species richness (mean = 4.79 species) and downstream species richness (mean = 5.86 species; paired t-test; p < 0.05; Fig. 5); and between upstream abundance (mean = 54.14 individuals) and downstream abundance (mean = 94.17 individuals; paired t-test, p < 0.05; Fig. 6).

We found that differences in species richness and abundance between fragmented and unfragmented sites were related with a variety of physical attributes of structures. Of the 29 sites with potential barriers, 20 sites had no vertical outlet drop and 9 sites had a vertical outlet drop. For sites with a structure without a vertical drop, we observed a large difference in mean abundance between upstream segments (mean = 57.55 individuals) vs. downstream segments (mean = 78.7 individuals), but the difference only approached statistical significance (paired ttest; p < 0.06; Fig. 7). For perched sites, we saw large differences in abundance between upstream segments (mean: 46.56) vs. downstream segments (mean: 128.56) than non-perched sites, still only approaching statistical significance (paired t-test; p = 0.06; Fig. 8). Of our 29 sites that included potential barriers, 11 were pipe culverts and 18 consisted of other types of structures (box culvert, low water dam, arch culvert). At sites with pipe culverts, we saw large differences in mean abundance but only approached significance between upstream segments (mean = 54.14 individuals) vs. downstream segments (mean = 94.17 individuals); paired t-test, p = 0.06; Fig. 9). For other types of structures, we also saw large differences in mean abundance between upstream segments (mean = 64.17 individuals) vs. downstream segments (mean = 102.13 individuals), but a paired t-test only approached significance (paired t-test; p = 0.06; Fig. 10). For sites with pipe culverts saw a statistically significant relationship in mean species richness between upstream segments (mean = 4.79 species) vs. downstream segments (mean = 5.86 species; paired t-test; p < 0.05); Fig. 11). With our field season being heavily dominated by cyprinids, we ran similar tests to see if cyprinids constituted most of the change in species abundance and richness. When excluding cyprinids, did not find a statistically significant difference between species richness at upstream sites (mean = 2.69 species) and downstream species richness (mean = 3.28 species; paired t-test; p > 0.05; Fig. 12). Similarly, we did not find a statistically significant difference between abundance at upstream sites (mean = 15.45individuals) and downstream sites (mean = 20.55 individuals; paired t-test, p > 0.05; Fig. 13).

We found a negative relationship between vertical drop height and both stream fish abundance (linear regression; p < 0.05) and richness (linear regression; p < 0.05; Fig. 14). When we included the entire fish community in our analyses, we did not find a statistically significant relationship between the length of the barrier and species abundance (linear regression; p > 0.05) nor species richness (linear regression; p > 0.05) (Fig. 15). When we excluded cyprinids from our analysis, however, we did not find a statistically significant relationship between the length of the barrier and species abundance (linear regression; p > 0.05; Fig. 15). We did not find a statistically significant relationship between the plunge pool depth and species abundance (linear regression; p > 0.05) but species richness approached significance (linear regression; p = 0.08; Fig. 16). We did not find a statistically significant relationship between structure condition and species abundance (linear regression; p > 0.05) but we found a statically significant relationship on species richness (linear regression; p < 0.05; Fig. 17). When excluding cyprinids, we saw a statistically significant relationship between structure condition and species abundance (linear regression; p < 0.05) and only approaching significance with species richness (linear regression; p = 0.08; Fig. 17).

Exploration of the Bray-Curtis Dissimilarity Index values revealed differences fish community structure among upstream, downstream, and unfragmented sites. On average, the upstream had pairs of sites that were almost similar in composition, but most pairs of sites were very different in species composition as measured by the Bray-Curtis Dissimilarity Index (min = 0.16, μ = 0.9, max = 1). We saw similar results for our downstream pairs of sites (min = 0.16, μ = 0.9, max = 1). Lastly, for our control sites we recorded similar results (min = 0.11, μ = 0.85, max = 1; Fig. 18).

We also found that upstream and downstream segments at fragmented sites were more similar to each other than to control sites. For our upstream and downstream segment pairs, we had an average BCI of 0.59. For our upstream segments and their corresponding control site segments we had an average BCI of 0.79. For our downstream segments and corresponding control site segment we had an average BCI of 0.78. Lastly, we saw statistical significance between the means of the groups (ANOVA; p < 0.05) (Fig. 19).

Discussion

From our field survey efforts, we found that structures that block fish movement tend to impact fish communities adjacent to those structures. At sites with an impassable structure, we saw an average Bray-Curtis similarity coefficient of 0.41 between upstream vs downstream segments, meaning that the fish communities were very dissimilar (Fig. 19). We saw effects of vertical outlet drops on species composition from the upstream segments vs the downstream segments (Fig. 8, 13). We also saw difference in species richness and abundance depending on the type of structure present in that stream system (Fig. 9-12). Thus, our study adds to the growing body of evidence on the effects of fragmentation on stream fish communities in the Great Plains (Bouska and Paukert, 2010; Perkin and Gido, 2012; Worthington et al., 2017) and other regions around the world (Nislow et al., 2011; Macpherson et al., 2012; Maitland and et al., 2016).

We also found that effects of culverts on fish communities varied with both culvert type and the physical characteristics of the culvert. At sites with a vertical drop at the outlet of the culvert, there was a noticeable difference in species richness and abundance between the upstream vs downstream habitat (Fig. 14). For the fish in this region the presence of a vertical drop can be challenging since these species can rarely jump over a drop greater than 5cm (Ficke, Myrick, and

Jud, 2011). Thus, we hypothesize that the larger differences in richness and abundance at sites with perched culverts reflects native fishes' inability to leap past this vertical drop.

We did not find any significant effect of culvert length on fish communities (Fig. 15). Specifically, we did not find significant relationships between culvert lengths and differences in species abundance and richness between upstream vs downstream sites. This finding differs from the results of Bouska and Paukert in Kansas (2010), who found that culvert length did affect fish passability. Since culverts concentrate water flow-resulting in higher water velocities-the length of the culvert obviously impacts swimming distances and potentially fish passage because fish are unable to swim against higher water velocities for long lengths (Toepher et al., 1999; Adams et al., 2000; Bouska and Paukert, 2010). While we did measure water velocity through the culverts, we found that it did not have an effect on differences in stream fish composition on either side of the structure.

The differences in species richness and abundance between the upstream and downstream sites with the presence of pipe culverts (Fig 9,11-13), suggest that the type of road-stream crossing community structure. Species abundance also differed between upstream and downstream sites with the presence of other styles of structures (Fig. 10). In both natural and artificial barriers, different species have different rates of movement across them (Warren and Pardew, 1998; Lonzarich et al., 2000; Schaefer et al., 2003). In both natural and artificial settings, riffle length, current velocity, and thalweg depth affect fish movement (Schaefer 1999, 2001; Schaefer et al., 2003). Implementing culvert designs that are shorter in length, maintain natural flow velocity, and have enough depth for fish to migrate through them would be a solution that would decrease the challenges fish face.

The mean dissimilarity between pairs of sites from each group (i.e., between pairs of sites that are both upstream of physical structures; pairs of sites that are both downstream of physical structures; and between pairs of unfragmented sites) had very dissimilar fish community compositions (Fig. 18). We saw an average Bray-Curtis dissimilarity coefficient of 0.9 for our upstream sites suggesting that our upstream sites were very dissimilar in species composition. We saw a similar dissimilarity coefficient of 0.9 for our downstream pairs of sites. Lastly, we saw a dissimilarity coefficient of 0.85 for our unfragmented sites. More importantly, when looking at our fragmented sites we had a Bray-Curtis coefficient of 0.59 suggesting that the difference in species composition from the upstream sites to our downstream sites was large. Our results coincide with Perkin and Gido (2012) who also found lower species richness and higher species dissimilarity at fragmented streams than unfragmented stream reaches.

Most stream crossing structures are starting to reach the end of their lifespan (Alkhrdaji 1999; Doyle et al., 2008; Sleight and Neeson, 2018) and the need for renovation and replacement is in the near future. These aging structures are a shared priority for both conservation groups and transportation agencies, because culverts in poor physical condition have both a high risk of catastrophic failure and are often the most impassable for stream fishes (Cahoon 2002). During our field season our fish collections were very cyprinid dominant. After removing cyprinids from our analysis, we found that both species richness and species abundance were significantly correlated with culvert condition (Fig. 17). Thus, culverts in poor condition tended to be least passable for stream fishes and should be priority projects for both conservation groups and transportation agencies (Neeson and Sleight, 2018).

Despite our results, our field work had its limitations. Towards the end of the summer finding perennial streams proved difficult. With the lack of perennial streams, we also saw a lack of

road-stream crossing structures that had water flowing through them. Sampling more sites without physical structures gave us larger differences in species richness and abundance when compared to our upstream and downstream sites. In this study we were focused primarily on fish community structure, so we did not give passability ratings for each of our fragmented sites to quantify the degree of fragmentation on the stream network (Cahoon, 2002; Januchowski-Hartley et al., 2014). While we used seines for sampling fish communities instead of electroshocking backpacks, there is potential for failing to detect all fish within a given stream reach.

Restoring connectivity and flow is imperative for the survival of pelagic broadcast spawning species (Perkin and Gido, 2011; Worthington et al., 2017). One potential solution is to create free-flowing sections of river systems by the removing dams and retrofitting road crossings to facilitate fish movements. Renovating stream crossing structures with open bottoms that closely resemble the surrounding stream system would be the most ideal option (Bouska and Paukert, 2010) Creating a structure designed for fish movement would be ideal because it would result in normal flow velocities in stream reaches, allow dispersal of stream fish, and minimize geomorphic changes within the stream itself (Angermeier and Schlosser, 1995; Warren and Pardew, 1998; Bouska and Paukert, 2010). The restoration of connectivity has been shown to help reestablish or increase dispersal of fishes that are affected by habitat fragmentation (Catalano et al., 2007; Walters et al., 2014). Restoring connectivity with passable structures would be significantly helpful for regions that often have periods of drought and low-flow conditions during the summer, because it would reduce the incident of the ecological ratchet effect (Perkin et al., 2014, Perkin et al., 2015) that occurs from the interactive effects of drought and fragmentation.

In addition to describing the effects of fragmentation on stream fish communities, a second aim of this thesis was to provide an update on the population status of stream fishes in the Ozarks and Ouachita Mountains regions of Oklahoma. Overall, we detected 8,370 individuals across 55 species (Table 1). Three species listed as federally endangered are believe to occur (or have historically occurred) in our study region: Arkansas River Shiner (*Notropis Girardi*), Leopard Darter (*Percina pantherina*), and Neosho Madtom (*Noturus placidus*). However, we did not detect any of these three species. Our analysis also provides an update on the population status of species considered as Species of Greatest Conservation Need by the Oklahoma Department of Wildlife Conservation. Species are then placed within tiers one through three (one being the highest). We did not find any Tier 1 species. However, we did encounter four several Tier II species (Table 3).

Overall, this study provides a first assessment of the effects of road culverts on stream fish communities in the Ozarks and Ouachita Mountains of Oklahoma, and an update on the population status of stream fishes of conservation need in this region. These findings can enhance on-the-ground efforts to restore aquatic ecosystem connectivity in the region by retrofitting impassable road culverts. Conservation practitioners could use these data to create a cost-benefit analysis for identifying the road culvert mitigation projects that might reconnect the most habitat for the stream system (O'Hanley and Tomberlin, 2005; Neeson et al., 2018). The ODWC Streams Team would be a great resource for doing these surveys. Creating another facet of the streams program for sampling these smaller order streams and assessing the road-stream crossing structures would be a start for future conservation efforts. The methodology of this study could create a framework for sampling these smaller stream systems not only in the Ozarks and Ouachita's but other smaller riverine networks. We saw the biggest differences in species

abundance and richness with our structures that contained vertical outlet drops; thus, structures with a vertical outlet drop should be prioritized higher for culvert renovation. Pipe culverts on average had a larger difference in species abundance from the upstream segment vs downstream segment than the other types of culverts we sampled; thus, pipe culverts in particular should be prioritized for replacement. Our finding that culverts in poor physical condition also have low passability suggests a potential for shared project priorities between conservation practitioners and transportation agencies. Going forward, efforts to restore aquatic ecosystem connectivity will need to occur alongside a broader suite of conservation actions: understanding flow variations, small barrier removal, experimental population reintroduction, and large-scale riverscape coordinated research between conservation agencies, road managers, and NGOs (Worthington et al. 2017). Thus, future work must focus on spatial patterning and interactions of a diverse set of stressors and strategies for prioritizing conservation actions in these ecosystems.

Conclusions

From our field surveys, it is evident the effects of road crossings and fragmentation have on fish populations in the Ozark and Ouachita regions of Oklahoma. The locations visited in this field season are definitely not all of the stream crossing structures in this region. With the effects of climate change and stream fragmentation it is imperative we allocate resources for the further study of these streams in this region. The data collected above will be a stepping stone for future road impact projects for this region and the state of Oklahoma. Not only is there a lack of data collection on stream fish species in Oklahoma but there are very little road crossing impact studies on fish in the region. With additional information on fish populations and the locations of potentially problematic stream crossing structures conservation agencies can make informed decisions for restoration projects.

The need for culvert restoration projections is apparent throughout the Ozarks and Ouachita's. With the upper echelon of culverts facing the end of their lifespan road managers and conservation agencies are facing opportunities for renovating culverts to create more freeflowing stream segments. This would result in restored connectivity of these stream systems. Restored connectivity would help restore migratory patterns of the stream fishes and their ability to be reproductively successful.

Being able to prioritize which stream crossings would require a two-pronged approach. One would be assessing the physical condition of the culvert and how it affects the adjacent stream segments. Second would be to assess the fish communities on either side of the structure. If we see disparities between the downstream community vs the upstream community, road managers and conservation agencies could create a guideline for fish passability and prioritize certain

structures for renovation. Implementing stream crossing that resemble the natural stream bed would be the most ideal to maintain free-flowing connectivity. Although an issue with renovating these structures would be the cost. Prioritization of culverts would be a cost-benefit analysis of opening up the most amount of free-flowing stream segments for the least amount of monetary involvement. There are initiatives to where county level government agencies can apply to have structures removed or renovated and the US Fish and Wildlife Service will match the amount of money allotted for renovation to implement a crossing that would be better for fish movement.

We see the effects of fragmentation in our streams in Oklahoma and these effects are replicated along large-scale regional studies. Implementing large-scale regional studies for watersheds in the Ozark and Ouachita Mountain regions by creating renovation prioritization protocols in conjunction with fish community structure surveys will help conservation practitioners create free-flowing stream segments. With this they could look at a species level for restoring range of endangered or species of greatest conservation need.

Figures



Figure 1. Culvert sampled during our field season. Upper Left is in Sequoyah Co. along Fourmile Creek. Upper Right is Hodge Creek in Le Flore Co. Bottom Left is Garrison Creek in Sequoyah Co.



Figure 2. Our field site locations in Eastern Oklahoma. This shows whether each site was fragmented (possessed a physical structure) and unfragmented (did not possess a physical structure)



Figure 3. Mean abundance (based on 8370 individuals and 68 sites) at each of three types of stream survey sites: upstream of structures at fragmented sites (mean = 54.14); downstream of structures at fragmented sites (mean = 94.17); and at free-flowing, unfragmented control sites (mean = 104.33). Frequency is number of individuals.



Figure 4. Mean richness (based on 55 species total) at each of three types of stream survey sites: upstream of structures at fragmented sites (mean = 4.79); downstream of structures at fragmented sites (mean = 5.86); and at free-flowing, unfragmented control sites (mean = 6.36). Frequency is number of species.



Figure 5. Mean richness between downstream of structures at fragmented sites (mean = 5.86) and upstream of structures at fragmented sites (mean = 4.79).



Figure 6. Mean abundance between downstream of structures at fragmented sites (mean = 94.17) and upstream of structures at fragmented sites (mean = 54.14).



Figure 7. Mean abundance between downstream of structures at fragmented sites (mean = 78.7) and upstream of structures at fragmented sites (mean = 57.55) without vertical outlet drops.



Figure 8. Mean abundance between downstream of structures at fragmented sites (mean = 128.56) and upstream of structures at fragmented sites (mean = 46.56) with vertical outlet drops.



Figure 9. Mean abundance between downstream of structures at fragmented sites (mean = 94.17) and upstream of structures at fragmented sites (mean = 54.14) with pipe culverts.



Figure 10. Mean abundance between downstream of structures at fragmented sites (mean = 102.13) and upstream of structures at fragmented sites (mean = 64.17) with other structures (Box culvert, arch culvert, low water dam).



Figure 11. Mean richness between downstream of structures at fragmented sites (mean = 5.86) and upstream of structures at fragmented sites (mean = 4.79) with pipe culverts.



Figure 12. Mean richness between downstream of structures at fragmented sites (mean = 3.28) and upstream of structures at fragmented sites (mean = 2.69) with pipe culverts excluding cyprinids.



Figure 13. Mean abundance between downstream of structures at fragmented sites (mean = 20.55) and upstream of structures at fragmented sites (mean = 15.45) with pipe culverts excluding cyprinids.



Figure 14. Relationships between the vertical distance between the water surface and the culvert outlet (drop height; x-axis) and fish abundance and species richness. Panels A and B give the difference in abundance between sites upstream and downstream of the structures for the entire fish community (A), and the same relationships without cyprinids (B). Panels C and D give the difference in species richness between sites upstream and downstream of structures as determined for the entire fish community (C) and without cyprinids (D). Lines give the best-fit linear regression to each set of points.



Figure 15. Relationships between the length of the culvert (culvert length; x-axis) and fish abundance and species richness. Panels A and B give the difference in abundance between sites upstream and downstream of the structures for the entire fish community (A), and the same relationships without cyprinids (B). Panels C and D give the difference in species richness between sites upstream and downstream of structures as determined for the entire fish community (C) and without cyprinids (D). Lines give the best-fit linear regression to each set of points.



Figure 16. Relationships between the depth of the plunge pool (plunge pool; x-axis) and fish abundance and species richness. Panels A and B give the difference in abundance between sites upstream and downstream of the structures for the entire fish community (A), and the same relationships without cyprinids (B). Panels C and D give the difference in species richness between sites upstream and downstream of structures as determined for the entire fish community (C) and without cyprinids (D). Lines give the best-fit linear regression to each set of points.



Figure 17. Relationships between the deterioration level of the culvert (culvert deterioration level; x-axis) and fish abundance and species richness. Panels A and B give the difference in abundance between sites upstream and downstream of the structures for the entire fish community (A), and the same relationships without cyprinids (B). Panels C and D give the difference in species richness between sites upstream and downstream of structures as determined for the entire fish community (C) and without cyprinids (D). Lines give the best-fit linear regression to each set of points.



Figure 18. Histograms of fish community dissimilarity (as measured by the Bray-Curtis Index) for all pairwise combinations of all upstream sites (A), all downstream sites (B), and all non-fragmented control sites (C). BCI values of 1 indicate maximum dissimilarity in species composition.



Figure 19. Mean Bray-Curtis Indices between groups of sites (Upstream and Downstream sites [Fragmented] (mean = 0.59), Upstream and Control Sites (mean = 0.79), Downstream and Control Sites (mean = 0.78).

Lonicostidoo	Column1	Column3	Total Caught	Total Fich Caught
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	Common Name	Scientific Name	44	
Churchister	Spotted Gar	Lepisosteus oculates	11	0270
Ciupeidae		a "		8370
A 1 1 1	Gizzard Shad	Dorosoma cepedianum	29	
Cyprinidae				
	Ozark Minnow	Notropis nubilus	113	
	wedgespot Sniner	Notropis greenei	45	
	Golden Shiner	Notemigonus crysoleucas	8	
	Carp	Cyprinus carpio	3	
	Redspot Chub	Nocomis asper	2	
	Sand Shiner	Notropis stramineus	4	
	Redfin Shiner	Lythrurus umbratilis	9	
	Emerald Shiner	Notropis atherinoides	800	
	Bigeye Shiner	Notropis boops	303	
	Steelcolor Shiner	Cyprinella whipplei	226	
	Red Shiner	Cyprinella lutrensis	116	
	Central Stoneroller	Campostoma anomalum	496	
	Cardinal Shiner	Luxilus cardinalis	2734	
	Plains Minnow	Hybognathus placitus	262	
	Suckermouth Minnow	Phenacobius mirabilis	61	
	Southern Redbelly Dace	Chrosomus erythrogaster	629	
	Bluntose Minnow	Pimephales notatus	69	
	Largescale Stoneroller	Campostoma oligolepis	61	
	Bullhead Minnow	Pimephales vigilax	5	
	Creek Chub	Semotilus atromaculatus	52	
Catastomidae				
	Northern Hog Sucker	Hypentelium nigricans	23	
	River Redhorse	Moxostoma carinatum	13	
	Golden Redhorse	Moxostoma erythrurum	1	
	Black Buffalo	Ictiobus niger	1	
Ictaluridae				
	Slender Madtom	Noturus exilis	2	
	Yellow Bullhead	Ameiurus natalis	7	
	Freckled Madtom	Noturus nocturnus	3	
Esocidae				
	Redfin Pickerel	Esox americanus	1	
Fundulidae				
	Blackspot Topminnow	Fundulus olivacues	1	
	Northern Studfish	Fundulus catenatus	11	
	Blackstripe Topminnow	Fundulus notatus	195	
Atherinopsidae				
	Brook Silverside	Labidesthes sicculus	738	
Poecilidae				
	Western Mosquitofish	Gambusia affinis	376	
Cottidae				
	Banded Sculpin	Cottus carolinae	17	
Centrarchidae				
	Longear Sunfish	Lepomis megalotis	141	
	Bluegill Sunfish	Lepomis macrochirus	341	
	Redear Sunfish	Lepomis microlophus	72	
	Warmouth	Lepomis gulosis	3	
	Green Sunfish	Lepomis cyanellus	9	
	Rock Bass	Ambloplites rupestris	28	
	Largemouth Bass	Micropterus salmoides	235	
	Smallmouth Bass	Micropterus dolomieu	48	
	Redbreast Sunfish	Lepomis auritus	1	
	White Crappie	Pomoxis annularis	8	
Percidae				
	Channel Darter	Percina copelandi	1	
	Stippled Darter	Etheostoma punctulatum	6	
	Log Perch	Percina caprodes	1	
	Fantail Darter	Etheostoma flabellare	3	
	Banded Darter	Etheostoma zonale	3	
	Redfin Darter	Etheostoma whipplei	2	
	Orangebelly Darter	Etheostoma radiosum	2	
	Greenside Darter	Etheostoma blennioides	1	
	Orangethroat Darter	Etheostoma spectabile	38	

Figure 20. Overview of all species and their abundances caught during our field surveys.

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111 Sequoyah Salt Branch DS HWY 10and HWY 64 351006 50.0486 10.6 39 0.0334 112 Sequoyah Vian Creek DS OK-82 35.53726 94.97 1.2 94 2.0107429 113 Sequoyah Vian Creek US OK-82 35.53726 94.97 1.7 88 0.04842786 13 Sequoyah Big Shiloh BIDS Drake Road 55.4449 94.8529 31.2 85 9.05292393 14 Sequoyah Big Shiloh BIDS Drake Road 55.4449 94.8529 14.3 5 32.110417 15 Sequoyah Camp Creek Control JATIM No US-64 df T, Sk494 94.4737 9 61 0.5239045 15 Sequoyah Gam Creek Control JATIM No IN-4600K1 d5.575061 94.575 6.9 46 0 15 Sequoyah Sait Creek LIS Interaction FMA74 85.7501 94.575 6.9 46 0 15 Sequoyah Big Shiloh Bi	28 13 124 5 89 60 28 30 32 25 166 102 38 225 102 38 102 1 38 102 1 38 29 82 0 45 45 45 29 82 0 14 44 44 75 16
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12 Sequoyah Vian Creek IDS OK-82 35.3726 -94.97 1.2 6 9.20207429 13 Sequoyah Big Shilo No Control Sallisaw Car Park 35.4647 -94.802 3.1.2 85 9.0529298 14 Sequoyah Big Shilo No D Drake Road 35.4449 -94.802 3.1.2 85 9.0529298 14 Sequoyah Big Shilo No D Drake Road 35.4449 -94.802 3.1.3 85 3.1.10477 15 Sequoyah Lift Sellas Control Drake Road 35.4449 -94.802 14.8 97 0.049 15 Sequoyah Lift Sellas Control Shallow Creek Corl 54.4426 44.579 14.8 9 3 0.5757 15 Sequoyah Garison Crecotrol Imi Non M420047 55.7501 -94.557 5 46 0 0 25 Sequoyah Garison Crecotrol Imi Non M420047 35.7504 -94.5564 12 100 0.054947 115 0.054947 115 0.054947 12 12.400040 13.9127 5 45 0 0.0597 10 0.054967 14.4029 6 10 0.054947 12 10.05496 11	124 5 89 60 28 30 32 25 166 102 38 122 1 32 0 45 29 82 0 45 29 14 44 44 75 16
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113 Sequoyah Big Shilo Bisov Control Sallisav Cat Part 35.4447 94.802 31.2 85 9.00529293 14 Sequoyah Big Shilo Biso Drake Road 35.4449 94.8529 14.3 55 32.1104/7 15 Sequoyah Big Shilo Biuso Drake Road 35.4449 94.8529 14.3 95 32.1104/7 15 Sequoyah Little Schlark Control Shallow Creek Gorf 35.4446 94.771 28.8 93 0.0577 15 Sequoyah Gens Creek Control Shallow Creek Gorf 35.4426 94.771 28.8 93 0.05320045 15 Sequoyah Gens Creek Control Init N on H400044 35.7501 94.557 6 9 0 0.05320045 21 Sequoyah Salt Creek I Init In Con H40040 35.7501 94.557 5 4 0 0.05467 22 Sequoyah Big Shin Bay Control off 0x-101 35.5273 94.9556 12 11 0.0054645 23 Sequoyah Genson Creek Control NA bin M429806 32 12 2.02004 3.0757 23 Adair Sallaw Cree Control NA bin M429806 32 12 12 3.0757 <td< td=""><td>89 60 28 30 32 25 166 102 38 122 1 38 122 1 38 22 0 45 29 82 0 14 44 44 75 16</td></td<>	89 60 28 30 32 25 166 102 38 122 1 38 122 1 38 22 0 45 29 82 0 14 44 44 75 16
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114 Sequeyah Big Shiloh BUS Drake Rad 55 43449 94 8529 14.3 55 32.1104177 115 Sequeyah Litte Sallisa Control Shallow Creek Golf 35.4469 94 7671 28.8 55 0.65797 115 Sequeyah Camp Creek Control SATARM 94 7571 28.8 93 0.7544 115 Sequeyah Camp Creek Control Imit marcatio of N479 357501 94 4557 5 45 0 125 Sequeyah Satt Creek US Interactio of N474 3557601 94 557 5 45 0 0 20 Sequeyah Little te Cr Control 1/Ami Eoff HW-100 355740 94 4552 6 54 0.3577 22 Sequeyah Garison CreDS 1mi Son N7978040 357149 94 4956 11 77 0.19 23 Adair Sallsaw Cre Control R8 bridge ner Bunis S7739 94 557 4.6 0.31 17587142 24 Adair Sallsaw Cre Control Sa 7149 94 557 4.7 0.235 11.77 0.19 25 Adair Sallsaw Cre Control Sa 7149 94 557 4.6 0.3 17785743 26 Adair Os <	28 30 32 25 166 38 102 38 122 1 32 0 45 29 82 0 44 5 29 82 0 14 44 44 75 16
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11 Sequeyab Lutti Salliaz Control Shallow Creek Goff 35.4422 -94.7671 22.8 53 0.5377 12 Sequeyab Camo Creek Control Im N on N400XH (55.2313 -94.531 9 33 -0.754 13 Sequeyab Salt Creek D5 Intersectio of N474 55.7601 -94.557 5 45 0 20 Sequeyab Salt Creek US Intersectio of N474 35.5704 -94.557 5 45 0 21 Sequeyab Big Skin Boy Control 01 OF 0-101 35.5204 -94.552 6 54 0.35671 22 Sequeyab Garrison CreDS Im I Son N47900K 55.734 -94.9656 1 77 0.19 23 Adair Salliaav Cre Control S5.7353 -94.6529 6 33 10.7455 24 Adair Salliaav Cre Control R bridge near Bun 57.733 -94.6527 6.7 67 0.255 24 Adair Salliaav Cre Control R bridge near Bun 57.737 -94.657 6.7 67 0.255 24 Adair Salliaav Cre Control R bridge near Bun 57.737 <td>32 25 166 102 38 122 1 32 0 45 29 82 0 0 14 44 5 0 14 44 5 16</td>	32 25 166 102 38 122 1 32 0 45 29 82 0 0 14 44 5 0 14 44 5 16
117 Sequeyab Camo Creek Control 547208 Muldow, el 557233 -94531 9 33 -0.754 18 Sequeyab Camso Creek DS Intersectio of N474 557601 -94557 6.9 46 0 13 Sequeyab Salt Creek DS Intersectio of N474 3557601 -94557 6.9 45 0 12 Sequeyab Salt Creek DS Intersectio of N474 3557601 -94557 6.9 45 0 21 Sequeyab Bartis Creek US Intersectio of N474 3557601 -94557 6.9 45 0 0 22 Sequeyab Bartis Creek US Inti Son N47900K 553744 -944556 12 119 0.055544 23 Adair Saltas V Cree Control IR N hrigenear Bun 356414 944972 15.8 21 22.035 24 Adair Saltas V Cree Control R bridgenear Bun 357733 -944557 4.6 33 1.78571439 26 Adair DS On US-59 near2ion 557231 -944557 4.6 33 1.78571439 26 Adair DS On US-59 near2ion 557231 -944557 5 19 1.8445138	25 166 102 38 122 1 32 0 45 29 82 0 14 44 75 16
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19 Sequeyak Salt Creek DS Intersection of N474 35.7501 -94.557 5 45 0 19 Sequeyak Nuttle Lee Control J/mil Eoff NVF1D 35.5704 -94.5564 22 75 4.1067 21 Sequeyak Nuttle Lee Control J/mil Eoff NVF1D 35.5704 -94.5554 22 75 4.1067 21 Sequeyak Garrison CreDS Imil Son N47900K 35.5744 -94.9656 8.1 77 -0.19 23 Adair Saltisav Cre Control IR bridge near Bum 35.6414 -94.9775 1.8 21 22.085 24 Adair Saltisav Cre Control RR bridge near Bum 35.6733 -94.775 1.8 21 22.085 24 Adair DS On US-59 near 210m 35.7737 -94.627 4.6 3.3 1.7857/1439 26 Adair DS On US-59 near 210m 35.7737 -94.6257 4.4 0.32 0.17357/1439 26 Adair Russel BrancControl On OK	102 38 122 1 32 0 45 29 82 0 14 44 75 16
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12. Equipying Garrison CreDS 11. In San 44,7900. 55.7249 44.9456 12 11.9 0.0054544 22. Sequeryah Garrison CreDS Im Is on 14.7900. 55.7249 44.9456 8.1 77 0.19 23. Adair Salitaw Cre Control RR bridge near Bun 55.6414 94.7755 15.8 21 22.035 24. Adair Salitaw Cre Control RR bridge near Bun 55.6733 94.7751 14.6 33 1.7857/1439 26. Adair Dis On US-59 near2ion 55.77973 94.6377 4.6 0.32 0.117857/1439 26. Adair US On US-59 near2ion 57.7973 94.6377 4.6 0.32 0.217857/1439 27. Adair Cancy Cree105 Next work Brive Ler 55.82131 94.631 4.7 3.4 4.26167 28. Adair Russell Branch Cree105 On C480004 55.1231 94.6537 5.5 19 15.8445138 30. Adair Cancy Cree Kontrol On D499681 55.8306 94.6591 1.6 52.23 1.406302265 </td <td>32 0 45 29 82 0 14 44 75 16</td>	32 0 45 29 82 0 14 44 75 16
Lectory Control Control Lin Suffrage 111 Suffrage 211 Suffrage 112 113 0000000 22 Sequeya Gardian Cred S57404 94.965 8.1 77 0.19 23 Adair Salitav Cre Control R bridge ner Suff 35743 94.9751 1.5 3.1 10.6745 25 Adair Salitav Cre Control No 559 ner 210 35.7933 94.6257 4.4 0.32 0.117857143 26 Adair US On US-59 ner 210 35.7937 94.6257 6.7 6.7 0.255 27 Adair Caney Cree 10S Rext to Sliwel car 35.8231 94.94257 4.6 6.7 3.53125 29 Adair Evansvill Crub S on 06830d 35.8131 94.9527 45.6 6.7 3.53125 29 Adair Evansvill Crub S on 06830d 35.8131 94.5527 5.5 19 13.8446158 30 Adair Evansvill Crub S on 06830d 35.8331 94.5521 1.8 53 2.07.53318 31 Adair Peavine Cre US On 4710	0 45 29 82 0 14 44 75 16
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24 Adair Selizav Cre Control IRR bridge near Sun 35 Ar33 -94.7561 12.5 31 10.6745 25 Adair DS On US-59 near 21:on 35.7937 -94.657 4.6 0.32 0.1178571439 26 Adair DS On US-59 near 21:on 35.7937 -94.657 6.7 6.7 0.255 27 Adair Caney CreeVDS Next wors 11/web property, bit 35.131 -94.6424 4.3 36 4.49375 28 Adair Russell Bran Control On 0K-100 55.7913 -94.6414 4.7 34 4.26167 28 Adair Russell Bran Control On 0K-100 55.7913 -94.6517 5.5 19 15.8445138 30 Adair Caney CreeVControl on 0469864 55.8231 -94.6517 5 19 15.8445138 30 Adair Peavine Cre US ON 471084 35.8987 -94.6301 7.6 22 6.67.53846 31 Adair Peavine Cre US On 007958d 35.7889 -94.655 10.3 43 33.13 33 Adair Peavheater US On 007958d 35.89841 -94.655 10.3	29 82 0 14 44 75 16
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27. Adair Caney Creek US Private propers, possibility of a statuli - 94-644 4.3 36 4.49375 27. Adair Caney Creek US Private propers, possibility of a statuli - 94-644 4.7 34 4.26167 28. Adair Russell Brancontrol On OK-100 53.731.3 94.5519 5 73 0.474285714 29. Adair Evansvill CrtUPS on E03080d 55.8123.1 94.5527 5.5 19 15.8446153 30. Adair Caney Creek Control on E03080d 55.833.6 94.5527 5.5 19 15.84461538 31. Adair Peavine Cre US ON 47108d 55.8967 94.6501 7.6 22 6.675153846 31. Adair Peavine Cre US ON 47108d 55.8967 94.6501 5.8 43 6.1275 32. Adair Peavine Cre US ON 47108d 55.8967 94.588 12.2 18.053 5.33.33 33. Adair Peavine Arc Lobroto 55.9384 -94.655 10.3 43 33.13 34.4021 Peavine Arc Lobroto 55.9387 94.616 4 37 3.09027 <t< td=""><td>44 75 16</td></t<>	44 75 16
27 Adair Caney Creek US Private propery, so 35 82131 -94.6414 4.7 34 4.26167 28 Adair Russell Bronchortol On OK-100 537913 94.9519 5 73 0.474287214 29 Adair Evanovill CrcUS on D6830Rd 35.81231 94.5527 43.6 67 3.558125 29 Adair Caney Creek Control on D4896Rd 35.8376 94.6549 11.8 53 2.07528138 31 Adair Peavine Cre US ON 4710Rd 35.8907 94.6301 7.6 22 6.675153846 31 Adair Peavine Cre US ON 4710Rd 35.8908 94.6301 7.8 43 6.1275 32 Adair Evanovill CrcUS On D0795Rd 35.7898 94.568 10.3 43 93.131 33 Adair Peacheater US 35.89884 -94.655 10.3 43 19.12285714 34 Adair Peacheater US 55.9287 -94.655 10.3 43 19.12285714 34 Adair Peacheater US 55.9287 <td>75 16</td>	75 16
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29. Adair Evansvill CruDS on E0830Ad 35.1231 -94.5527 43.6 67 3.558125 29. Adair Evansvill CruDS on E0830Ad 35.1331 -94.5527 5.5 19 15.84461538 30. Adair Caney Creek Control on E0830Ad 35.8378 -94.6549 11.8 53 2.075263158 31. Adair Peavine Cre US ON 4710Kd 35.8987 -94.6301 5.8 43 6.1275 32. Adair Evansvill CruDS On D0795Rd 35.7889 -94.588 12.2 18.5 8.90056 33. Adair Peacheter IOS 35.7889 -94.588 10.3 43 19.1925714 34. Adair Peacheter IOS 35.7889 -94.586 10.3 43 19.1925714 34. Adair Peacheter IOS 35.98841 -94.656 10.3 43 19.1925714 34. Adair Shell Branc/Control 35.98841 -94.656 10.3 43 19.1925714 35. Cherokee Goodman BrUS 1 mi's on Ok.62, off 55.5555	
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31. Adair Peavine Cre DS ON 470Rd 358087 -94.6301 7.6 22 6.675153846 31. Adair Peavine Cre US ON 470Rd 358087 -94.6301 5.8 43 6.1225 32. Adair Evansvill Crc DS On D0795Rd 35.78589 -94.568 20.5 22.3 1.406296296 33. Adair Peacheater DS S5.89841 -94.655 10.3 43 33.13 33. Adair Peacheater US S5.98841 -94.655 10.3 43 0.91677 34. Adair Shell Branch Control DS.92387 -94.616 4 37 0.89167 35. Cherokee Goodman BrUS 1 mils on OK-82, off 35.8565 94.7748 9.8 24 14.7753333 36. Cherokee Tahlequah COS Felts Park 35.9035 94.9716 7.8 6.1 3.60776209 36. Cherokee Tahlequah COS Felts Park 35.9035 94.9716 7.8 6.1 3.607762046 37. Cherokee Fourteennin DS 56.0024 9.49966 6.9 24<	83
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32. Adair Evansvill Crc DS On D0795Rd 35.7858 -94.588 20.5 223 1.40259236 32. Adair Evansvill Crc US On D0795Rd 35.7858 -94.588 12.2 18.5 8.90056 33. Adair Peachester US 55.98841 -94.655 10.3 43 33.13 34. Adair Peachester US 55.98841 -94.655 10.3 43 33.13 35. Adair Peachester US 55.98841 -94.655 10.3 43 33.13 35. Adair Peachester Chortorl 100.05.82.07 55.5856 94.7788 9.8 84 14.7753333 35. Cherokee Goodman BrUS 1.mils on Ok.42.07 55.8556 94.7784 9.8 29.47753333 36.0776209 9.02 36. Cherokee Tahlequah CUS Felts Park 35.0085 94.9716 7.3 22 12.4456217 37. Cherokee Fourteenmi DS 56.0024 9.47786 9.8 40 6.371538462 37. Cherokee Fourteenmi Control 67.06325 94.9966 7.3	74
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34 Adair Shell Branch Control 35 32387 -94 516 4 37 5.089167 35 Cherokee Goodman BrUS 1 mils on UK-82, off 35 552565 -94 7748 9.8 84 14 77533333 35 Cherokee Goodman BrUS 1 mils on UK-82, off 35 552565 -94 7748 9.8 84 14 77533333 35 Cherokee Goodman BrUS 1 mils on UK-82, off 35 55256 -94 9776 7.3 61 3.60772509 36 Cherokee Tahequah OLS Felts Park 35 90185 -94 9716 9.3 40 6.377538462 37 Cherokee Tahequah OLS Felts Park 35 90185 -94 9716 9.3 40 6.377538462 37 Cherokee Fourteenmi Lostrol 0 50 0084 -95 0308 18 54 3.357586207 39 Cherokee Tahequah OLS 1 Eon Powellricht 58 2555 -94 9564 10.7 37 7.2277777 40 Cherokee Fourteenmi Control 56 00187 -95 0381 20.7 71 2.37258055 41 Cherokee Pocan Creek IS On S Coss Rd 35 90531 -95 0383 10 <t< td=""><td>88</td></t<>	88
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36 Cherokee Tahlequah CDS Felts Park 35 0028 94.9715 7.3 61 3.604782869 36 Cherokee Tahlequah CDS Felts Park 35 90028 94.9715 9.3 40 6.77538462 37 Cherokee Tahlequah CUS Felts Park 35 90028 94.9716 7.3 21 24.455217 37 Cherokee Fourteenmi DS 55 0023 94.9986 7.3 22 12.4455217 38 Cherokee Fourteenmi Ost 56 0023 94.9986 6.9 24 18.49117647 38 Cherokee Fourteenmi Control of 0K.82, Imi K of 58.0026 94.95564 10.7 37 7.2277778 40 Cherokee Tahlequah CUS Imi Eon Powellrdf 58.9556.1 20.7 71 2.372258055 41 Cherokee Pounteenmi Control Imi Eon Powellrdf 55.90381 20.7 71 2.372258055 41 Cherokee Pount CreekUS On S Coss Rd 35.90331 45.0288 10 -0.2 42 Cherokee Pount CreekUS On S Coss Rd 35.90321 45.1028 9 10 0.06 43 Cherokee Rattesmake Control	109
36 Oheroke Tahlequah (US Felts Park 55 0035 34.9716 9.3 40 6.97538462 37 Oheroke Fourteenni US 56 0023 94.9986 7.3 22 12.4455217 37 Oheroke Fourteenni US 56 0023 94.9986 6.9 24 18.4917647 38 Oheroke Fourteenni US 58 0023 94.9986 6.9 24 18.4917647 38 Oheroke Fourteenni US 58 0025 94.9986 6.9 24 18.4917647 39 Oheroke Tahlequah (DS Imi Eon Powellrdf 55.8925 94.99564 10.7 37 7.2277778 40 Oheroke Fourteenni Control 55 0031 95.0031 20.7 71 2.57258055 41 Oheroke Poan CreekUS On S Coss Rd 35.90321 95.0281 3.9 -0 -0.2 42 Oheroke Poan CreekUS On S Coss Rd 35.90331 95.0281 3.0 -0 -0.2 43 Oherokee Poan CreekUS On S Coss Rd 35.90331 95.028 3.9 10 -0.06 44 Oherokee PoantCreekUS On S Coss Rd 35.9031<	26
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37 (herbike Fourteenini US 30.0023 -94.3986 7.3 22 12.4480217 37 (herbike Fourteenini US of 0K-82, Imi N of C 36.0084 -95.0388 18 54 13.35786207 39 (herbike Fourteenini US of 0K-82, Imi N of C 36.01084 -95.0388 18 54 3.35786207 39 (herbike Tahlequah CDS Imi E on Powellrid f 55.89256 94.9564 10.7 81 95.1252941 39 (herbike Tahlequah CDS Imi E on Powellrid f 55.89256 94.9564 10.7 37 7.29277778 40 (herbike Fourteenini Control 56.0127 -55.0828 10 71 2.372258055 41 (herbike Pean Creek DS On S Coss Rd 35.9031 -55.0828 3.9 10 -0.2 41 (herbike Pount Crentrol Ubbert Park 35.9341 -56.1378 10.2 85 10.1009009 43 (herbike Fourteenini US On N 440Rd 35.9821 -55.1005 13.2 100 2.601578947 44 (herbike Fourteenini US On N 440Rd 35.9821 -55.1005 13.2 100 2.6	100
39 Otherbise Foundation 50.0023 -94.3960 6.9 24 18.4911/64/ 38 Cherokee Fourteenmi Control of OK.82, Lmi N of C \$6.01084 -50.038 18 54 35.7566077 39 Cherokee Tahequah (OS Lmi Eon Powellrdf 55.80285 -94.9564 10.7 37 7.2277778 40 Cherokee Fourteenmi Control Ini Eon Powellrdf 55.80281 20.7 71 2.372258065 41 Cherokee Fourteenmi Control 65.0084 35.9031 20.7 71 2.372258065 41 Cherokee Pocan Creek/DS On S Coss Rd 35.9031 -95.0028 3.9 10 -0.2 42 Cherokee Pocan Creek/DS On S Coss Rd 35.90321 -95.0028 3.9 10 -0.2 43 Cherokee Rait smake Control S5.9821 -95.1026 9 110 0.06 44 Cherokee Fourteenmi DS On N 4408d 35.9821 -95.1066 13.2 160 2.601578947 44 Cherokee Fourteenmi US	129
38 Cherokee Fourteer F	100
39 (heroke Tahlequah (DS Imi Eon Powellrdt 558256 -94.9564 10.7 81 9.512332411 39 (heroke Tahlequah (DS Imi Eon Powellrdt 558256 -94.9564 10.7 37 7.2277778 40 (herokee Tahlequah (DS Imi Eon Powellrdt 558256 -94.9564 10.7 37 7.2277778 40 (herokee Fourteenni Control 55.0031 55.0038 20.7 71 2.372258055 41 (herokee Pacan CreekUS On S Coss Rd 55.90381 95.0038 3.9 40 -0.2258125 41 (herokee Pacan CreekUS On S Coss Rd 55.9028 3.9 10 -0.21 42 (herokee Ratt snake Control Hulbert Park 55.90281 -95.1006 13.2 160 2.60578947 44 (herokee Fourteenni DS On N440Rd 35.98821 -95.1006 13.2 160 2.60578947 45 (herokee Bourteenni US On N440Rd 35.98821 -95.1006 13.2 160 2.60378947 46 (herokee Bourteenni US On N440Rd 35.98821 -95.005 13.2 46 34 7.73558462	130
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40 Cherokee Fourteenni Control 56:0187 -95:0381 20.7 71 2.372259065 41 Cherokee Pecan CreekUS On S Coss Rd 35:0031 -95:0281 11 49 -0.2258125 41 Cherokee Pacan CreekUS On S Coss Rd 35:0031 -95:0281 3.9 10 -0.2 42 Cherokee Pouble Spri/Control Hulbert Park 35:9331 -95:028 3.9 10 -0.2 43 Cherokee Ratt snake Control 55:89252 -95:1026 9 110 0.06 44 Cherokee Fourteenni US On N440Rd 35:98212 -95:1006 13.2 160 2.603578947 44 Cherokee Fourteenni US On N440Rd 35:9821 -95:1006 13.2 160 2.603578947 45 Cherokee BouthChrid Control On W Killabrew Rd 36:10181 -95:0513 6.4 34 7.73538462 46 Cherokee Spring Creel Control On E626Rd nearMo 36:10631 -94:3305 9.85 66 -0.27167 47 Delaware FlyCreek Control S6:0315 -94:3305 9.85 66 <t< td=""><td>60</td></t<>	60
41 (herokee Pecan Creek DS On S Coss Rd 35:9033 -95:0828 11 49 -0.22548125 41 (herokee Pecan Creek US On S Coss Rd 35:9031 -95:0828 3.9 10 -0.2 42 (herokee Pacan Creek US On S Coss Rd 35:9031 -95:0828 3.9 10 -0.2 43 (herokee Pacan Creek Control B3:9925 -95:1078 10.2 85 10.14009099 43 (herokee Ratit snake Control Do N 440Rd 35:9821 -95:1068 9 10 0.06 44 (herokee Fourteenmi DS On N 440Rd 35:9821 -95:106 13.2 160 2.601578947 44 (herokee Fourteenmi US On N 440Rd 35:9821 -95:106 10.2 43 2.43125 45 Cherokee Spring Creel Control On WKillabreve Rd 36:01918 -95:0513 6.4 34 7.731538462 46 (herokee Spring Creel Control On E6:6816 + ard M3 36:0313 -94:3936 8 42 4.814 47 Delaware Fly Creek Control S6:6815 -94:395 9.85 <t< td=""><td>87</td></t<>	87
41 (heroke Pecan Creek VS On S Coss Rd 35 3031 45 0.0828 3.9 10 -0.2 42 (heroke Pouble Sprinkontori Hubert Park 35 39341 +55.1378 10.2 85 10.0109009 43 (heroke Rattlesnake Control 35 39341 +55.1378 10.2 85 10.0109009 43 (heroke Rattlesnake Control 0 N 440Rd 35.98212 +55.1006 13.2 160 2.601578947 44 (heroke Fourteenmi US On N 440Rd 35.98821 -95.1006 10.2 43 2.43125 45 Cheroke Blackbird CrControl On W Killahrew Rd 36.1038 +95.0513 6.4 34 7.731538462 46 (heroke Barkbird CrControl On K Killahrew Rd 36.1038 -94.9336 9.85 66 -0.27167	166
42 Cherokee Double Sprit Control Hulbert Park 55:3931 -05:1378 10.2 85 1.01490999 43 Cherokee Ratt snake Control 55:39252 -95:108 9 10 0.06 44 Cherokee Fourteenmi D5 On N 440Rd 35:9821 -95:106 13.2 160 2:601578947 44 Cherokee Fourteenmi U5 On N 440Rd 35:9821 -95:106 13.2 13 2:43125 45 Cherokee Bourteenmi U5 On N 440Rd 35:9821 -95:0513 6.4 34 7:31539462 46 Cherokee Spritterming Creet Control On E5/26M rearMo 36:1063 -94:3939 8 42 4:814 47 Delaware FlyCreek Control 56:6381 -94:3936 9.85 66 -0:27167	220
43 Cherokee Rattlesnake Control 55 89521 95.5628 9 110 0.06 44 Cherokee Fourteenmi US On N440Rd 55 98821 95.1006 13.2 160 2.601578947 44 Cherokee Fourteenmi US On N440Rd 55 98821 95.1006 13.2 43 2.43125 45 Cherokee Branctenewi US On W Killabrewi Rd 36.0138 95.0513 6.4 34 7.731539462 45 Cherokee Spring Creek Control On E626Rd near Mo 36.1063 9.49889 8 42 4.814 47 Delaware FlyCreek Control 36.63815 -94.93356 9.85 66 -0.27167	244
44 Cherokee Fourteenmi D5 On N 440Rd 35:8821 -95:1006 13.2 160 2.601578947 44 Cherokee Fourteenmi U5 On N 440Rd 35:8821 -95:1006 10.2 43 2.43125 45 Cherokee Blackbird Croontrol On W Killbarew Rd 36:00181 -95:0513 6.4 34 7.31539462 46 Cherokee Spring Creel Control On E636Rd rearMo 36:1083 -94:3899 8 42 4.814 47 Deleware FlyCreek Control S6:6881 -94:335 9.85 66 -0.27167	79
44 Cherokee Fourteenmi US On N4400d 35.98821 -95.1006 10.2 43 2.43125 45 Cherokee Blackbird Cr Control On W Killabrew Rd 56.0138 -95.0513 6.4 34 7.731538462 46 Cherokee Spring Creek Control On 6526Rd near Moi 36.1063 -94.9889 8 42 4.814 47 Delaware Fly Creek Control 36.63815 -94.9336 9.85 66 -0.27167	271
45 Cherokee Blackbird Cr Control On W Killsherw Rd 56:0131 -95:0513 6.4 34 7.731539462 46 Cherokee Bjorng Creel Control On E626Rd nearMo 36:1063 -94:3896 8 42 4.814 47 Deleware FlyCreek Control 36:083 -94:3336 9.85 66 -0.27167	67
46 Cheroke Spring Creel Control On E636Rd near Mo 36.1063 -94.9889 8 42 4.814 47 Delaware FlyCreek Control 36.68815 -94.9336 9.85 66 -0.27167	78
47 Delaware Fly Creek Control 36.63815 -94.9336 9.85 66 -0.27167	135
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48 De laware Hickory Creé DS On S595Rd 36.6638 -94.8169 5 52 0.2689	18
48 De laware Hickory Cre€US On S595Rd 36.6638 -94.8169 4.7 34 0.121	73
49 De laware Control 36,54197 -94,7019 24,5 64 3,298695652	86
50 De laware. Neosho RiveDS Little Blue State Par 36,47687 -95,0055 14,5 22 3,230357143	296
50 De laware Neosho RiveUS Little Blue State Par 36.47687 -95.0055 18 42 0.42057145	53
51 Delaware Saline Creek Control Blue Hole Park 36.30159 -95.0495 14.8 25 8.51785097	200
52 Delaware Flint Creek Control Flint Creek Waterpi 36 18844 -94 7062 33 325 4 9653125	129
53 Delaware Flint Creek Control New Life Ranch 36 2006 - 94 6419 22 58 13 776535	185
	131
55 Delaware pound Saria DS On SS10 pd 35 4500 04 4777 1 E En + En	112
55 Defermine nound spring 15 On S510 Pd 96 (2007) 1.5 50 1.5825	50
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5/ peraware ppavinaw CrControl On EU4,25k0 36,420,28 -94,9643 23,3 170 12,168	108
S8 Delaware beaty creek control on D0430Rd 36.39713 -94.6618 10.5 77 10.315	94
59 Ottawa Sycamore C(Control On HWY-10 36.76807 -94.6919 9.1 51 10.19652174	209
60 Ottawa Brush Creek DS On 670RD 36.7767 -94.6797 7 59 5.149	199
60 Ottawa Brush Creek US On 670RD 36.7767 94.6797 8.5 16 23.76	72
61 Ottawa Coal Creek DS On OK-59 36.85916 -94.9212 10.1 152 -0.798571429	73
61 Ottawa Coal Creek US On OK-59 36.85916 -94.9212 8.5 58 -20625	
62 Ottawa Tar Creek Control Rockdale Blvd in Mi 36.88234 -94.8619 17.5 45 0.38583	117
63 Ottawa Tar Creek Control East 060RD in Comm 36.92908 -94.859 4.8 16 1.856428571	117 78
64 Ottawa Lost Creek DS OK/MO county line 36.84074 -94.6124 13.8 80 6	117 78 361
64 Ottawa Lost Creek US OK/MO county line 36 84074 -94 6124 9.6 44 7 5	117 78 361 122
65 Ottawa Rock Branch Control State Line Rd 36,98319 -94,6185 8.3 445 1.5	117 78 361 122 77
66 Ottawa Fivemile CrcDS 5mile kids camp 36,98814 -94.65 27 63 45	117 78 361 122 77 19
66 Ottawa Fivemile CrcUS 5mile kids camp 36.98814 -94.65 27 63 0	117 78 361 122 77 19 213
57 (Train Russell (Train Control on HWY 59 35 0553 .05.0831 0.1 37 0.700/11/200	117 78 361 122 77 19 213 4
52 Crain Elm Crack Control On HWV 50 35 02151 0.0000 0.0 52 54 57 57 57 57 57 57 57 57 57 57 57 57 57	117 78 361 122 77 19 213 4 53

Figure 21. Overview of our field sites with total abundance and richness per site.

Species	Scientific Name	Tier	# Individuals	Site(s) Present At
Wedgespot Shiner	Notropis greenei	П	45	1
Redspot Chub	Nocomis asper	II	2	2
Cardinal Shiner	Luxilus cardinalis	П	2,734	35
Orangebelly Darter	Etheostoma radios	П	2	1
Plains Minnow	Hybognathus placit	(III	262	13
Black Buffalo	Ictiobus niger	111	1	1

Figure 22. Species of Greatest Conservation Need sample and at how many sites they were present at.

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