LOCAL FISH COMMUNITY STRUCTURE BEFORE AND AFTER BREACHING OF THE WOOLEN MILLS DAM, RIVANNA RIVER, VIRGINIA

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Abstract

Dams significantly alter stream ecosystems in which they are constructed. This can have a dramatic effect on the stream's ability to function normally and support native fish populations. We explored the short-term effects on the fish community structure of a dam removal on the upper Rivanna River in the James River drainage. Here, we report on three seasons of pre- and post-dam removal fish sampling at two stations below the dam, three stations above it, and at one control site in a comparable tributary within the watershed. We electrofished at each station in low-flow conditions from June-October in 2006-2008. Over all three years, species diversity indices were lowest at the above-dam stations in the formerly impounded region of the river, which were dominated by centrarchids. On average, species diversty indices were highest at the below-dam station immediately downstream of the plunge pool. Both below-dam stations and the single station upstream of the impoundment all showed species composition and diversity indices characteristic of an ecologically healthy high-order Piedmont stream of the mid-Atlantic region. After the dam was breached, diversity indices at all of the above-dam sites increased, most dramatically so at the formerly impounded site immediately above of the dam. Species diversity at all sites except the control site increased after dam removal. Diversity at the control site was static throughout the study. Habitat changed most dramatically in the two sites above the dam that were impounded prior to dam removal; water depth decreased and percent rocky substrate increased. Below-dam sites and the uppermost above-dam site did not change dramatically in habitat. After dam removal, we expected to see improved habitat quality and restored native migration routes for many species, including the anadromous American shad (*Alosa sapidissima*)

and the catadromous American eel (*Anguilla rostrata*). Although American shad fry have been stocked above the Woolen Mills dam since 2005, we did not see American shad in our study. A long-term goal of future monitoring efforts is to determine if a shad run can be re-established and the to estimate the long-term effects of the removal on the community.

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Introduction

Dams are an important part of the world's waterscape, with over 800,000 in existence worldwide (Joyce 1997). There are fewer than 60 rivers with 100 km or more of free-flowing stretches of river in the US (Doyle 2000). Dams serve many important functions, including hydroelectric power, irrigation and water supply for communities, improving navigation, storage for industries, flood control, and habitat creation for fish and other organisms. In the United States, hydroelectric power alone accounts for 13% of all electrical power (Joyce 1997). There are 1,637 dams in Virginia, with 970 serving recreation purposes, 49 for hydroelectric power, 186 for flood control, 221 for irrigation, 3 for fish and wildlife purposes, and the remainder with various other uses (State Dam Inventory, 2008). The majority of Virginia dams were completed between 1960 and 1969. Along with the numerous uses for dams, however, come effects to the river that many times prove detrimental. Dams can affect the composition of fish assemblages (Santucci et al 2005), fish migration, macroinvertebrate communities (Benstead et al 1999), aquatic habitat types, and availability and quality of aquatic habitats (Santucci et al 2005).

Efforts are often made to alleviate negative effects of dams, such as construction of fish passages. Fish passages can prove to be effective for some dam systems, like Bosher's dam in Richmond, Virginia. The Bosher's dam fishway has successfully passed over 800,000 fish, representing at least 23 species in the first ten years of operation. Although fish passages have been constructed in many dams to assist upstream migration of fish, there are several problems associated with travel through the passages and many have proven to be ineffective. In many cases, dam removal or breaching is less expensive than dam repair, especially when a fish pass is needed (Doyle, 2000). The problem of stream quality and habitat alteration by dams, however, cannot be easily alleviated by a simple structure addition such as fish passages.

Thus, with consideration of costs and effects on ecosystems, many people view dam removal as a solution to obolete dams and the associated altered habitats. Many studies have been done to assess the effects of dam removal on almost every aspect of the ecosystem in which they were constructed (Kanehl et al, 1997; Benstead et al 1999). Results indicate that dam removal works to restore habitats and fish populations to pre-dam conditions, in many cases increasing the stream's overall health (Kanehl et al, 1997). Dam removal also opens large sections of river that may have been previously unaccessible to fish. The Embrey dam removal in the Rappahannock River, Virginia created 184 miles of free flowing stream, perhaps the longest stretch on the East coast. As many of the world's dams are becoming nonfunctional or in desrepair, the importance of studies of the consequences of dams and their removal is growing.

Effects of Dams on Fish Communities

Dams significantly alter the stream in which they are constructed, creating new fluvial characteristics and habitat types (Kanehl et al., 1997). Dams change the natural lotic system, creating impounded areas above the dam and altered flow downstream. Impounded areas provide an artificial lentic habitat for species of fish not typically found in the natural free flowing system. The quality of fish community, as defined by diversity (in this study, quantified by Shannon-Wiener diversity index) and species richness (number of species), is lower in impounded areas than free-flowing reaches of streams (Santucci, 2005). Fragmentation of streams decreases stream health by creating large, unnatural variations in habitat types and by inhibiting natural flow of sediments, nutrients and both micro and macroorganisms. Impounded areas typically provide habitat to species tolerant to environmental stresses, such as many centrarchids and large game fish, whereas unfragmented areas and reaches far from dams are more favorable to minnows (cyprinids) and darters (percids) (Taylor et al., 2001; Santucci et al., 2005). Minnows and darters are generally intolerant or moderately tolerant of environmental stresses and thus serve as indicator species of general health in streams. Taylor et al. (2001) compared pre and post-dam fish assemblages, and the results indicated a 53 percent decrease in cyprinid abundance as well as a 47 percent increase in percent centrarchid abundance following dam removal (Taylor et al., 2001). Large piscivorous species were also more dominant in fragmented reaches than in unfragmented reaches (Guenther et al., 2006). In general, the ability of many fish species to inhabit impounded areas is limited greatly by the degraded quality of the water and habitat caused by fragmentation to a natural flow regime and thus the assemblage found in impoundments differs vastly from the river's natural assemblage.

Consequences of Dam Removal

With the combination of dam deterioration, the Federal Energy Regulatory Commission's 50 year relicensing requirement for dams, as well as increased public awareness and acceptance of green river management programs, dam removal is becoming a realistic option for a number of cases in the United States (Doyle 2000). In 1997, public input influenced the federal decision to remove the 3.5 megawatt hydroelectric Edwards Dam in Augusta, Maine. The removal was expected to benefit nine species of migratory fish (Joyce 1997). Dams of all sizes have been removed, but the greatest number of dam removals are concerning dams less than 5 m tall, thus providing a bias in dam removal case studies (Doyle 2000). As dam removal becomes increasingly important in determining the future of our riverine ecosystems, more studies are needed to determine the implications and effects of dam removal.

Dam removal returns rivers to their natural flow regime and greatly influences the number of species and number of individuals of fish. Dam removal drains the artificial deep warm water pools created by the impoundment and eliminates the altered stream flow downstream of the dam site. Kanehl and Lyons assessed the impact of these changes on the fish community following dam removal in Wisconsin (1997). Their study was used as a template in designing our study due to its similarities with our project. The study demonstrated a dramatic increase in the biomass of smallmouth bass (*Micropterus dolomieu)*, a popular game fish that cannot tolerate poor water quality, in three sampling stations upstream of the dam. Kanehl and Lyons also indicated a slight increase in smallmouth bass biomass in a sampling station just below the dam site. The most significant increase in smallmouth was found at the sampling station furthest upstream from the dam, most likely due to an increase in reproduction and recruitment. The numbers of common carp (*Cyprinus carpio*), a species adapted to warm water, decreased dramatically at the two former impoundment stations due to elimination of habitat. Declines in common carp biomass and abundance were much more gradual in the sampling station downstream of the dam and the sampling station furthest upstream from the dam. Overall, fisheries values were enhanced by removal of the Wisconsin Woolen

Mills Dam, with an increase in smallmouth bass populations and a decrease in common carp abundance.

Maclin (1999) analyzed the effects of the removal of the Waterworks Dam on the Baraboo River in Wisconsin. The 1997 removal of the dam has allowed the river to run free for the first time in 140 years. The abundance of sturgeon once found in the river began to decline rapidly after the dam was constructed. Shortly after removal, however, biologists identified sturgeon in the river at the former dam site. Only eighteen months later, the number of fish species had jumped from 11 to 24, and the number of smallmouth bass had increased from 3 to 87 in the former impoundment. In a similar removal study on the Kennebeck River in Maine, striped bass returned to previously inaccessible reaches of the river after removal of the Edwards Dam (Maclin, 1999). On the Rappahannock (a Virginia Chesapeake Bay drainage river) the removal of Embrey Dam has allowed American shad to use at least 28 miles of the formerly blocked habitat and hickory shad, blueback herring and striped bass have been found 5 miles upstream (A. Weaver, Personal Communication, April 16, 2009).

Although dam removal is an important solution for the recovery of native fish communities, some riverine ecosystems may need more than barrier removal to positively affect the fish communities. In modeling the Columbia-Snake River system and the effects of dam removal, Kareiva et al (2000) showed that in addition to dam removal, habitat, channel and watershed restoration were necessary to restore Chinook salmon populations. In most river systems, ability of fish to recolonize an area may be strongly dependent on two limiting factors; migration and/or habitat (Kareiva et al 2000).

The Woolen Mills Dam

The goal of this study is to assess the short-term changes in local fish community composition and habitat following the removal of the Woolen Mills Dam in the upper Rivanna River. The Rivanna River is a sixth order piedmont stream and a James River tributary. The Woolen Mills dam was built in 1830 as a power source for the mill and remained in use until 1920. The mill closed in 1964 and since then the dam has been allowed to deteriorate.

The Woolen Mills dam fragmented the local fish populations of the Rivanna and blocked upstream migration of anadromous fish. It also restricted recreational kayakers from full access to the stream and was a dangerous drop off to the unsuspecting boater. The dam, which was no longer in use to power the mills, was deteriorating and dam removal was the most appropriate solution for these problems.

The removal of the dam created unobstructed river access for fish from the Atlantic Ocean to both the North and South Forks of the Rivanna River, Charlottesville, via the Chesapeake Bay, James River and mainstem Rivanna River. The Woolen Mills Dam was the first man-made impediment faced by fish traveling up the river from the Atlantic Ocean via the James River above Bosher's Dam on the James River in Richmond, Virginia. A vertical slot fishway was built at Bosher's Dam in 1999 to allow anadromous fish such as American Shad to swim upstream past the dam to spawn. American shad and sea lamprey (*Petromyzon marinus*), native anadromous species, have been confirmed using the fishway.

Objectives

In this study, we assess the short-term changes in fish community composition and habitat following dam removal. The study was done in collaboration with the Fisheries Divsion of the Virginia Department of Game and Inland Fisheries. By assessing habitat quality and estimating relative abundance of the species we can then characterize the structure of the fish community and its dependence on spatial and temporal variables. Although our data includes only one year of data after the dam removal, we developed a good understanding of the mechanisms involved in structuring in the Rivanna's freshwater fish community and gained a perspective of how the dam removal might affect community structure in the long term. Through this study, we have developed an estimated snapshot of the existing community and a template that can be used to understand the dynamics of changes in the ichthyofauna due to dam removal.

Two important objectives for removal of the Woolen Mills Dam were improved habitat quality and restored native migration routes for several species, including the anadromous American shad and the catadromous American eel (*Anguilla rostrata*). Historically, American shad ascended the Rivanna River and provided an important fishery for the local economy, however no American shad have been seen in the area for many years. Shad fry stocking upstream of the dam began in 2005 by the Virginia Department of Game and Inland Fisheries in anticipation of removal and has continued yearly since. A longer-term goal of this monitoring effort is to determine if a shad run can be re-established and the local fish community can be restored to its native composition or a modern equivalent.

Site Description and Methods

Study area

The Rivanna River is a tributary of the James River and lies within the Northern Blue Ridge and Piedmont physiographic provinces of central Virginia. A moderate gradient, sixth order stream, the mainstem Rivanna River flows approximately 68 km from the joining of its North and South forks in the Piedmont Foothill Zone to its confluence with the James River in Columbia, Virginia, in the Piedmont Lowlands. The Rivanna River watershed drains 1,985 km^2 (Thomas Jefferson Planning District Commission, 1998). 64% of the watershed is covered by forest, 20% by pasture and 15% by impervious land.

The Woolen Mills Dam was built around 1830 approximately 6.5 km south of the confluence of the North and South Forks of the Rivanna River, and was removed in August 2007. The dam was in use until about 1920 as a power source for the Woolen Mills textile company's manufacturing plant on the bank of the river at the dam. It is a stone block and timber lowhead crib dam about 3 m high and approximately 84 m long.

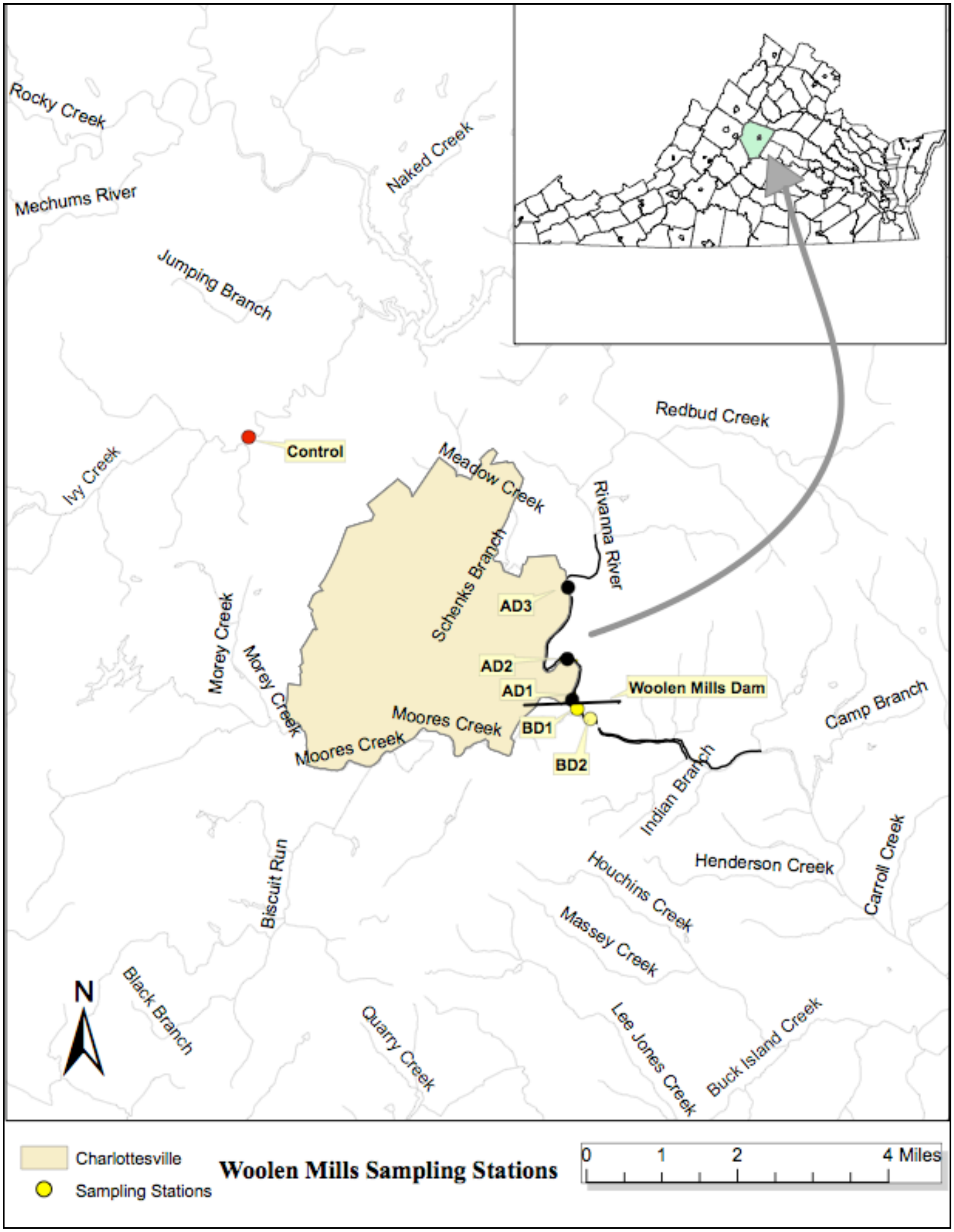
Efforts to remove the Woolen Mills dam were led by the Rivanna Conservation Society. Partners included the Virginia Department of Game and Inland Fisheries, the EPA Chesapeake Bay Program, and the USFWS. A contractor was hired to evaluate the project's feasibility and carry out sediment testing, surveying, and removal design. The feasibility study described the hydrology, impoundment, substrate topography and composition of river bottom sediment to test for the presence of toxins. Pressure to remove the dam intensified with a drowning at the dam in 2004.

During deconstruction, track hoes were used to remove the dam block by block, which allowed for a gradual release of the impounded water and sediment. Beginning August 15, 2007, the entire Woolen Mills Dam deconstruction took less than 3 weeks. Approximately 60 meters of the 84 m structure were removed, leaving small sections of the dam standing on both sides of the river, including a defunct retrofitted fish ladder on the Eastern bank.

Fish Sampling

Five sample stations (referred to as both stations and sites within this text) were established in the mainstem Rivanna River (Figure 1); two below dam (BD1, BD2), three above dam (AD1-AD3). We sampled the composition of the fish community by electrofishing each of the five transects in each year of the study. The locations of the sample stations were chosen in an effort to include a diversity of riffle, run and pool habitats. Our sample locations are also in part based on access to the river with boats and other equipment and for consistency among sampling efforts in current and future sampling. A control station was established in Ivy Creek, a tributary 24 river kilometers upstream of the dam. The control station was chosen for its similarities to the five mainstem sample stations in fish community composition and stream substrate, and its proximity to the dam.

Figure 1. Map of Rivanna River showing Woolen Mills sampling stations and control site



Sampling station BD1 extends from the dam approximately 100m downstream and includes three major stream habitat types: plunge pool, riffle and run. Station BD2 lies approximately 430 m downstream of BD1 and is dominated by riffle/run habitat with a few large pools up to 1.5 m deep. Station AD1(above dam 1) begins at the dam and extends approximately 285 m upstream to include the majority of the heavily impounded area above it. Station AD2 begins approximately 600 m upstream of the upstream terminus of AD1, extends approximately 130 m upstream, and includes only the northeastern bank of the river. All stations except AD2 were sampled from bank to bank and included all present habitats. Station AD2 is in a 1-2m deep slow moving run in the thalweg of the river bend. AD3 (Above dam site 3) is located at Darden Towe Park, beginning 2.7 km above the dam and extending approximately 50 m upstream. It is a swift moving reach characterized by a riffle/run habitat up to 1m in depth.

All stations were sampled by electrofishing, using one of three methods depending on water depth (Table 1). Immobilized fish were captured by at least two dip netters and were temporarily held in plastic containers during data collection and then returned live to the stream. Data collection was done in collaboration with the Virginia Department of Game and Inland Fisheries as well as with help from local volunteers. Transects that were heavily impounded by the dam before dam removal (sites AD1 and AD2) were sampled using a 12 foot aluminum jon boat equipped with a generator shocker (Smith-Root 2.5 GPP shocker system, generator and pulse box.) In both pre-dam removal years, AD1 was sampled in three transects, one hugging each bank and a sample down the middle of the river. AD2 sampling was conducted only on the North-East bank.

In 2008, after dam removal, the former impoundment was accessible by tote barge and backpack, but not by jon boat. We used a 2.5 GPP Smith-Root 2500 watts max output tote barge (electrofishing by wading personnel; generator mounted to bottom of a small fiberglass barge that is pushed along the transect) for two transects along the left bank, and completed the third with a backpack electrofisher, described below, along the right bank. We also completed two runs along the right bank (staying in close proximity to the thalweg) with the tote barge at AD2.

We sampled stations BD2 and AD3 by wading upstream with a Smith-Root LR-24 Backpack Electrofisher (350-400 watts max output) in a zigzag pattern from bank to bank. BD1 was sampled with a tote barge. Sampling in this station was done approximately in the middle of the river, moving upstream.

All stations were sampled in low flow months (June-October) mostly on sunny, warm days (Table 1). Sampled fish were identified to species (if possible) and returned to the water as quickly as possible. Game fish (Centrarchidae) and eels were measured for total length and weighed individually. Voucher specimens of unidentified species were collected for later confirmation. Sample time was approximately 900 seconds per transect. The number of transects per station varied depended on the characteristics at each station but varied little among years.

Habitat

Substrate composition and water-depth were measured in the vicinity of each of the five mainstem fish sampling stations in 2007 (pre-dam removal) and 2008 (post-dam removal). Three substrate sampling transects were established for each station, extending bank-to-bank and perpendicular to flow, and were spaced 30 m apart. We laid a metal chain with sampling marks at 10 m intervals on the river bed along each transect.

Substrate sampling differed along wadeable versus non-wadeable transects. Along wadeable transects, a one square foot sampling grid was dropped onto the substrate at each sampling mark. Then, by using a view scope or taking a grab sample from each sampling grid, dominant substrate type and largest substrate size (length, in cm, along long axis of largest substrate item). Stream depth was also recorded at each mark. The Wentworth classification for substrate types was used to identify substrate (Table 2). In stations where water was too deep to wade, substrate data was taken along transects in a canoe. A 12-foot aluminum pole with depth markings was used to prod the stream bottom to determine dominant substrate type and stream depth. Largest substrate size and aquatic vegetation data were not collected at non-wadeable sites due to inability to access the stream bottom.

Data Analysis

Raw data included numbers of individuals captured for each species. Relative abundance for each site was calculated for each species by dividing the number of individuals of a species by the total number of individuals collected at that site. To estimate diversity, we used the Shannon-Wiener (SW) index, which takes into account both the relative abundance per species and the total number of species. The Shannon-Wiener Diversity Index is shown by equation 1, where S= Number of species, and p_i = relative abundance of each species (Figure 1). Species evenness is calculated by dividing the total Shannon-Wiener diversity of a site by the natural log of the number of species present.

Equation 1. Shannon-Wiener Diversity Equation

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

Shannon-Wiener diversity, richness and evenness were subjected to one-way analysis of variance (ANOVA, using SAS 9.1) to determine the effect of the dam (upstream vs. downstream) and dam removal (before and after). We used principal components analysis (PCA, using SAS 9.1) to determine grouping patterns in all the families found in the study. Results of the principal components analysis were also used in a one-way ANOVA to determine if the dam had significant effects on the grouping explained by the principal components.

Substrate type was simplified from the Wentworth classification to rocky or non-rocky substrate. Boulder, cobble, and gravel were collapsed to the category "rocky " whereas sand, silt, clay and colloid were collapsed to "non-rocky". Percent rocky substrate was then calculated for each site and evaluated in a one-way ANOVA to test for effects of the dam and dam removal on the percent rocky substrate.

Results

Fish Community

We sampled 4,526 fish representing 10 families and 55 identified species among the six sample sites and all three years of sampling (Table 15). Individuals that could not be identified to species due to their very young age and small size were identified to either family or genus. Fish community structure (as determined by the variety of species present) varied predictably throughout the years and sampling stations according to location relative to the dam as well as the presence or absence of the dam.

Thirty-six species of fish were found in the five sampling stations above and below the dam in the first year of sampling. The majority of species were in the family Cyprinidae, and of those, most were shiners (*Cyprinella, Luxilus* and *Notropis*). The species we found at each site were consistent with predicted fish communities as determined by dominant habitat types. Sampling site BD1 had three distinct habitat types; plunge pool, riffle and run. This station had the highest species richness and highest S-W diversity, but not the highest species evenness score, due to the high relative abundance of *Scartomyzan cervinus*, *Percina roanoka* and *Nocomis raneyi*.

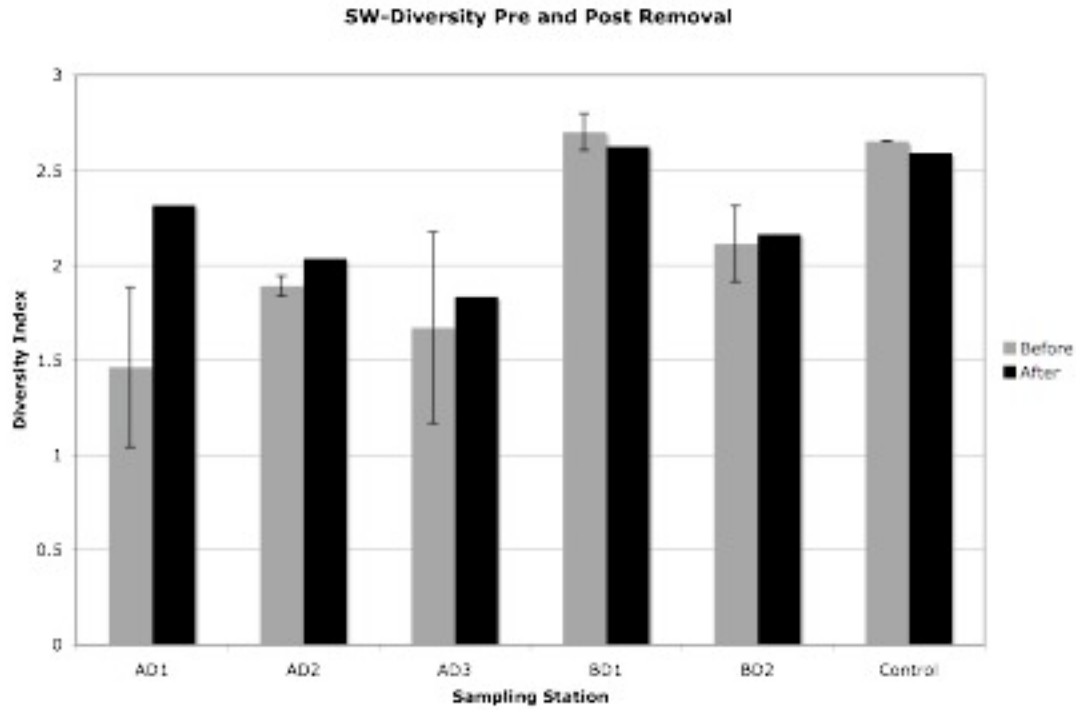
Before dam removal (2006 & 2007), sampling stations AD1 and AD2 yielded mostly centrarchids and catostomids, and AD1 had two cyprinid species (*Notropis hudsonius, and Semotilus corporalis*). After dam removal, station AD1 yielded 12 species of cyprinid. Neither AD1 nor AD2 showed any presence of percids before dam removal (Table 11). After dam removal, AD1 yielded four species of darter, including *Percina roanoka,* which attributed 11% of the total abundance that year. AD2 also showed an increase to two species of darter after dam removal.

Over all three years, site BD1, the site directly below the dam, consistently held the highest species richness. Before dam removal, site AD2 had the lowest average species richness, however all three above dam sites increased between sampling years 2006 and 2007. After dam removal, the site with the highest richness remained BD1, but the second highest richness was found at AD1, the former impoundment. AD1 also had the greatest increase in species number after dam removal, with an increase from 6 species the first sampling year to 25 the last sampling year, after dam removal. As expected, the control site richness remained constant before and after dam removal, with 23 species both years. The average richness for all species and sites among all three years increased from 16.1 to 21.8 species after dam removal (Figure 5).

Site AD1 generally had the lowest scores for all diversity indices, including S-W diversity, evenness and total species number. Surprisingly, AD3, which was not impounded prior to dam removal, had lower average SW diversity in each of the three years (Figure 6) than AD2 and AD1, which were impounded. AD1 was heavily impounded by the dam and has formed an artificial deep warm water reservoir for which few species are adapted.

Station BD1 had the highest Shannon-Wiener index of diversity and the largest number of species (Figure 2). The sampling station included the plunge pool created by the dam as well as a riffle and a run. The sample station length and sampling time were greater than any of the other stations. Station BD2 contained mostly cyprinids, as the predominant habitat type in the station was a riffle/run. Cyprinids are best adapted to colder, fast moving water with rocky substrates and therefore thrive in healthy riffle habitats such as those found in BD2.

Figure 2. Shannon-Wiener diversity for all sites, before and after dam removal. Error bars represent standard error for the averages where there were repeated samples.



Shannon-Wiener diversity increased at all three above dam sites after dam removal. The largest increase was at the former impoundment, AD1. The average diversity among all sites was greater after dam removal than before. Below dam sites on average had higher diversity among all three years. The highest average diversity was at site BD1 (the site directly below the dam). The below dam sites did not change significantly. The control site diversity remained relatively constant between the two years, with a value of 2.257 in 2007 and 2.439 in 2008.

Evenness scores varied little in most sites except AD2 (Figure 7). BD1 and BD2 showed little variation in evenness scores among years while AD2 and AD3 decreased every year. Site AD2 showed a large decrease in evenness between the first year of sampling (before dam removal) and the last year of sampling (after dam removal).

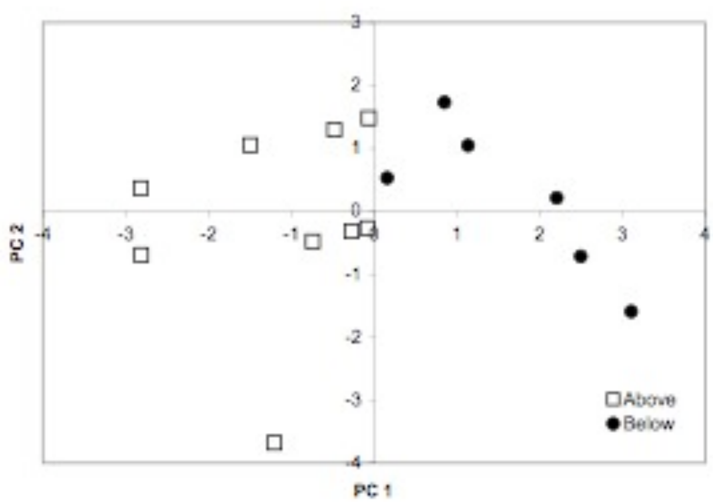
One species of livebearers, *Gambusia holbrooki,* was found at site AD3 in 2006. *Percina notogramma* was found exclusively at AD1 and AD3. *Ameirus nebulosis* was only found after dam removal and was sampled at AD2, BD1 and BD2. We sampled *Carpiodes cyprinis* in only one year (2007) and at one site, AD1, and found only two individuals. *Clinostomus funduloides* and *Etheostoma vitreum* were only found at the control site. One specimen each of *Dorosoma cepedianum, Lepisosteus osseus* and *Ictalurus punctatus* were found in 2007 at BD1 only. In 2008, we recorded 7 individuals of Sea lamprey (*Petromyzon marinus*), at BD2, a very interesting find, as there are no prior records of the species in the entire Rivanna Basin.

Several individuals at AD1 and AD 2 had superficial integumentary anomalies. One specimen each of both *Lepomis auritis* and *Notropis hudsonius* had moderate blackspot, a parasite that embeds in the skin (Jenkins and Burkhead, 1994). One specimen of *Catostomus commersoni* had bloodlike staining and healed scale damage.

One-way ANOVA's were conducted, using diversity, evenness and richness as dependent variables to determine the influence of the dam on each factor (Tables 3-5). The effects of the dam (testing for differences above and below it) and of dam removal (testing for differences before and after) were explored. The effects of the dam on the diversity were significant, with a p value of .0382 (Table 3). No other tests produced values of $p<.05$, however the effect of dam on richness was close with a p value of .0597 (Table 2). The effect of the dam removal (effect of time in the analysis) did not significantly affect diversity, richness or evenness.

A principal components analysis was run on the families to determine any spatial or temporal patterns in family distribution. The first three principal components explained 66% of the variation within the family data (Table 9). The correlation matrix indicated strong positive correlations between Anguillidae and Centrarchidae as well as between Cyprinidae and Ictaluridae (Table 8). It also indicated strong negative correlations between Cyprinidae and Centrarchidae, Percidae and Catostomidae as well as Centrarchidae and Percidae. The first principal component described a high affinity for Cyprinids, Percids and Ictalurids and a low affinity for Centrarchids. A one-way ANOVA was run on the effect of the dam on the first and second principal components (Tables 6-7). The results indicate that the dam significantly affects the first principal component. Thus, the family pattern demonstrated by principal component one can be attributed to spatial relation to the dam. This is also shown in the graph of the first two principal components and the above/below dam data (Figure 3).

Figure 3. Plot of principal component 1 and principal component 2 for distribution of families above and below the dam



Habitat

Substrate and average depth varied greatly among sites and among years. Habitat data was only taken in 2007 and 2008. The greatest average depth was found in the first above dam site, in the deepest part of the impoundment (AD1), followed by AD2 and AD3, predictably (Table 12). The depth decreased with increasing distance upstream of the dam. Before the dam removal, the impounded sites had a low percentage of rocky substrate, which then increased dramatically after the removal. The below dam sites were dominantly rocky substrate. Both impounded sites decreased in average depth by about 2 feet after dam removal, while AD3 and BD1 only increased by less than one foot. Stream channel profile gradients appeared consistent among the sites, with sand, silt or mud at the banks, gradually transitioning into larger rocky substrate toward the thalweg.

A one-way ANOVA was also run to test the effects of the dam and dam removal on the percent rocky substrate (Table 13). There were increases in percent rocky substrate at AD1 and AD2, the former impoundment sites, as well as BD1, just below the dam site. However, the results indicate that the dam did not have significant statistical effects on the percent rocky substrate.

Discussion

The Woolen Mills dam clearly affected the fish community structure among years and among sites. Family level analysis of the 50 species we sampled throughout the three years indicated the dam's strong effects on fish family composition. Benthic habitat quality as measured by percent rocky substrate improved at the formerly impounded sites after dam removal. The changes observed in this study occurred less than one year after dam removal, suggesting that fish community structure is influenced by short temporal scale fluxes in habitat quality and area recruitment access. Our results suggests that although there may be long-term patterns and causes controlling fish migration and community structure, the local fish community is largely plastic and depends mostly on immediate habitat availability and unobstructed access for movement. Long term monitoring of the changes in the community structure in the Rivanna River surrounding the Woolen Mills area may further indicate underlying mechanisms of change and provide a more comprehensive understanding of larger scale temporal effects.

In the first partof the discussion, I interpret the patterns of species diversity and spatial distribution. In the following section, I analyze family level patterns as they pertain to our sampling stations. Finally, I will review previous Rivanna studies and draw conclusions and future expectations.

Impounded reaches of rivers can create habitat suitable for species tolerant of environmental stresses, such as large game fish, whereas unfragmented reaches generally harbor species such as minnows and darters (Taylor et al., 2001; Santucci et al., 2005). Our data indeed supports these findings, with low species diversity in the impoundment dominated mostly by large sunfish and higher diversity immediately below the dam, with many families represented including lotic, intolerant species.

Our results support the serial discontinuity theory, which applies the river continuum concept to reaches of river fragmented by dams (Standford and Ward, 2001; Vannote et al., 1980). The hypothesis holds that river characteristics, including both biotic and abiotic components, follow a predictable longitudinal pattern that is interrupted by impoundments. The discontinuity distance is defined as the reach of river surrounding a dam in which a given parameter has been altered from its native value via a longitudinal shift varying by the distance from the dam (Stanford and Ward, 2001). This theory, although mainly applicable to regulated (dammed) streams, seems also applicable to unregulated streams. The accuracy of the river continuum concept has been debated, because many unregulated streams have natural habitat fragmentation that contributes to smaller longitudinal effects than those predicted by the hypothesis (Sedell et al., 1989). Our data supports a theory of discontinuity, however the changes we found do not seem to follow a longitudinal pattern that covaries with distance from the dam. For instance, relative abundance data directly above the dam suggest a fish community structure drastically affected by the presence of Centrarchids just upstream of the dam. This effect is demonstrated by the dominance of Centrarchids in station AD1. This effect decreases upstream toward the upper reach of the impoundment (Table 11). Below the dam, the fish population seems to have a community structure like that of an unfragmented reach, with a dominance of cyprinids and darters. Like the upstream sites, the community composition changes as distance from the dam increases, with fewer percids and cyprinids in site BD2.

Many of the results of this study were as we expected based on previous research. We expected species diversity and richness to be highest in the below-dam sites, where habitats closely approximated those of an unaltered stream system. We expected increases in diversity and richness and changes in habitat to be the largest in the former impoundment sites, where the habitat was most altered by the dam, and most improved by its removal. We also expected that there would be a shift in fish community omposition in the former impoundment from predominantly warm water adapted fish like introduced game fish to more native riverine species such as cyprinids and darters. We expected there to be observable changes in the fish community composition shortly after the dam removal, which we did observe. Long-term changes can only be determined in future studies.

Species richness among all the mainstem sampling stations increased after dam removal, but not significantly. Shannon-Wiener diversity increased at all three above dam sites, the most so at the most heavily impounded site. These results indicate that dam removal allowed for better local recruitment and availability of better habitat, which allowed for more species to thrive in the former impoundment. Also as expected, average Shannon-Wiener diversity over all years was higher for below dam sites compared to above-dam sites. The below dam sites provided a habitat for the fish that most closely approximated natural riverine conditions, and therefore held higher species diversity and richness. Because of the dam, such dramatic differences in richness and diversity can be seen over a distance of merely 30 m.

Species evenness among sites did not change significantly before and after dam removal or below and above dam. This suggests that before dam removal, and even in the deepest part of the impoundment, the evenness scores may not have been greatly impacted by the habitat. This also suggests that even with the altered ecosystem in the impoundment, there was not one dominant species that through either predation or competition controlled the abundance of other species. This indicates a healthy community, one not dominated by introduced species.

The increases in Shannon-Wiener diversity at the above-dam sites following dam removal were not significant in a one-way analysis of variance. With further repeated sampling in a second year following dam removal, we suspect a statistically significant effect would be seen.   Analysis of variance did show a significant effect of the location of the sites on the diversity; that is, the diversity depended on whether the sites were above or below dam.

In the first year of data collection, sampling stations AD1 and AD2 yielded mostly centrarchids (*Lepomis macrochirus* – an introduced species) and catostomids (*Catostomus commersoni and Hypentelium nigricans*), and AD1 had one cyprinid species (*Notropis hudsonius*). Centrarchids, or sunfish, are common to deep pools and reservoirs of warm water rivers and streams (Jenkins and Burkhead, 1993). This explains the abundance of these fish in this reservoir formed by the dam. Station AD3 also contained mostly centrarchids (*Lepomis auritis* – a native species -- was most abundant) as well as unidentified cyprinids and three species of darters (Table 1). In 2007, the species composition at AD2 remained similar, and included one satinfin shiner (*Cyprinella analostana).* As predicted, the draw down of the impoundment created habitat more suitable for cyprinids, and less than a year after the dam was removed, we saw a large increase in the abundance of cyprinids and percids in the former impoundment.

Principal components analysis revealed interesting correlations among occurrance of fish families. The matrix indicated a strong positive correlation between Anguillidae and Centrarchidae. Both of these families are tolerant to environmental stresses and can be found in a variety of habitats, including warm water reservoirs. Thus, it is not surprising that occurrance of these two families is highly correlated. Also highly correlated were the cyprinids and the ictalurids. Since the majority of Ictalurids we sampled were the native margined madtom, which is adapted to cooler, faster flowing waters, this correlation is expected. Although they have a broad range of habitat and food requirements, some cyprinids are bottom feeders, feeding on insects and plant matter. The ictalurids are also bottom feeders, making the correlation between the two families understandable.

Highly negatively correlated families included the Cyprinidae and Centrarchidae. These families are generally found in quite different habitats. In our study, we found the majority of the centrarchids in the impoundment, whereas most of the cyprinids were found in the more lotic sites, such as the two below dam sites. These families' different habitat and feeding habits help explain the negative correlation. Several other pairs of families with differences in habitat and feeding requirements.were negatively correlated, Percidae (all Percids we sampled were darters) and Catostomidae, as well as Centrarchidae and Percidae. An ANOVA was run on this PCA data to determine if the dam or the dam removal was significantly responsible for the observed distrubition in the fish families. The results of the principal components analysis indicated that family distribution is signifacntly affected by the location of the sample, whether above or below the dam.

The dam affects the fish community in many ways, including blocking migration routes. The ability of fish to migrate is important to their survival. Many species require distinct aquatic habitat types for each cycle of their life including reproduction, growth and sexual maturation. Although potadromous fish, which inhabit freshwater throughout their entire life cycle, do not rely on long distance migrations to oceanic environments, distances up to a few hundred kilometers may separate their reproduction and feeding zones. Dams can block upstream spawning migration of anadromous fish such as

American shad. Many years ago in an attempt to provide fish passage, Woolen Mills Dam was retrofitted with a pool and weir. However, this virtually non-functional fishway was an ineffective design and was also poorly constructed, as the entrance channel could be seen lying far above the water level prior to dam removal.

The catatdromous American eel reproduces in the Sargasso Sea. The elver life stage migrates upriver, where the eel until sexually mature, at which point it returns to the Sargasso Sea to reproduce (Jenkins and Berkhead, 1994). Because of its tolerance to environmental stresses, the American eel occupies a broad variety of habitat types, and was found in all of our sampling stations. Dams affect the distributon of the American eel. Like other species of freshwater fish, downstream migration can be difficult, especially in seasons of low flow when the water level is low and the flow over dams may be greatly reduced. Eels are known to start their downstream migration late in the summer when these low-flow conditions are prevalent, and therefore may find it difficult to travel over dams (Jenkins and Berhead, 1994). After spawning, the adults die and the new young then make the long trek back upstream to their parents' native stream. Elvers migrating upstream face the same barrier to upstream migration as the Shad, but sometimes find ways over or around the dam. Young elvers have been seen bypassing dams by slithering around the dam on land, especially on wet nights, as they can stay out of water for a considerable amount of time under moist conditions (Wang and Kernehan, 1979). Another account noted young eels trying to climb vertically up dams in Delaware. The incidence of of over-land travel, and of scaling dames is probably limited, and probably mostly to strong, healthy eels. Dams probably reduce the number of American eels inhabiting upland regions.

The number of eels at the two below dam sites decreased after dam removal. In the site immediately below the dam, BD1, the number of eels decreased from a before-removal average of 52.5 per year to 13 in the year following dam removal. In the lowermost site, BD2, the number of eels decreased from an average of 7 before dam removal to 0 after dam removal. One possible reason for the decline in eel abundance in below dam sites following dam removal is the increase in available upstream habitat. The lack of diversity in the center of the impoundment found in our study could be indicative of a lack of habitable substrate and anoxic conditions. Thus, when the dam was removed and the anoxic water and highly silted river bottom disappeared, migration to the area may have become highly desirable, leading to a decrease in species abundance in the nearby sites. Relative abundance of eels below dam was on average higher than above dam before dam removal, however the abundance numbers followed more closely above and below dam after dam removal. Our eel data suggests that dam removal may have facilitated eel migration and created more suitable habitat for this species.

The sunfish family is the second largest freshwater fish family indigenous to North America and includes the smallmouth bass, largemouth bass, bluegill, redbreast sunfish, warmouth, green sunfish, and many others. Smallmouth bass, green sunfish and bluegill are introduced in the James Drainage, and so to the Rivanna River. Most Centrarchids are generalized carnivores, preying by sight on crustaceans, insects and other fish, however some species tend to be more specialized. Bluegills are omnivorous, which could be an important factor in their ability to thrive in impoundments versus natural, undisturbed streams (A.Weaver, Personal Communication). Most sunfishes and basses live in lakes, ponds, pools, and backwaters of streams, and thrive in impoundments such as that created by the Woolen Mills dam.

More than 10 species of sunfish, including bluegill, redbreast sunfish, and both smallmouth and largemouth bass, are found in the Rivanna around the Woolen Mills dam, with the majority of the sunfish in the impoundment and plunge pool. Surprisingly, the relative abundance of the sunfishes increased at the two formerly impounded sites following dam removal, but decreased at the uppermost site, AD3. Relative abundance also increased at the two below dam stations. These results indicate that the changes in community structure arise from a combination of stochastic and deterministic short-term causes, and that the expected result of a decrease in sunfish in the former impoundment may take years to see. The increase in sunfish downstream of the dam site could also be caused by a release of nutrient-laden sediment to the downstream sites, causing a multi-trophic level reaction that would allow the sunfish to flourish. Walters et al. showed that the relative proportion of centrarchids increased with silt and clay in the substrate as well as water turbidity (2001). These findings are congruent with our data, and will be further reinforced if future studies show a decrease in centrarchids such as largemouth and blugills, which would likely be a result of reduced suspended sediment after enough time has passed since the dam removal.

These game fish have most likely inhabited the Rivanna for some time, long before the dam was constructed, however, the number and size of bream (which include bluegills, redbreast and similar species) and largemouth bass has likely increased. Smallmouth bass, however, generally inhabit clear, healthy streams with rocky substrates and a combination of riffle, run, and pool habitats (Rohde et al., 1994; Lobb and Orth, 1991). They are rarely found in soft-bottomed ponds or lowland reservoirs. The majority of smallmouth bass found in the region were located at sites further from the dam, such as AD3 and BD2. The majority of the largemouth, however, and some of the biggest, could be found in the impoundment, right next to the dam.

Although the dam may have decreased available habitat for species such as the smallmouth, the impoundment had created an ideal environment for sunfishes such as black crappie, largemouth, bluegill and redbreast. The deep, slow moving warm water and underwater structures such as trees provided good habitat for these fish and had thus altered the species composition that would naturally be found in the area. Since it was the dam and its associated impoundment that allowed such deep pool adapted species to flourish in the area, it can be expected that the dam removal over time will allow the Rivanna to support more fish adapted to free flowing environments, as the river almost certainly did before the dam.

Darters are some of the most conspicuous members of the stream fish fauna in faster flowing waters. Geographical isolation coupled with their limited mobility has resulted in a high level of speciation and endemism in the darters. Most darter species, such as those of the genus *Etheostoma* (those found in the Rivanna include the Johnny darter (*Etheostoma nigrum)*, glassy darter (*Etheostoma vitreum*), and fan-tailed darter (*Etheostoma flaballare*), are associated with clear swift streams, although some have successfully invaded slackwater areas. Most darters require specific habitat and are usually only found in shallow riffles. Of the darters, however, the Roanoke darter is locally quite abundant in the Rivanna and can be found in the below-dam sampling stations. The majority of darters, such as *Etheostoma flaballare* and *Percina roanoka* were seen in the below dam sites, however, the abundance of darters in the impoundment increased dramatically after dam removal. This is most likely due to the change in habitat from reservoir, with slow moving warm water and silted bottom, to a shallow, cooler, fast moving river with a rocky bottom better for Percid spawning habits.

One species of livebearers was found in sampling station AD3 in 2006: *Gambusia holbrooki*, the Eastern mosquitofish. The species is primarily adapted to lowland slackwaters and is uncommon above the fall line (Jenkins and Berkhead, 1994), making its discovery in AD3 (well above the fall line) surprising. The species' habitat usually consists of muddy or sandy substrates, and in sampling station AD3 the mosquitofish finding may be influenced slightly by the presence of the dam downstream. The species is commonly used as a biological mosquito control method, and may have been introduced locally to the area for that reason.

We found 7 specimens of sea lamprey (*Petromyzon marinus*) at the furthermost downstream site, BD2, in 2008. The Sea lamprey is an anadromous species found in the North Atlantic Ocean, Baltic Sea, Mediterranean Sea and associated freshwaters (Jenkins and Burkhead, 1994). It is a stage-dependent, highly adaptive species that occupies a large variety of habitats and has broad feeding requirements. The individuals were in the early stages of transformation from ammocoetes to juveniles. Accounts of sea lamprey are noted in the mainsteam of the James River, as well as the Piney River a tributary of the Tye River. (Personal communication, Brian Watson, VDGIF). The Tye River enters the James above the Rivanna, but our record of sea lamprey in the Rivanna appears to be the first known record of this species in the entire Rivanna River Basin. Our recent find of Lamprey may be due to new recruitment, introduction, or timing of sampling efforts.

Substantial numbers of sea lamprey pass through Boshers Dam fishway (James River in Richmond, Virginia) annually, beginning in 1999 (Weaver, 2003).

Some of our results may have been affected by unequal sampling effort at some stations. For example, in the first year of sampling, with approximately one hour of total sampling, the sampling time at BD1 was not proportional to other sampling times; however the second longest sampling time exhibited the lowest number of species, so sampling time discrepancies may be negligible. Sampling protocol was not perfected until after the first sampling date, and as a result, sampling times per station were not consistent. In all sampling stations, we tried to consistently sample in 900s intervals, however, the number of transects used varied among sampling stations, depending on the size and accessibility.

While our methods are sufficient for characterizing the local fish community, there is no way to ensure that every species actually present was found in the course of this study. There are likely unaccounted species present in the Rivanna River in the vicinity of the dam.

In 1998, the Virginia Department of Game and Inland Fisheries conducted a Rivanna River Fish Community Investigation to determine the species present in the Rivanna River and its tributaries. The investigators found a total of 56 species in Rivanna and its tributaries, and a total of 30 species in the main branch of the Rivanna, where our study was conducted. Of the species found in the mainstem Rivanna in the 1998 study and additional observation databases, many were not found in our study. The species include the river chub, creek chubsucker, spotted bass, white crappie, shorthead redhorse, grass carp, cutlips minnow, tennessee shiner, mountain redbelly dace, creek chub, northern pike, muskellunge, chain pickerel, longfin darter, tessellated darter, walleye, rainbow trout, brown trout and brook trout. We did not expect to see some of the species found in the 1998 study based on the location of our study, such as trout and walleye. The Glassy darter was found only in our control station. Although we saw one species of chub, the bull chub, the river chub (*Nocomis micropogon*) is restricted primarily to larger river systems and rarely extends up into 10m wide sections of tributaries (Jenkins and Berkhead, 1994).

Although there were numerous false identifications of gizzard shad as American shad in the Rivanna River, we did not find any American shad. It has likely been several hundred years since species like the American shad flourished in the Woolen Mills area. With the help of the Virginia Department of Game and Inland Fisheries' Shad stocking program, the recolonization of the American shad is a tangible goal in the immediate future. There are many factors that may be restricting for the recolonization efforts; however, one of the most important factors may be the length of time that has passed since the shad were present. With the elapsed time most likely came several introductions and recruitments of new species that have since flourished in the area. Competition and predation by these newly dominant species could inhibit the rehabilitation of the American Shad population in the Rivanna, and therefore it may be a number of years before any progress will be seen. In addition, American shad do not mature sexually until five years of age, and since our study was conducted prior to five years after the shad restocking begun, it is possible that the fry that were stocked in the Rivanna have not matured enough to return to the Rivanna to spawn. The goal of this study, however, was not to try to find an immediate recolonization of species like the

Shad, but to understand the underlying mechanisms of population change surrounding dams in the hope of making informed decisions concerning dam removal in the future.

Over time, we expect to see a shift from a highly modified environment to a healthy free-flowing stream system. With the transition back to the natural environment, we expect an associated change in fish assemblage to a more diverse community including a greater proportion of fish adapted to riffle and run habitats. In less than one year after the dam was removed, the change in habitat was immense. The observed changes in richness and diversity indicate that dam removal may prove beneficial for the local fish community in the long term. The immediate response of the local fish community could either be a short-term artifact of the environmental effects of the dam removal, or it could be an indicator of the change to come. The correlation of the changes in habitat structure with the increases in diversity, however, point toward the beginning of long-term changes in the community composition. We can expect that the diversity and richness of the former impoundment sites will increase quickly to the levels seen in the below dam sites in little time. Overall increases in local species richness, however, will likely take many years to see.

It will likely prove beneficial to continue to monitor the fish community in the Rivanna River in the years to come. The results presented here represent change on a small temporal scale, yet serve as a predictor of changes to come. The results of our study provide optimism for efforts to restore native freshwater fish communities by means of dam removal and will hopefully spur continued studies of the underlying mechanisms of change in these systems.

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Appendix:

Table 1. Sampling methods and date sampled for each sampling station

Sample Stn.	Date Sampled	Sampling Method
AD1	Aug 23, 2006 June 15, 2007 July 18, 2008	Boat Boat Tote Barge and Backpack
AD2	Aug 23, 2006 June 15, 2007 August 13, 2008	Boat Boat Tote Barge
AD3	Sept 15, 2006 July 26, 3007 July 20, 2008	Backpack Tote Barge Tote Barge
BD1	June 23, 2006 June 28, 2007 June 23, 2008	Tote Barge and Backpack Tote Barge Tote Barge
BD2	Aug 27, 2006 June 23, 2007 September 18, 2008	Backpack Backpack Backpack
Control	July 27, 2007 September 3, 2008	Backpack Backpack

Table 2. Wentworth classification scheme for substrate

Size range (metric)	*Size range* (approx. inches)	*Aggregate name* (Wentworth Class)	*Other names*
> 256 mm	> 10.1 in	Boulder	
64–256 mm	2.5–10.1 in	Cobble	
32–64 mm	1.26–2.5 in	Very coarse gravel	Pebble
16–32 mm	0.63–1.26 in	Coarse gravel	Pebble
8–16 mm	0.31–0.63 in	Medium gravel	Pebble
4–8 mm	0.157–0.31 in	Fine gravel	Pebble
2–4 mm	0.079–0.157 in	Very fine gravel	Granule
1–2 mm	0.039–0.079 in	Very coarse sand	
½–1 mm	0.020–0.039 in	Coarse sand	
¼–½ mm	0.010–0.020 in	Medium sand	
125–250 µm	0.0049–0.010 in	Fine sand	
62.5–125 µm	0.0025–0.0049 in	Very fine sand	
3.90625–62.5 µm	0.00015–0.0025 in	Silt	Mud
< 3.90625 µm	< 0.00015 in	Clay	Mud
< 1 µm	< 0.000039 in	Colloid	Mud

Table 3. ANOVA results for diversity

Diversity					
Source	**DF**	**SS**	**MS**	**F**	**Pr > F**
Model	6	2.1268	.35447	2.39	.1265
Time	1	0.11190786	0.11190786	0.75	.4104
Dam	1	0.91121147	0.91121147	6.14	**.0382**
Name(Dam)	3	0.53149829	0.17716610	1.19	.3718
Time*Dam	1	0.12728514	0.12728514	.86	.3814

Table 4. ANOVA results for richness

Richness					
Source	**DF**	**SS**	**MS**	**F**	**Pr > F**
Model	6	744.75	124.125	3.07	.0726
Time	1	76.05	76.05	1.88	.2073
Dam	1	194.272222	194.27222	4.81	**.0597**
Name(Dam)	3	279.5	93.16666667	2.31	.1534
Time*Dam	1	54.45	54.45	1.35	.2792

Table 5. ANOVA results for evenness

Evenness					
Source	**DF**	**SS**	**MS**	**F**	**Pr > F**
Model	6	.06174608	.01029101	.69	.2501
Time	1	0.00432933	0.00432933	1.35	.4289
Dam	1	0.00841196	0.00841196	2.54	.2789
Name(Dam)	3	0.04745898	0.01581966	2.54	.1301
Time*Dam	1	0.00175440	0.00175440	.28	.6102

Table 6. ANOVA results for principal component 1

Principal Component 1					
Source	**DF**	**SS**	**MS**	**F**	**Pr > F**
Model	6	34.55470819	5.75911803	5.33	.0170
Time	1	.10803939	.10803939	.10	.7599
Dam	1	23.18681561	23.18681561	21.46	**.0017**
Name(Dam)	3	6.65002429	2.21667476	2.05	.1852
Time*Dam	1	.16359512	.16359512	.15	.7073

Table 7. ANOVA results for principal component 2

Principal Component 2					
Source	**DF**	**SS**	**MS**	**F**	**Pr > F**
Model	6	15.99296219	2.66549370	1.94	.1888
Time	1	.46663558	.46663558	.34	.5757
Dam	1	.03170473	.03170473	.02	.8829
Name(Dam)	3	13.73962365	4.57987455	3.34	.0766

Table 8. Correlation Matrix for Principal Components Procedure

	Ang	**Cat**	**Cent**	**Clu**	**Cyp**	**Ict**	**Lep**	**Per**	**Poe**	**Lam**
Ang	1	0.121	**0.2606**	-0.2471	-0.406	0.166	0.2867	-0.2657	-0.2701	-0.1524
Cat	0.121	1	-0.0114	0.0691	-0.0076	-0.2059	0.0481	**-0.5181**	-0.3365	-0.1579
Cent	0.2606	-0.0114	1	-0.0343	**-0.7862**	-0.7473	-0.1946	**-0.6297**	0.2795	-0.2309
Clu	-0.2471	0.0691	-0.0343	1	0.2312	-0.0759	0.0107	-0.1831	-0.0775	-0.0775
Cyp	-0.406	-0.0076	-0.7862	0.2312	1	0.3648	0.1823	0.1897	-0.3737	-0.064
Ict	0.166	-0.2059	-0.7473	-0.0759	**0.3648**	1	0.1162	0.664	-0.223	0.5124
Lep	0.2867	0.0481	-0.1946	0.0107	0.1823	0.1162	1	-0.0001	-0.0714	-0.0714
Per	-0.2657	-0.5181	-0.6297	-0.1831	0.1897	0.664	-0.0001	1	0.2036	0.4034
Poe	-0.2701	-0.3365	0.2795	-0.0775	-0.3737	-0.223	-0.0714	0.2036	1	-0.0714
Lam	-0.1524	-0.1579	-0.2309	-0.0775	-0.064	0.5124	-0.0714	0.4034	-0.0714	1

Table 9. Eigenvalues for Principal Components

	Eigenvalue	Difference	Proportion	Cumulative
1	3.08555374	1.15974202	0.3086	0.3086
2	1.92581172	0.33357527	0.1926	0.5011
3	1.59223645	0.50698357	0.1592	0.6604
4	1.08525288	0.24765501	0.1085	0.7689
5	0.83759787	0.14434152	0.0838	0.8526
6	0.69325635	0.18078417	0.0693	0.922
7	0.51247218	0.2765031	0.0512	0.9732
8	0.23596908	0.2045845	0.0236	0.9968
9	0.03138458	0.03091945	0.0031	1
10	0.00046513		0	1

Table 10. Eigenvectors for Principal Components Analysis

	Prin1	Prin2	Prin3	Prin4	Prin5
Ang	-0.162558	0.144514	0.675909	0.105599	0.144666
Cat	-0.169872	0.474718	0.034306	-0.318824	-0.193859
Cent	-0.522051	-0.209955	0.051917	-0.060088	0.190996
Clu	0.00025	0.233584	-0.447496	0.002858	0.776288
Cyp	0.372318	0.375545	-0.31269	0.165952	-0.197966
Ict	0.484093	0.000134	0.306513	-0.094868	0.133247
Lep	0.07612	0.248551	0.271889	0.669559	0.28298
Per	0.451845	-0.349037	0.0434	0.101398	-0.074089
Poe	-0.10802	-0.527558	-0.201826	0.355354	0.00124
Lam	0.278544	-0.228385	0.175374	-0.512029	0.399843

Table 11. Percent abundance for selected families among years and stations

	Station	2006	2007	2008	Change
Cyprinidae	AD1	0.00	0.13	3.27	3.20
	AD2	0.00	0.02	1.06	1.05
	AD3	0.00	5.04	0.95	-1.57
	BD1	7.69	5.26	9.41	2.94
	BD2	2.63	1.08	0.62	-1.24
	Control		3.36	1.79	-1.57
Centarchidae	AD1	1.24	1.57	3.20	1.80
	AD2	0.31	0.62	1.99	1.52
	AD3	0.31	3.67	1.90	-0.09
	BD1	0.53	1.81	4.86	3.69
	BD2	0.04	0.02	0.27	0.23
	Control		0.38	0.88	0.51
Percidae	AD1	0.00	0.00	1.22	1.22
	AD2	0.00	0.00	0.11	0.11
	AD3	0.15	0.57	0.40	0.03
	BD1	3.56	2.01	1.08	-1.70
	BD2	2.85	0.75	0.86	-0.94
	Control		0.91	0.20	-0.71
Anguillidae	AD1	0.18	0.09	0.18	0.04
	AD2	0.07	0.02	0.11	0.07
	AD3	0.00	0.42	0.27	0.06
	BD1	1.35	0.97	0.29	-0.87
	BD2	0.09	0.22	0.04	-0.11
	Control		0.00	0.00	0.00

Table 12. Percent rocky substrate and depth among years and stations

Year	Station	% Rocky	Average Depth (ft)
2007	AD1	21.05	7.62
2008	AD1	65.00	5.21
2007	AD2	4.17	4.80
2008	AD2	42.86	2.01
2007	AD3	65.38	3.19
2008	AD3	26.67	2.60
2007	BD1	82.35	1.20
2008	BD1	100.00	0.98
2007	BD2	100.00	1.66
2008	BD2	23.53	

Table 13. ANOVA results for percent rocky substrate

Percent Rocky Substrate					
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Time	1	130.923635	130.923635	0.09	0.7836
Dam	1	3640.915323	3640.915323	2.51	0.2115
Name(Dam)	3	1462.836244	487.612081	0.34	0.803
Time*Dam	1	1164.33295	1164.33295	0.8	0.4366

Table 14. Richness per year

Year	Station	Richness
2006	BD1	29
2006	BD2	16
2006	AD1	6
2006	AD2	7
2006	AD3	5
2007	BD1	31
2007	BD2	17
2007	AD1	14
2007	AD2	10
2007	AD3	26
2008	BD1	30
2008	BD2	18
2008	AD1	25
2008	AD2	19
2008	AD3	17

Figure 4. Averaged Shannon-Wiener diversity values compared before and after dam removal

Figure 5. Species richness averaged over all sites before and after dam removal

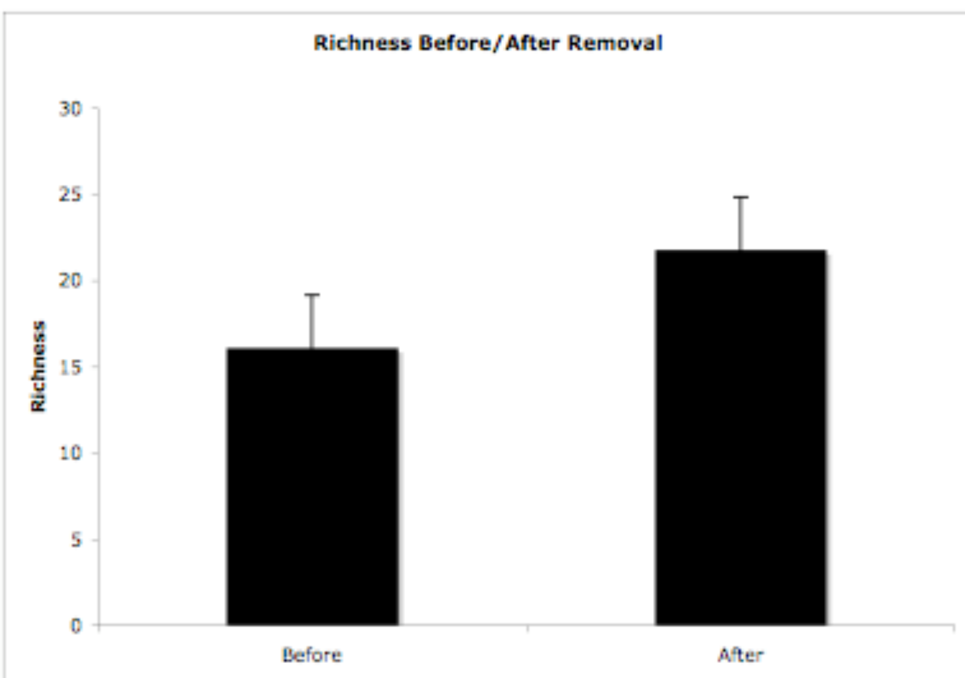

Figure 6. Total Shannon-Wiener index for all three sampling years broken down by sampling station

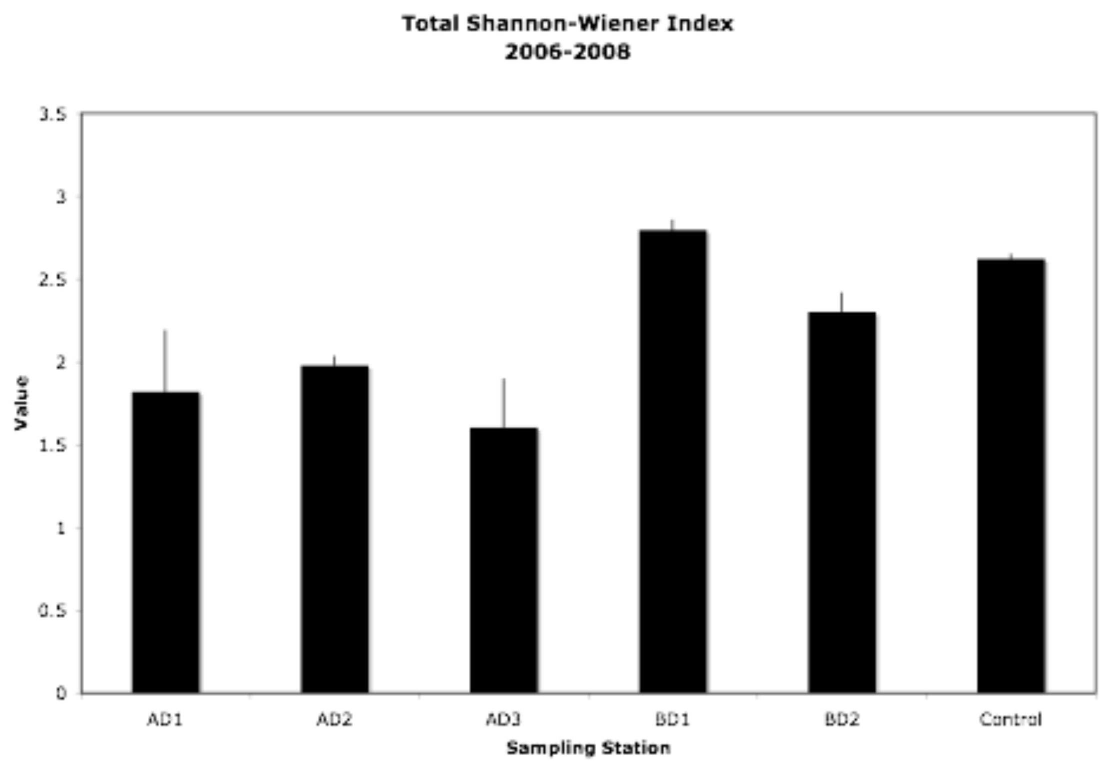

Figure 7. Evenness scores for each site and each year of sampling

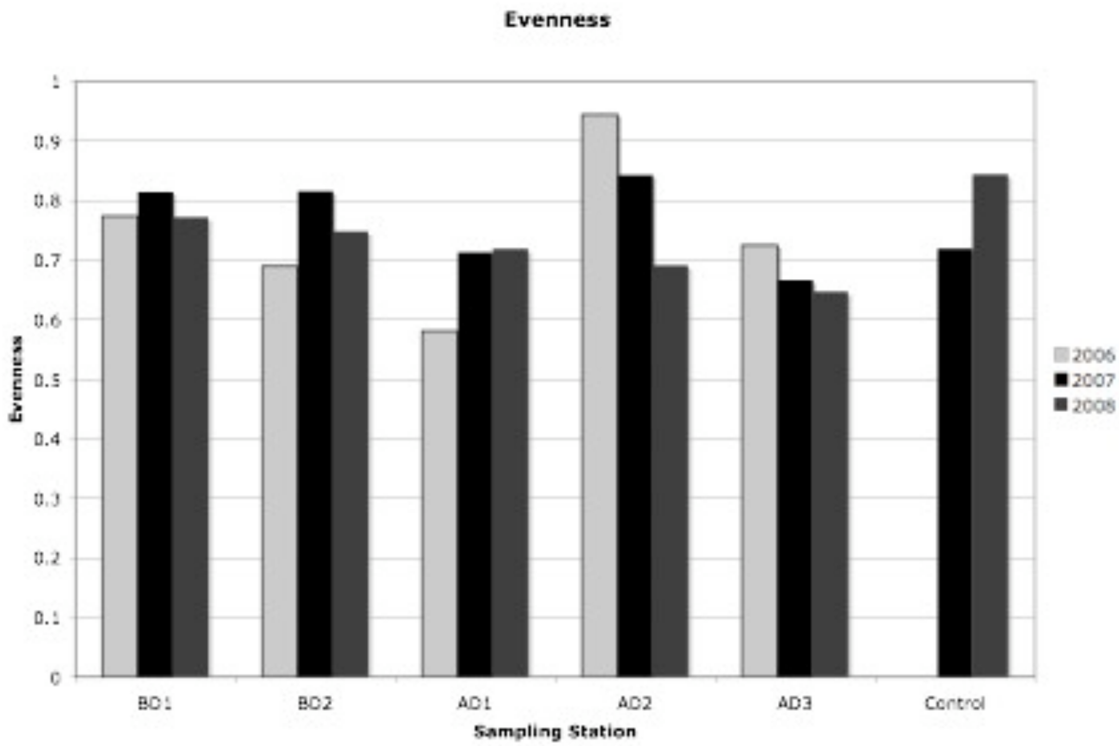

Figure 8. Plot of principal component 1 and principal component 2 for family distribution before and after dam removal

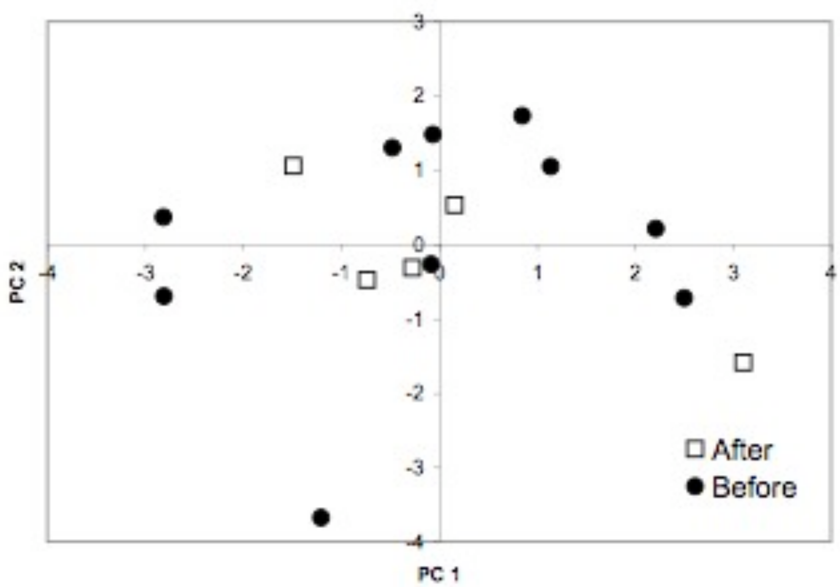

Figure 9. Plot of principal component 3 and principal component one for family distribution above and below dam

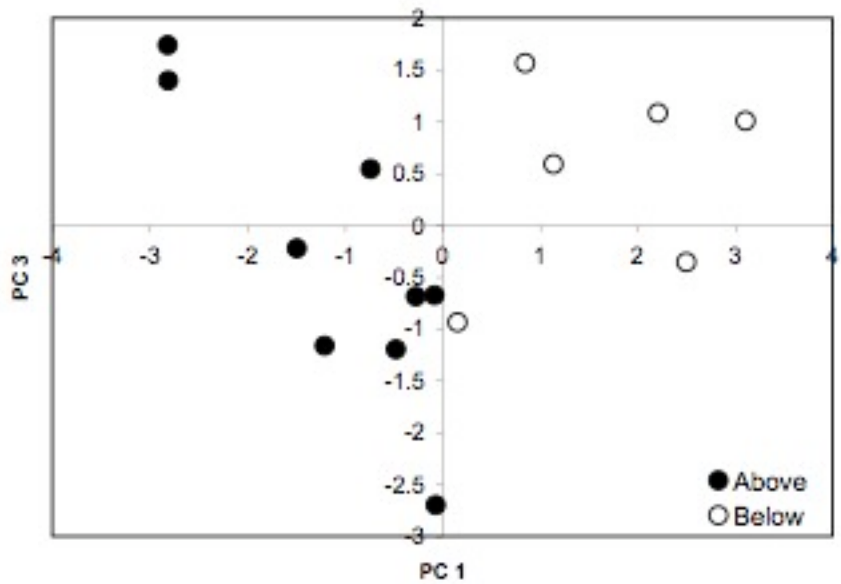

Figure 10. Percent abundance of Cyprinids for each sampling station and for all years

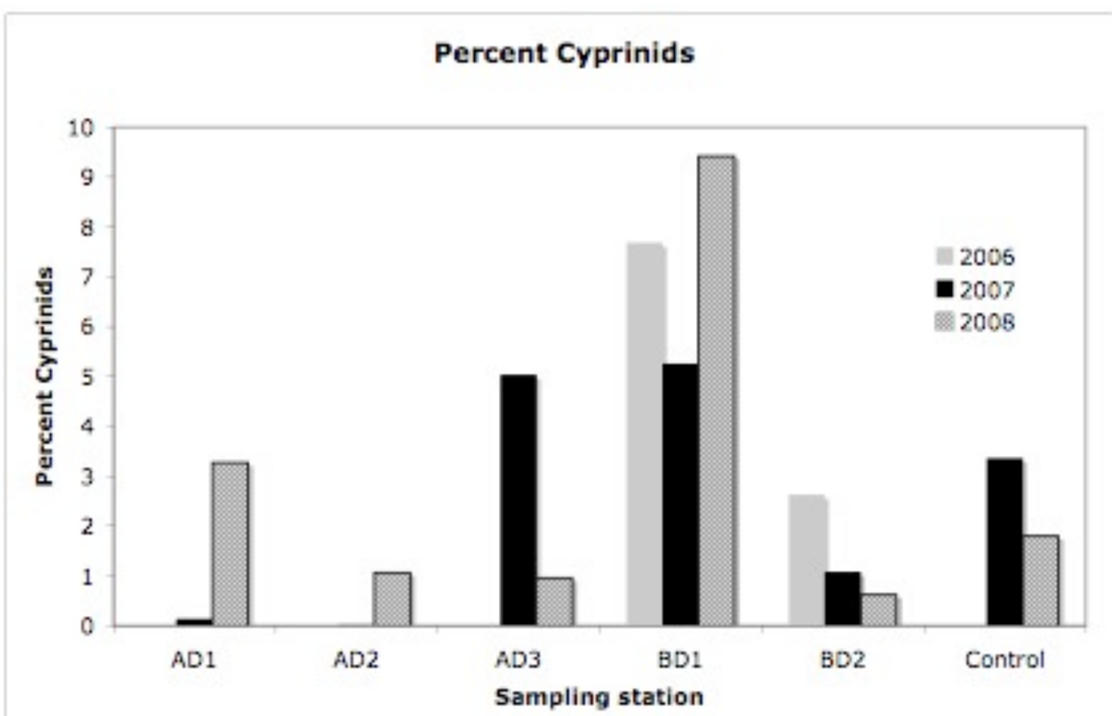

Figure 11. Percent abundance of Centrarchids for each sampling station and for all years

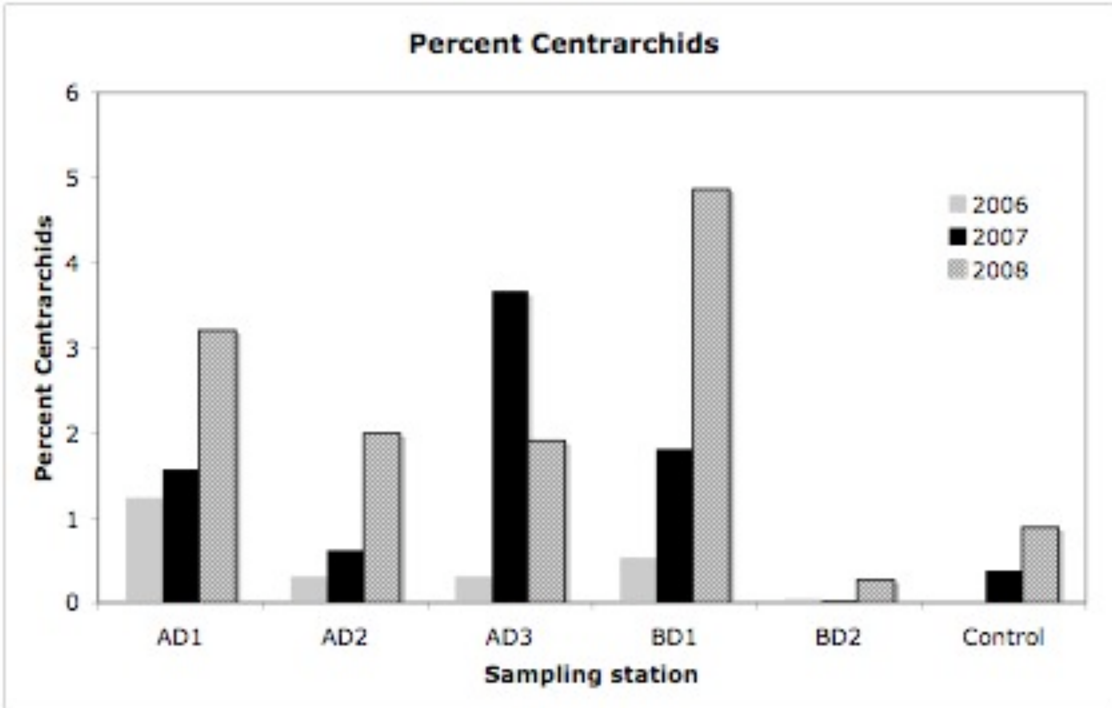

Figure 12. Percent rocky substrate for each sampling station in 2007 and 2008

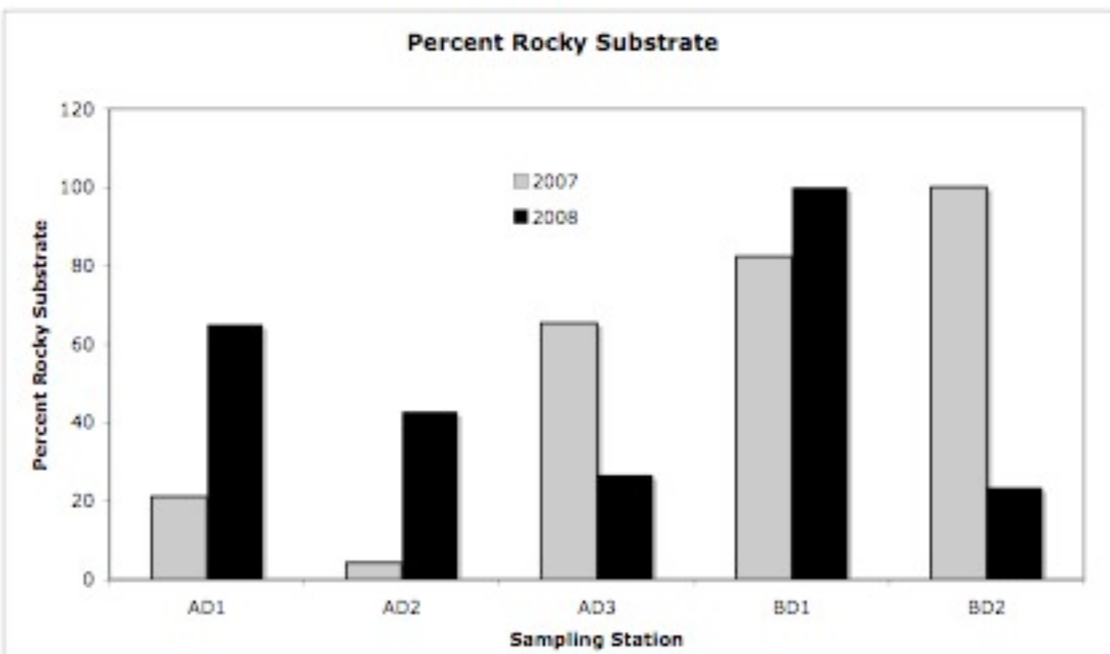

Table 15. Raw data including species richness and individual counts for each site

Family	Species	Year	Site	#
Anguillidae	Anguilla rostrata	2006	AD1	8
Anguillidae	Anguilla rostrata	2007	AD1	4
Anguillidae	Anguilla rostrata	2008	AD1	8
Anguillidae	Anguilla rostrata	2006	AD2	3
Anguillidae	Anguilla rostrata	2007	AD2	1
Anguillidae	Anguilla rostrata	2008	AD2	5
Anguillidae	Anguilla rostrata	2006	AD3	0
Anguillidae	Anguilla rostrata	2007	AD3	19
Anguillidae	Anguilla rostrata	2008	AD3	12
Anguillidae	Anguilla rostrata	2006	BD1	61
Anguillidae	Anguilla rostrata	2007	BD1	44
Anguillidae	Anguilla rostrata	2008	BD1	13
Anguillidae	Anguilla rostrata	2006	BD2	4
Anguillidae	Anguilla rostrata	2007	BD2	10
Anguillidae	Anguilla rostrata	2008	BD2	2
Anguillidae	Anguilla rostrata	2007	Control	0
Anguillidae	Anguilla rostrata	2008	Control	0
Catostomidae	Catostomus commersoni	2006	AD1	4
Catostomidae	Catostomus commersoni	2007	AD1	6
Catostomidae	Catostomus commersoni	2008	AD1	0
Catostomidae	Catostomus commersoni	2006	AD2	2
Catostomidae	Catostomus commersoni	2007	AD2	6
Catostomidae	Catostomus commersoni	2008	AD2	14
Catostomidae	Catostomus commersoni	2006	AD3	0
Catostomidae	Catostomus commersoni	2007	AD3	0
Catostomidae	Catostomus commersoni	2008	AD3	1
Catostomidae	Catostomus commersoni	2006	BD1	2
Catostomidae	Catostomus commersoni	2007	BD1	0
Catostomidae	Catostomus commersoni	2008	BD1	1
Catostomidae	Catostomus commersoni	2006	BD2	0
Catostomidae	Catostomus commersoni	2007	BD2	0
Catostomidae	Catostomus commersoni	2008	BD2	0
Catostomidae	Catostomus commersoni	2007	Control	7
Catostomidae	Catostomus commersoni	2008	Control	0
Catostomidae	Hypentelium nigricans	2006	AD1	0
Catostomidae	Hypentelium nigricans	2007	AD1	0
Catostomidae	Hypentelium nigricans	2008	AD1	0
Catostomidae	Hypentelium nigricans	2006	AD2	3
Catostomidae	Hypentelium nigricans	2007	AD2	0
Catostomidae	Hypentelium nigricans	2008	AD2	10
Catostomidae	Hypentelium nigricans	2006	AD3	0
Catostomidae	Hypentelium nigricans	2007	AD3	5
Catostomidae	Hypentelium nigricans	2008	AD3	0
Catostomidae	Hypentelium nigricans	2006	BD1	17
Catostomidae	Hypentelium nigricans	2007	BD1	2

Catostomidae	Hypentelium nigricans	2008	BD1	1
Catostomidae	Hypentelium nigricans	2006	BD2	0
Catostomidae	Hypentelium nigricans	2007	BD2	0
Catostomidae	Hypentelium nigricans	2008	BD2	2
Catostomidae	Hypentelium nigricans	2007	Control	1
Catostomidae	Hypentelium nigricans	2008	Control	0
Catostomidae	Maxostoma erythrurum	2006	AD1	0
Catostomidae	Maxostoma erythrurum	2007	AD1	0
Catostomidae	Maxostoma erythrurum	2008	AD1	0
Catostomidae	Maxostoma erythrurum	2006	AD2	0
Catostomidae	Maxostoma erythrurum	2007	AD2	4
Catostomidae	Maxostoma erythrurum	2008	AD2	14
Catostomidae	Maxostoma erythrurum	2006	AD3	0
Catostomidae	Maxostoma erythrurum	2007	AD3	0
Catostomidae	Maxostoma erythrurum	2008	AD3	0
Catostomidae	Maxostoma erythrurum	2006	BD1	1
Catostomidae	Maxostoma erythrurum	2007	BD1	0
Catostomidae	Maxostoma erythrurum	2008	BD1	0
Catostomidae	Maxostoma erythrurum	2006	BD2	0
Catostomidae	Maxostoma erythrurum	2007	BD2	0
Catostomidae	Maxostoma erythrurum	2008	BD2	0
Catostomidae	Maxostoma erythrurum	2007	Control	0
Catostomidae	Maxostoma erythrurum	2008	Control	0
Catostomidae	Maxostoma macrolepidotum	2007	AD1	1
Catostomidae	Maxostoma macrolepidotum	2008	AD1	0
Catostomidae	Maxostoma macrolepidotum	2007	AD2	0
Catostomidae	Maxostoma macrolepidotum	2008	AD2	0
Catostomidae	Maxostoma macrolepidotum	2007	AD3	0
Catostomidae	Maxostoma macrolepidotum	2008	AD3	0
Catostomidae	Maxostoma macrolepidotum	2007	BD1	0
Catostomidae	Maxostoma macrolepidotum	2008	BD1	0
Catostomidae	Maxostoma macrolepidotum	2007	BD2	0
Catostomidae	Maxostoma macrolepidotum	2008	BD2	0
Catostomidae	Maxostoma macrolepidotum	2007	Control	0
Catostomidae	Maxostoma macrolepidotum	2008	Control	0
Catostomidae	Scartomyzon cervinus	2006	AD1	0
Catostomidae	Scartomyzon cervinus	2007	AD1	1
Catostomidae	Scartomyzon cervinus	2008	AD1	9
Catostomidae	Scartomyzon cervinus	2006	AD2	0
Catostomidae	Scartomyzon cervinus	2007	AD2	0
Catostomidae	Scartomyzon cervinus	2008	AD2	30
Catostomidae	Scartomyzon cervinus	2006	AD3	0
Catostomidae	Scartomyzon cervinus	2007	AD3	34
Catostomidae	Scartomyzon cervinus	2008	AD3	2
Catostomidae	Scartomyzon cervinus	2006	BD1	132
Catostomidae	Scartomyzon cervinus	2007	BD1	68
Catostomidae	Scartomyzon cervinus	2008	BD1	50
Catostomidae	Scartomyzon cervinus	2006	BD2	4

Catostomidae	Scartomyzon cervinus	2007	BD2	7
Catostomidae	Scartomyzon cervinus	2008	BD2	3
Catostomidae	Scartomyzon cervinus	2007	Control	0
Catostomidae	Scartomyzon cervinus	2008	Control	0
Catostomidae	Thoburnia rhothoeca	2006	AD1	0
Catostomidae	Thoburnia rhothoeca	2007	AD1	0
Catostomidae	Thoburnia rhothoeca	2008	AD1	1
Catostomidae	Thoburnia rhothoeca	2006	AD2	0
Catostomidae	Thoburnia rhothoeca	2007	AD2	0
Catostomidae	Thoburnia rhothoeca	2008	AD2	0
Catostomidae	Thoburnia rhothoeca	2006	AD3	0
Catostomidae	Thoburnia rhothoeca	2007	AD3	2
Catostomidae	Thoburnia rhothoeca	2008	AD3	1
Catostomidae	Thoburnia rhothoeca	2006	BD1	8
Catostomidae	Thoburnia rhothoeca	2007	BD1	0
Catostomidae	Thoburnia rhothoeca	2008	BD1	5
Catostomidae	Thoburnia rhothoeca	2006	BD2	0
Catostomidae	Thoburnia rhothoeca	2007	BD2	1
Catostomidae	Thoburnia rhothoeca	2008	BD2	1
Catostomidae	Thoburnia rhothoeca	2007	Control	54
Catostomidae	Thoburnia rhothoeca	2008	Control	33
Catostomidae	Unidentified juvenile catostomid	2007	AD1	0
Catostomidae	Unidentified juvenile catostomid	2008	AD1	0
Catostomidae	Unidentified juvenile catostomid	2007	AD2	0
Catostomidae	Unidentified juvenile catostomid	2008	AD2	0
Catostomidae	Unidentified juvenile catostomid	2007	AD3	4
Catostomidae	Unidentified juvenile catostomid	2008	AD3	0
Catostomidae	Unidentified juvenile catostomid	2007	BD1	0
Catostomidae	Unidentified juvenile catostomid	2008	BD1	0
Catostomidae	Unidentified juvenile catostomid	2007	BD2	0
Catostomidae	Unidentified juvenile catostomid	2008	BD2	0
Catostomidae	Unidentified juvenile catostomid	2007	Control	1
Catostomidae	Unidentified juvenile catostomid	2008	Control	0
Centrarchidae	Ambloplites rupestris	2006	AD1	0
Centrarchidae	Ambloplites rupestris	2007	AD1	0
Centrarchidae	Ambloplites rupestris	2008	AD1	1
Centrarchidae	Ambloplites rupestris	2006	AD2	0
Centrarchidae	Ambloplites rupestris	2007	AD2	0
Centrarchidae	Ambloplites rupestris	2008	AD2	0
Centrarchidae	Ambloplites rupestris	2006	AD3	0
Centrarchidae	Ambloplites rupestris	2007	AD3	2
Centrarchidae	Ambloplites rupestris	2008	AD3	2
Centrarchidae	Ambloplites rupestris	2006	BD1	1
Centrarchidae	Ambloplites rupestris	2007	BD1	3
Centrarchidae	Ambloplites rupestris	2008	BD1	1
Centrarchidae	Ambloplites rupestris	2006	BD2	0
Centrarchidae	Ambloplites rupestris	2007	BD2	0
Centrarchidae	Ambloplites rupestris	2008	BD2	1

Centrarchidae	Ambloplites rupestris	2007	Control	2
Centrarchidae	Ambloplites rupestris	2008	Control	0
Centrarchidae	Lepomis auritis	2006	AD1	4
Centrarchidae	Lepomis auritis	2007	AD1	25
Centrarchidae	Lepomis auritis	2008	AD1	102
Centrarchidae	Lepomis auritis	2006	AD2	3
Centrarchidae	Lepomis auritis	2007	AD2	11
Centrarchidae	Lepomis auritis	2008	AD2	44
Centrarchidae	Lepomis auritis	2006	AD3	14
Centrarchidae	Lepomis auritis	2007	AD3	118
Centrarchidae	Lepomis auritis	2008	AD3	68
Centrarchidae	Lepomis auritis	2006	BD1	9
Centrarchidae	Lepomis auritis	2007	BD1	28
Centrarchidae	Lepomis auritis	2008	BD1	106
Centrarchidae	Lepomis auritis	2006	BD2	2
Centrarchidae	Lepomis auritis	2007	BD2	0
Centrarchidae	Lepomis auritis	2008	BD2	6
Centrarchidae	Lepomis auritis	2007	Control	7
Centrarchidae	Lepomis auritis	2008	Control	15
Centrarchidae	Lepomis cyanellus	2007	AD1	1
Centrarchidae	Lepomis cyanellus	2008	AD1	6
Centrarchidae	Lepomis cyanellus	2007	AD2	0
Centrarchidae	Lepomis cyanellus	2008	AD2	0
Centrarchidae	Lepomis cyanellus	2007	AD3	1
Centrarchidae	Lepomis cyanellus	2008	AD3	0
Centrarchidae	Lepomis cyanellus	2007	BD1	0
Centrarchidae	Lepomis cyanellus	2008	BD1	7
Centrarchidae	Lepomis cyanellus	2007	BD2	0
Centrarchidae	Lepomis cyanellus	2008	BD2	0
Centrarchidae	Lepomis cyanellus	2007	Control	0
Centrarchidae	Lepomis cyanellus	2008	Control	0
Centrarchidae	Lepomis gibbosus	2007	AD1	1
Centrarchidae	Lepomis gibbosus	2008	AD1	0
Centrarchidae	Lepomis gibbosus	2007	AD2	0
Centrarchidae	Lepomis gibbosus	2008	AD2	0
Centrarchidae	Lepomis gibbosus	2007	AD3	2
Centrarchidae	Lepomis gibbosus	2008	AD3	0
Centrarchidae	Lepomis gibbosus	2007	BD1	1
Centrarchidae	Lepomis gibbosus	2008	BD1	0
Centrarchidae	Lepomis gibbosus	2008	BD2	0
Centrarchidae	Lepomis gibbosus	2007	Control	0
Centrarchidae	Lepomis gibbosus	2008	Control	1
Centrarchidae	Lepomis gibossus	2007	BD2	0
Centrarchidae	Lepomis gulosis	2006	AD1	0
Centrarchidae	Lepomis gulosis	2007	AD1	2
Centrarchidae	Lepomis gulosis	2008	AD1	0
Centrarchidae	Lepomis gulosis	2006	AD2	0
Centrarchidae	Lepomis gulosis	2007	AD2	0

Centrarchidae	Lepomis gulosis	2008	AD2	0
Centrarchidae	Lepomis gulosis	2006	AD3	0
Centrarchidae	Lepomis gulosis	2007	AD3	0
Centrarchidae	Lepomis gulosis	2008	AD3	0
Centrarchidae	Lepomis gulosis	2006	BD1	1
Centrarchidae	Lepomis gulosis	2007	BD1	0
Centrarchidae	Lepomis gulosis	2008	BD1	0
Centrarchidae	Lepomis gulosis	2006	BD2	0
Centrarchidae	Lepomis gulosis	2007	BD2	0
Centrarchidae	Lepomis gulosis	2008	BD2	0
Centrarchidae	Lepomis gulosis	2007	Control	0
Centrarchidae	Lepomis gulosis	2008	Control	0
Centrarchidae	Lepomis macrochirus	2006	AD1	47
Centrarchidae	Lepomis macrochirus	2007	AD1	30
Centrarchidae	Lepomis macrochirus	2008	AD1	31
Centrarchidae	Lepomis macrochirus	2006	AD2	6
Centrarchidae	Lepomis macrochirus	2007	AD2	10
Centrarchidae	Lepomis macrochirus	2008	AD2	33
Centrarchidae	Lepomis macrochirus	2006	AD3	0
Centrarchidae	Lepomis macrochirus	2007	AD3	17
Centrarchidae	Lepomis macrochirus	2008	AD3	11
Centrarchidae	Lepomis macrochirus	2006	BD1	7
Centrarchidae	Lepomis macrochirus	2007	BD1	26
Centrarchidae	Lepomis macrochirus	2008	BD1	79
Centrarchidae	Lepomis macrochirus	2006	BD2	0
Centrarchidae	Lepomis macrochirus	2007	BD2	0
Centrarchidae	Lepomis macrochirus	2008	BD2	3
Centrarchidae	Lepomis macrochirus	2007	Control	0
Centrarchidae	Lepomis macrochirus	2008	Control	21
Centrarchidae	Lepomis microlophus	2007	AD1	0
Centrarchidae	Lepomis microlophus	2008	AD1	0
Centrarchidae	Lepomis microlophus	2007	AD2	1
Centrarchidae	Lepomis microlophus	2008	AD2	0
Centrarchidae	Lepomis microlophus	2007	AD3	1
Centrarchidae	Lepomis microlophus	2008	AD3	0
Centrarchidae	Lepomis microlophus	2007	BD1	1
Centrarchidae	Lepomis microlophus	2008	BD1	4
Centrarchidae	Lepomis microlophus	2007	BD2	0
Centrarchidae	Lepomis microlophus	2008	BD2	0
Centrarchidae	Lepomis microlophus	2007	Control	0
Centrarchidae	Lepomis microlophus	2008	Control	0
Centrarchidae	Micropterus dolomieu	2006	AD1	0
Centrarchidae	Micropterus dolomieu	2007	AD1	2
Centrarchidae	Micropterus dolomieu	2008	AD1	2
Centrarchidae	Micropterus dolomieu	2006	AD2	4
Centrarchidae	Micropterus dolomieu	2007	AD2	2
Centrarchidae	Micropterus dolomieu	2008	AD2	4
Centrarchidae	Micropterus dolomieu	2006	AD3	0

Centrarchidae	Micropterus dolomieu	2007	AD3	21
Centrarchidae	Micropterus dolomieu	2008	AD3	3
Centrarchidae	Micropterus dolomieu	2006	BD1	5
Centrarchidae	Micropterus dolomieu	2007	BD1	17
Centrarchidae	Micropterus dolomieu	2008	BD1	7
Centrarchidae	Micropterus dolomieu	2006	BD2	0
Centrarchidae	Micropterus dolomieu	2007	BD2	1
Centrarchidae	Micropterus dolomieu	2008	BD2	1
Centrarchidae	Micropterus dolomieu	2007	Control	4
Centrarchidae	Micropterus dolomieu	2008	Control	3
Centrarchidae	Micropterus salmoides	2006	AD1	3
Centrarchidae	Micropterus salmoides	2007	AD1	8
Centrarchidae	Micropterus salmoides	2008	AD1	3
Centrarchidae	Micropterus salmoides	2006	AD2	1
Centrarchidae	Micropterus salmoides	2007	AD2	4
Centrarchidae	Micropterus salmoides	2008	AD2	8
Centrarchidae	Micropterus salmoides	2006	AD3	0
Centrarchidae	Micropterus salmoides	2007	AD3	4
Centrarchidae	Micropterus salmoides	2008	AD3	2
Centrarchidae	Micropterus salmoides	2006	BD1	0
Centrarchidae	Micropterus salmoides	2007	BD1	1
Centrarchidae	Micropterus salmoides	2008	BD1	13
Centrarchidae	Micropterus salmoides	2006	BD2	0
Centrarchidae	Micropterus salmoides	2007	BD2	0
Centrarchidae	Micropterus salmoides	2008	BD2	0
Centrarchidae	Micropterus salmoides	2007	Control	0
Centrarchidae	Micropterus salmoides	2008	Control	0
Centrarchidae	Pomoxis nigromaculatus	2006	AD1	0
Centrarchidae	Pomoxis nigromaculatus	2008	AD1	0
Centrarchidae	Pomoxis nigromaculatus	2007	AD1	1
Centrarchidae	Pomoxis nigromaculatus	2006	AD2	0
Centrarchidae	Pomoxis nigromaculatus	2008	AD2	0
Centrarchidae	Pomoxis nigromaculatus	2007	AD2	0
Centrarchidae	Pomoxis nigromaculatus	2006	AD3	0
Centrarchidae	Pomoxis nigromaculatus	2008	AD3	0
Centrarchidae	Pomoxis nigromaculatus	2007	AD3	0
Centrarchidae	Pomoxis nigromaculatus	2006	BD1	1
Centrarchidae	Pomoxis nigromaculatus	2007	BD1	0
Centrarchidae	Pomoxis nigromaculatus	2008	BD1	0
Centrarchidae	Pomoxis nigromaculatus	2006	BD2	0
Centrarchidae	Pomoxis nigromaculatus	2008	BD2	0
Centrarchidae	Pomoxis nigromaculatus	2007	BD2	0
Centrarchidae	Pomoxis nigromaculatus	2008	Control	0
Centrarchidae	Pomoxis nigromaculatus	2007	Control	0
Centrarchidae	Unidentified juvenile centrarchids	2006	AD1	2
Centrarchidae	Unidentified juvenile centrarchids	2006	AD2	0
Centrarchidae	Unidentified juvenile centrarchids	2006	AD3	0
Centrarchidae	Unidentified juvenile centrarchids	2007	AD1	0

Centrarchidae	Unidentified juvenile centrarchids	2008	AD1	0
Centrarchidae	Unidentified juvenile centrarchids	2007	AD2	0
Centrarchidae	Unidentified juvenile centrarchids	2008	AD2	0
Centrarchidae	Unidentified juvenile centrarchids	2007	AD3	0
Centrarchidae	Unidentified juvenile centrarchids	2008	AD3	0
Centrarchidae	Unidentified juvenile centrarchids	2006	BD1	0
Centrarchidae	Unidentified juvenile centrarchids	2007	BD1	1
Centrarchidae	Unidentified juvenile centrarchids	2008	BD1	1
Centrarchidae	Unidentified juvenile centrarchids	2006	BD2	0
Centrarchidae	Unidentified juvenile centrarchids	2007	BD2	0
Centrarchidae	Unidentified juvenile centrarchids	2008	BD2	0
Centrarchidae	Unidentified juvenile centrarchids	2007	Control	0
Centrarchidae	Unidentified juvenile centrarchids	2008	Control	0
Centrarchidae	Unidentified Juvenile Lepomis	2007	AD1	2
Centrarchidae	Unidentified Juvenile Lepomis	2008	AD1	0
Centrarchidae	Unidentified Juvenile Lepomis	2007	AD2	0
Centrarchidae	Unidentified Juvenile Lepomis	2008	AD2	1
Centrarchidae	Unidentified Juvenile Lepomis	2007	AD3	0
Centrarchidae	Unidentified Juvenile Lepomis	2008	AD3	0
Centrarchidae	Unidentified Juvenile Lepomis	2007	BD1	4
Centrarchidae	Unidentified Juvenile Lepomis	2008	BD1	2
Centrarchidae	Unidentified Juvenile Lepomis	2007	BD2	0
Centrarchidae	Unidentified Juvenile Lepomis	2008	BD2	1
Centrarchidae	Unidentified Juvenile Lepomis	2007	Control	0
Centrarchidae	Unidentified Juvenile Lepomis	2008	Control	0
Clupeidae	Dorosoma cepedianum	2007	AD1	0
Clupeidae	Dorosoma cepedianum	2008	AD1	0
Clupeidae	Dorosoma cepedianum	2007	AD2	0
Clupeidae	Dorosoma cepedianum	2008	AD2	0
Clupeidae	Dorosoma cepedianum	2007	AD3	0
Clupeidae	Dorosoma cepedianum	2008	AD3	0
Clupeidae	Dorosoma cepedianum	2007	BD1	1
Clupeidae	Dorosoma cepedianum	2008	BD1	0
Clupeidae	Dorosoma cepedianum	2007	BD2	0
Clupeidae	Dorosoma cepedianum	2008	BD2	0
Clupeidae	Dorosoma cepedianum	2007	Control	0
Clupeidae	Dorosoma cepedianum	2008	Control	0
Cyprinidae	Campostoma anomalum	2006	AD1	0
Cyprinidae	Campostoma anomalum	2007	AD1	0
Cyprinidae	Campostoma anomalum	2008	AD1	13
Cyprinidae	Campostoma anomalum	2006	AD2	0
Cyprinidae	Campostoma anomalum	2007	AD2	0
Cyprinidae	Campostoma anomalum	2008	AD2	0
Cyprinidae	Campostoma anomalum	2006	AD3	0
Cyprinidae	Campostoma anomalum	2007	AD3	0
Cyprinidae	Campostoma anomalum	2008	AD3	0
Cyprinidae	Campostoma anomalum	2006	BD1	27
Cyprinidae	Campostoma anomalum	2007	BD1	8

Cyprinidae	Campostoma anomalum	2008	BD1	27
Cyprinidae	Campostoma anomalum	2006	BD2	2
Cyprinidae	Campostoma anomalum	2007	BD2	4
Cyprinidae	Campostoma anomalum	2008	BD2	2
Cyprinidae	Campostoma anomalum	2007	Control	23
Cyprinidae	Campostoma anomalum	2008	Control	4
Catostomidae	Carpiodes cyprinis	2007	AD1	2
Catostomidae	Carpiodes cyprinis	2008	AD1	0
Catostomidae	Carpiodes cyprinis	2007	AD2	0
Catostomidae	Carpiodes cyprinis	2008	AD2	0
Catostomidae	Carpiodes cyprinis	2007	AD3	0
Catostomidae	Carpiodes cyprinis	2008	AD3	0
Catostomidae	Carpiodes cyprinis	2007	BD1	0
Catostomidae	Carpiodes cyprinis	2008	BD1	0
Catostomidae	Carpiodes cyprinis	2007	BD2	0
Catostomidae	Carpiodes cyprinis	2008	BD2	0
Catostomidae	Carpiodes cyprinis	2007	Control	0
Catostomidae	Carpiodes cyprinis	2008	Control	0
Cyprinidae	Clinostomus funduloides	2007	AD1	0
Cyprinidae	Clinostomus funduloides	2008	AD1	0
Cyprinidae	Clinostomus funduloides	2007	AD2	0
Cyprinidae	Clinostomus funduloides	2008	AD2	0
Cyprinidae	Clinostomus funduloides	2007	AD3	0
Cyprinidae	Clinostomus funduloides	2008	AD3	0
Cyprinidae	Clinostomus funduloides	2007	BD1	0
Cyprinidae	Clinostomus funduloides	2008	BD1	0
Cyprinidae	Clinostomus funduloides	2007	BD2	0
Cyprinidae	Clinostomus funduloides	2008	BD2	0
Cyprinidae	Clinostomus funduloides	2007	Control	1
Cyprinidae	Clinostomus funduloides	2008	Control	0
Cyprinidae	Cyprinella analostana	2006	AD1	0
Cyprinidae	Cyprinella analostana	2007	AD1	0
Cyprinidae	Cyprinella analostana	2008	AD1	18
Cyprinidae	Cyprinella analostana	2006	AD2	0
Cyprinidae	Cyprinella analostana	2007	AD2	1
Cyprinidae	Cyprinella analostana	2008	AD2	1
Cyprinidae	Cyprinella analostana	2006	AD3	0
Cyprinidae	Cyprinella analostana	2008	AD3	0
Cyprinidae	Cyprinella analostana	2007	AD3	48
Cyprinidae	Cyprinella analostana	2006	BD1	12
Cyprinidae	Cyprinella analostana	2007	BD1	29
Cyprinidae	Cyprinella analostana	2008	BD1	13
Cyprinidae	Cyprinella analostana	2006	BD2	4
Cyprinidae	Cyprinella analostana	2007	BD2	10
Cyprinidae	Cyprinella analostana	2008	BD2	0
Cyprinidae	Cyprinella analostana	2008	Control	5
Cyprinidae	Cyprinella analostana	2007	Control	6
Cyprinidae	Luxilus cerasinus	2006	AD1	0

Cyprinidae	Luxilus cerasinus	2007	AD1	0
Cyprinidae	Luxilus cerasinus	2008	AD1	0
Cyprinidae	Luxilus cerasinus	2006	AD2	0
Cyprinidae	Luxilus cerasinus	2007	AD2	0
Cyprinidae	Luxilus cerasinus	2008	AD2	0
Cyprinidae	Luxilus cerasinus	2006	AD3	0
Cyprinidae	Luxilus cerasinus	2007	AD3	1
Cyprinidae	Luxilus cerasinus	2008	AD3	0
Cyprinidae	Luxilus cerasinus	2006	BD1	12
Cyprinidae	Luxilus cerasinus	2007	BD1	0
Cyprinidae	Luxilus cerasinus	2008	BD1	2
Cyprinidae	Luxilus cerasinus	2006	BD2	0
Cyprinidae	Luxilus cerasinus	2007	BD2	0
Cyprinidae	Luxilus cerasinus	2008	BD2	0
Cyprinidae	Luxilus cerasinus	2007	Control	1
Cyprinidae	Luxilus cerasinus	2008	Control	0
Cyprinidae	Luxilus cornutus	2006	AD1	0
Cyprinidae	Luxilus cornutus	2007	AD1	0
Cyprinidae	Luxilus cornutus	2008	AD1	13
Cyprinidae	Luxilus cornutus	2006	AD2	0
Cyprinidae	Luxilus cornutus	2007	AD2	0
Cyprinidae	Luxilus cornutus	2008	AD2	0
Cyprinidae	Luxilus cornutus	2006	AD3	0
Cyprinidae	Luxilus cornutus	2007	AD3	15
Cyprinidae	Luxilus cornutus	2008	AD3	3
Cyprinidae	Luxilus cornutus	2006	BD1	34
Cyprinidae	Luxilus cornutus	2007	BD1	16
Cyprinidae	Luxilus cornutus	2008	BD1	105
Cyprinidae	Luxilus cornutus	2006	BD2	30
Cyprinidae	Luxilus cornutus	2007	BD2	3
Cyprinidae	Luxilus cornutus	2008	BD2	7
Cyprinidae	Luxilus cornutus	2007	Control	38
Cyprinidae	Luxilus cornutus	2008	Control	19
Cyprinidae	Lythrurus ardens	2008	AD1	4
Cyprinidae	Lythrurus ardens	2008	AD2	0
Cyprinidae	Lythrurus ardens	2008	AD3	0
Cyprinidae	Lythrurus ardens	2008	BD1	4
Cyprinidae	Lythrurus ardens	2008	BD2	0
Cyprinidae	Lythrurus ardens	2008	Control	0
Cyprinidae	Nocomis micropogon	2007	AD1	0
Cyprinidae	Nocomis micropogon	2008	AD1	0
Cyprinidae	Nocomis micropogon	2007	AD2	0
Cyprinidae	Nocomis micropogon	2008	AD2	0
Cyprinidae	Nocomis micropogon	2007	AD3	0
Cyprinidae	Nocomis micropogon	2008	AD3	0
Cyprinidae	Nocomis micropogon	2007	BD1	6
Cyprinidae	Nocomis micropogon	2008	BD1	0
Cyprinidae	Nocomis micropogon	2007	BD2	0

Cyprinidae	Nocomis micropogon	2008	BD2	0
Cyprinidae	Nocomis micropogon	2007	Control	0
Cyprinidae	Nocomis micropogon	2008	Control	0
Cyprinidae	Nocomis raneyi	2006	AD1	0
Cyprinidae	Nocomis raneyi	2007	AD1	0
Cyprinidae	Nocomis raneyi	2008	AD1	80
Cyprinidae	Nocomis raneyi	2006	AD2	0
Cyprinidae	Nocomis raneyi	2007	AD2	0
Cyprinidae	Nocomis raneyi	2008	AD2	9
Cyprinidae	Nocomis raneyi	2006	AD3	0
Cyprinidae	Nocomis raneyi	2007	AD3	11
Cyprinidae	Nocomis raneyi	2008	AD3	6
Cyprinidae	Nocomis raneyi	2006	BD1	129
Cyprinidae	Nocomis raneyi	2007	BD1	57
Cyprinidae	Nocomis raneyi	2008	BD1	91
Cyprinidae	Nocomis raneyi	2006	BD2	13
Cyprinidae	Nocomis raneyi	2007	BD2	0
Cyprinidae	Nocomis raneyi	2008	BD2	0
Cyprinidae	Nocomis raneyi	2007	Control	13
Cyprinidae	Nocomis raneyi	2008	Control	15
Cyprinidae	Nocomis sp.	2006	AD1	0
Cyprinidae	Nocomis sp.	2007	AD1	0
Cyprinidae	Nocomis sp.	2008	AD1	0
Cyprinidae	Nocomis sp.	2006	AD2	0
Cyprinidae	Nocomis sp.	2007	AD2	0
Cyprinidae	Nocomis sp.	2008	AD2	6
Cyprinidae	Nocomis sp.	2006	AD3	0
Cyprinidae	Nocomis sp.	2007	AD3	0
Cyprinidae	Nocomis sp.	2008	AD3	0
Cyprinidae	Nocomis sp.	2006	BD1	1
Cyprinidae	Nocomis sp.	2007	BD1	0
Cyprinidae	Nocomis sp.	2008	BD1	0
Cyprinidae	Nocomis sp.	2006	BD2	0
Cyprinidae	Nocomis sp.	2007	BD2	21
Cyprinidae	Nocomis sp.	2008	BD2	0
Cyprinidae	Nocomis sp.	2007	Control	0
Cyprinidae	Nocomis sp.	2008	Control	0
Cyprinidae	Notemigonus chryosleucas	2006	AD1	0
Cyprinidae	Notemigonus chryosleucas	2007	AD1	0
Cyprinidae	Notemigonus chryosleucas	2008	AD1	0
Cyprinidae	Notemigonus chryosleucas	2006	AD2	0
Cyprinidae	Notemigonus chryosleucas	2007	AD2	0
Cyprinidae	Notemigonus chryosleucas	2008	AD2	0
Cyprinidae	Notemigonus chryosleucas	2006	AD3	0
Cyprinidae	Notemigonus chryosleucas	2007	AD3	0
Cyprinidae	Notemigonus chryosleucas	2008	AD3	0
Cyprinidae	Notemigonus chryosleucas	2006	BD1	2
Cyprinidae	Notemigonus chryosleucas	2007	BD1	0

Cyprinidae	Notemigonus chryosleucas	2008	BD1	0
Cyprinidae	Notemigonus chryosleucas	2006	BD2	0
Cyprinidae	Notemigonus chryosleucas	2007	BD2	0
Cyprinidae	Notemigonus chryosleucas	2008	BD2	0
Cyprinidae	Notemigonus chryosleucas	2007	Control	0
Cyprinidae	Notemigonus chryosleucas	2008	Control	0
Cyprinidae	Notropis amoenus	2006	AD1	0
Cyprinidae	Notropis amoenus	2007	AD1	0
Cyprinidae	Notropis amoenus	2008	AD1	8
Cyprinidae	Notropis amoenus	2006	AD2	0
Cyprinidae	Notropis amoenus	2007	AD2	0
Cyprinidae	Notropis amoenus	2008	AD2	6
Cyprinidae	Notropis amoenus	2006	AD3	0
Cyprinidae	Notropis amoenus	2007	AD3	4
Cyprinidae	Notropis amoenus	2008	AD3	3
Cyprinidae	Notropis amoenus	2006	BD1	14
Cyprinidae	Notropis amoenus	2007	BD1	10
Cyprinidae	Notropis amoenus	2008	BD1	0
Cyprinidae	Notropis amoenus	2006	BD2	1
Cyprinidae	Notropis amoenus	2007	BD2	2
Cyprinidae	Notropis amoenus	2008	BD2	3
Cyprinidae	Notropis amoenus	2007	Control	0
Cyprinidae	Notropis amoenus	2008	Control	0
Cyprinidae	Notropis hudsonius	2006	AD1	1
Cyprinidae	Notropis hudsonius	2007	AD1	0
Cyprinidae	Notropis hudsonius	2008	AD1	1
Cyprinidae	Notropis hudsonius	2006	AD2	0
Cyprinidae	Notropis hudsonius	2007	AD2	0
Cyprinidae	Notropis hudsonius	2008	AD2	6
Cyprinidae	Notropis hudsonius	2006	AD3	0
Cyprinidae	Notropis hudsonius	2007	AD3	2
Cyprinidae	Notropis hudsonius	2008	AD3	0
Cyprinidae	Notropis hudsonius	2006	BD1	39
Cyprinidae	Notropis hudsonius	2007	BD1	22
Cyprinidae	Notropis hudsonius	2008	BD1	38
Cyprinidae	Notropis hudsonius	2006	BD2	19
Cyprinidae	Notropis hudsonius	2007	BD2	2
Cyprinidae	Notropis hudsonius	2008	BD2	0
Cyprinidae	Notropis hudsonius	2007	Control	2
Cyprinidae	Notropis hudsonius	2008	Control	6
Cyprinidae	Notropis procne	2007	AD1	0
Cyprinidae	Notropis procne	2008	AD1	0
Cyprinidae	Notropis procne	2007	AD2	0
Cyprinidae	Notropis procne	2008	AD2	0
Cyprinidae	Notropis procne	2007	AD3	48
Cyprinidae	Notropis procne	2008	AD3	0
Cyprinidae	Notropis procne	2007	BD1	1
Cyprinidae	Notropis procne	2008	BD1	6

Cyprinidae	Notropis procne	2007	BD2	0
Cyprinidae	Notropis procne	2008	BD2	0
Cyprinidae	Notropis procne	2007	Control	4
Cyprinidae	Notropis procne	2008	Control	0
Cyprinidae	Notropis rubellus	2006	AD1	0
Cyprinidae	Notropis rubellus	2007	AD1	0
Cyprinidae	Notropis rubellus	2008	AD1	5
Cyprinidae	Notropis rubellus	2006	AD2	0
Cyprinidae	Notropis rubellus	2007	AD2	0
Cyprinidae	Notropis rubellus	2008	AD2	8
Cyprinidae	Notropis rubellus	2006	AD3	0
Cyprinidae	Notropis rubellus	2007	AD3	3
Cyprinidae	Notropis rubellus	2008	AD3	0
Cyprinidae	Notropis rubellus	2006	BD1	60
Cyprinidae	Notropis rubellus	2007	BD1	20
Cyprinidae	Notropis rubellus	2008	BD1	10
Cyprinidae	Notropis rubellus	2006	BD2	2
Cyprinidae	Notropis rubellus	2007	BD2	1
Cyprinidae	Notropis rubellus	2008	BD2	0
Cyprinidae	Notropis rubellus	2007	Control	0
Cyprinidae	Notropis rubellus	2008	Control	0
Cyprinidae	Notropis telescopis	2006	AD1	0
Cyprinidae	Notropis telescopis	2007	AD1	0
Cyprinidae	Notropis telescopis	2008	AD1	1
Cyprinidae	Notropis telescopis	2006	AD2	0
Cyprinidae	Notropis telescopis	2007	AD2	0
Cyprinidae	Notropis telescopis	2008	AD2	0
Cyprinidae	Notropis telescopis	2006	AD3	0
Cyprinidae	Notropis telescopis	2007	AD3	0
Cyprinidae	Notropis telescopis	2008	AD3	0
Cyprinidae	Notropis telescopis	2006	BD1	5
Cyprinidae	Notropis telescopis	2007	BD1	0
Cyprinidae	Notropis telescopis	2008	BD1	11
Cyprinidae	Notropis telescopis	2006	BD2	1
Cyprinidae	Notropis telescopis	2007	BD2	0
Cyprinidae	Notropis telescopis	2008	BD2	2
Cyprinidae	Notropis telescopis	2007	Control	0
Cyprinidae	Notropis telescopis	2008	Control	0
Cyprinidae	Pimephales notatus	2007	AD1	0
Cyprinidae	Pimephales notatus	2008	AD1	0
Cyprinidae	Pimephales notatus	2007	AD2	0
Cyprinidae	Pimephales notatus	2008	AD2	0
Cyprinidae	Pimephales notatus	2007	AD3	0
Cyprinidae	Pimephales notatus	2008	AD3	0
Cyprinidae	Pimephales notatus	2007	BD1	0
Cyprinidae	Pimephales notatus	2008	BD1	0
Cyprinidae	Pimephales notatus	2007	BD2	0
Cyprinidae	Pimephales notatus	2008	BD2	0

Cyprinidae	Pimephales notatus	2007	Control	2
Cyprinidae	Pimephales notatus	2008	Control	7
Cyprinidae	Rhinichthys atratulus	2007	AD1	0
Cyprinidae	Rhinichthys atratulus	2008	AD1	0
Cyprinidae	Rhinichthys atratulus	2007	AD2	0
Cyprinidae	Rhinichthys atratulus	2008	AD2	0
Cyprinidae	Rhinichthys atratulus	2007	AD3	0
Cyprinidae	Rhinichthys atratulus	2008	AD3	0
Cyprinidae	Rhinichthys atratulus	2007	BD1	0
Cyprinidae	Rhinichthys atratulus	2008	BD1	0
Cyprinidae	Rhinichthys atratulus	2007	BD2	0
Cyprinidae	Rhinichthys atratulus	2008	BD2	0
Cyprinidae	Rhinichthys atratulus	2007	Control	4
Cyprinidae	Rhinichthys atratulus	2008	Control	2
Cyprinidae	Rhinichthys cataractae	2007	Control	0
Cyprinidae	Rhinichthys cataractae	2006	AD1	0
Cyprinidae	Rhinichthys cataractae	2007	AD1	0
Cyprinidae	Rhinichthys cataractae	2008	AD1	2
Cyprinidae	Rhinichthys cataractae	2006	AD2	0
Cyprinidae	Rhinichthys cataractae	2007	AD2	0
Cyprinidae	Rhinichthys cataractae	2008	AD2	0
Cyprinidae	Rhinichthys cataractae	2006	AD3	0
Cyprinidae	Rhinichthys cataractae	2007	AD3	0
Cyprinidae	Rhinichthys cataractae	2008	AD3	0
Cyprinidae	Rhinichthys cataractae	2008	AD3	1
Cyprinidae	Rhinichthys cataractae	2006	BD1	0
Cyprinidae	Rhinichthys cataractae	2007	BD1	3
Cyprinidae	Rhinichthys cataractae	2008	BD1	0
Cyprinidae	Rhinichthys cataractae	2008	BD1	0
Cyprinidae	Rhinichthys cataractae	2006	BD2	1
Cyprinidae	Rhinichthys cataractae	2007	BD2	3
Cyprinidae	Rhinichthys cataractae	2008	BD2	0
Cyprinidae	Rhinichthys cataractae	2008	BD2	0
Cyprinidae	Rhinichthys cataractae	2008	Control	0
Cyprinidae	Rhinichthys cataractae	2008	Control	0
Cyprinidae	Semotilus corporalis	2006	AD1	0
Cyprinidae	Semotilus corporalis	2007	AD1	3
Cyprinidae	Semotilus corporalis	2008	AD1	0
Cyprinidae	Semotilus corporalis	2006	AD2	0
Cyprinidae	Semotilus corporalis	2007	AD2	0
Cyprinidae	Semotilus corporalis	2008	AD2	1
Cyprinidae	Semotilus corporalis	2006	AD3	0
Cyprinidae	Semotilus corporalis	2007	AD3	15
Cyprinidae	Semotilus corporalis	2008	AD3	0
Cyprinidae	Semotilus corporalis	2006	BD1	6
Cyprinidae	Semotilus corporalis	2007	BD1	0
Cyprinidae	Semotilus corporalis	2008	BD1	8
Cyprinidae	Semotilus corporalis	2006	BD2	0

Cyprinidae	Semotilus corporalis	2007	BD2	0
Cyprinidae	Semotilus corporalis	2008	BD2	0
Cyprinidae	Semotilus corporalis	2007	Control	22
Cyprinidae	Semotilus corporalis	2008	Control	5
Cyprinidae	Unidentified juvenile cyprinids	2006	AD1	0
Cyprinidae	Unidentified juvenile cyprinids	2007	AD1	0
Cyprinidae	Unidentified juvenile cyprinids	2008	AD1	1
Cyprinidae	Unidentified juvenile cyprinids	2006	AD2	0
Cyprinidae	Unidentified juvenile cyprinids	2007	AD2	0
Cyprinidae	Unidentified juvenile cyprinids	2008	AD2	1
Cyprinidae	Unidentified juvenile cyprinids	2006	AD3	2
Cyprinidae	Unidentified juvenile cyprinids	2007	AD3	24
Cyprinidae	Unidentified juvenile cyprinids	2008	AD3	12
Cyprinidae	Unidentified juvenile cyprinids	2006	BD1	7
Cyprinidae	Unidentified juvenile cyprinids	2007	BD1	49
Cyprinidae	Unidentified juvenile cyprinids	2008	BD1	34
Cyprinidae	Unidentified juvenile cyprinids	2006	BD2	36
Cyprinidae	Unidentified juvenile cyprinids	2007	BD2	3
Cyprinidae	Unidentified juvenile cyprinids	2008	BD2	1
Cyprinidae	Unidentified juvenile cyprinids	2007	Control	17
Cyprinidae	Unidentified juvenile cyprinids	2008	Control	8
Cyprinidae	Unidentified juvenile Nocomis	2006	AD1	0
Cyprinidae	Unidentified juvenile Nocomis	2007	AD1	0
Cyprinidae	Unidentified juvenile Nocomis	2008	AD1	2
Cyprinidae	Unidentified juvenile Nocomis	2006	AD2	0
Cyprinidae	Unidentified juvenile Nocomis	2007	AD2	0
Cyprinidae	Unidentified juvenile Nocomis	2008	AD2	10
Cyprinidae	Unidentified juvenile Nocomis	2006	AD3	0
Cyprinidae	Unidentified juvenile Nocomis	2007	AD3	57
Cyprinidae	Unidentified juvenile Nocomis	2008	AD3	17
Cyprinidae	Unidentified juvenile Nocomis	2006	BD1	0
Cyprinidae	Unidentified juvenile Nocomis	2007	BD1	17
Cyprinidae	Unidentified juvenile Nocomis	2008	BD1	77
Cyprinidae	Unidentified juvenile Nocomis	2006	BD2	10
Cyprinidae	Unidentified juvenile Nocomis	2007	BD2	0
Cyprinidae	Unidentified juvenile Nocomis	2008	BD2	13
Cyprinidae	Unidentified juvenile Nocomis	2007	Control	23
Cyprinidae	Unidentified juvenile Nocomis	2008	Control	10
Cyprinidae	Unidentified notropis	2008	AD3	1
Cyprinidae	Unidentified notropis	2008	BD1	0
Cyprinidae	Unidentified notropis	2008	BD2	0
Cyprinidae	Unidentified notropis	2008	Control	0
Ictaluridae	Ameirus natalis	2007	AD1	0
Ictaluridae	Ameirus natalis	2008	AD1	4
Ictaluridae	Ameirus natalis	2007	AD2	1
Ictaluridae	Ameirus natalis	2008	AD2	0
Ictaluridae	Ameirus natalis	2007	AD3	0
Ictaluridae	Ameirus natalis	2008	AD3	0

Ictaluridae	Ameirus natalis	2007	BD1	1
Ictaluridae	Ameirus natalis	2008	BD1	1
Ictaluridae	Ameirus natalis	2007	BD2	1
Ictaluridae	Ameirus natalis	2008	BD2	0
Ictaluridae	Ameirus natalis	2007	Control	0
Ictaluridae	Ameirus natalis	2008	Control	0
Ictaluridae	Ameirus nebulosis	2008	AD1	0
Ictaluridae	Ameirus nebulosis	2008	AD2	1
Ictaluridae	Ameirus nebulosis	2008	AD3	0
Ictaluridae	Ameirus nebulosis	2008	BD1	1
Ictaluridae	Ameirus nebulosis	2008	BD2	1
Ictaluridae	Ameirus nebulosis	2008	Control	0
Ictaluridae	Ictalurus punctatus	2007	AD1	0
Ictaluridae	Ictalurus punctatus	2008	AD1	0
Ictaluridae	Ictalurus punctatus	2007	AD2	0
Ictaluridae	Ictalurus punctatus	2008	AD2	0
Ictaluridae	Ictalurus punctatus	2007	AD3	0
Ictaluridae	Ictalurus punctatus	2008	AD3	0
Ictaluridae	Ictalurus punctatus	2007	BD1	1
Ictaluridae	Ictalurus punctatus	2008	BD1	0
Ictaluridae	Ictalurus punctatus	2007	BD2	0
Ictaluridae	Ictalurus punctatus	2008	BD2	0
Ictaluridae	Ictalurus punctatus	2007	Control	0
Ictaluridae	Ictalurus punctatus	2008	Control	0
Ictaluridae	Noturus insignis	2006	AD1	0
Ictaluridae	Noturus insignis	2007	AD1	0
Ictaluridae	Noturus insignis	2008	AD1	10
Ictaluridae	Noturus insignis	2006	AD2	0
Ictaluridae	Noturus insignis	2007	AD2	0
Ictaluridae	Noturus insignis	2008	AD2	0
Ictaluridae	Noturus insignis	2006	AD3	0
Ictaluridae	Noturus insignis	2007	AD3	5
Ictaluridae	Noturus insignis	2008	AD3	3
Ictaluridae	Noturus insignis	2006	BD1	32
Ictaluridae	Noturus insignis	2007	BD1	13
Ictaluridae	Noturus insignis	2008	BD1	5
Ictaluridae	Noturus insignis	2006	BD2	10
Ictaluridae	Noturus insignis	2007	BD2	6
Ictaluridae	Noturus insignis	2008	BD2	5
Ictaluridae	Noturus insignis	2007	Control	8
Ictaluridae	Noturus insignis	2008	Control	7
Lepisosteidae	Lepisosteus osseus	2007	Control	0
Lepisosteidae	Lepisosteus osseus	2007	AD1	0
Lepisosteidae	Lepisosteus osseus	2008	AD1	0
Lepisosteidae	Lepisosteus osseus	2007	AD2	0
Lepisosteidae	Lepisosteus osseus	2008	AD2	0
Lepisosteidae	Lepisosteus osseus	2007	AD3	0
Lepisosteidae	Lepisosteus osseus	2008	AD3	0

Lepisosteidae	**Lepisosteus osseus**	**2007**	**BD1**	**1**
Lepisosteidae	Lepisosteus osseus	2008	BD1	0
Lepisosteidae	Lepisosteus osseus	2007	BD2	0
Lepisosteidae	Lepisosteus osseus	2008	BD2	0
Lepisosteidae	Lepisosteus osseus	2008	Control	0
Percidae	Etheostoma flaballare	2006	AD1	0
Percidae	Etheostoma flaballare	2007	AD1	0
Percidae	Etheostoma flaballare	2008	AD1	3
Percidae	Etheostoma flaballare	2006	AD2	0
Percidae	Etheostoma flaballare	2007	AD2	0
Percidae	Etheostoma flaballare	2008	AD2	0
Percidae	Etheostoma flaballare	2006	AD3	2
Percidae	Etheostoma flaballare	2007	AD3	14
Percidae	Etheostoma flaballare	2008	AD3	5
Percidae	Etheostoma flaballare	2006	BD1	35
Percidae	Etheostoma flaballare	2007	BD1	24
Percidae	Etheostoma flaballare	2008	BD1	29
Percidae	Etheostoma flaballare	2006	BD2	22
Percidae	Etheostoma flaballare	2007	BD2	3
Percidae	Etheostoma flaballare	2008	BD2	5
Percidae	Etheostoma flaballare	2007	Control	5
Percidae	Etheostoma flaballare	2008	Control	2
Percidae	Etheostoma nigrum	2006	AD1	0
Percidae	Etheostoma nigrum	2007	AD1	0
Percidae	Etheostoma nigrum	2008	AD1	7
Percidae	Etheostoma nigrum	2006	AD2	0
Percidae	Etheostoma nigrum	2007	AD2	0
Percidae	Etheostoma nigrum	2008	AD2	1
Percidae	Etheostoma nigrum	2006	AD3	4
Percidae	Etheostoma nigrum	2007	AD3	6
Percidae	Etheostoma nigrum	2008	AD3	3
Percidae	Etheostoma nigrum	2006	BD1	6
Percidae	Etheostoma nigrum	2007	BD1	4
Percidae	Etheostoma nigrum	2008	BD1	13
Percidae	Etheostoma nigrum	2006	BD2	8
Percidae	Etheostoma nigrum	2007	BD2	5
Percidae	Etheostoma nigrum	2008	BD2	3
Percidae	Etheostoma nigrum	2007	Control	29
Percidae	Etheostoma nigrum	2008	Control	6
Percidae	Etheostoma sp.	2006	AD1	0
Percidae	Etheostoma sp.	2007	AD1	0
Percidae	Etheostoma sp.	2008	AD1	0
Percidae	Etheostoma sp.	2006	AD2	0
Percidae	Etheostoma sp.	2007	AD2	0
Percidae	Etheostoma sp.	2008	AD2	0
Percidae	Etheostoma sp.	2006	AD3	0
Percidae	Etheostoma sp.	2007	AD3	0
Percidae	Etheostoma sp.	2008	AD3	0

Percidae	Etheostoma sp.	2006	BD1	1
Percidae	Etheostoma sp.	2007	BD1	6
Percidae	Etheostoma sp.	2008	BD1	0
Percidae	Etheostoma sp.	2006	BD2	0
Percidae	Etheostoma sp.	2007	BD2	0
Percidae	Etheostoma sp.	2008	BD2	0
Percidae	Etheostoma sp.	2007	Control	1
Percidae	Etheostoma sp.	2008	Control	0
Percidae	Etheostoma vitreum	2007	AD1	0
Percidae	Etheostoma vitreum	2008	AD1	0
Percidae	Etheostoma vitreum	2007	AD2	0
Percidae	Etheostoma vitreum	2008	AD2	0
Percidae	Etheostoma vitreum	2007	AD3	0
Percidae	Etheostoma vitreum	2008	AD3	0
Percidae	Etheostoma vitreum	2007	BD1	0
Percidae	Etheostoma vitreum	2008	BD1	0
Percidae	Etheostoma vitreum	2007	BD2	0
Percidae	Etheostoma vitreum	2008	BD2	0
Percidae	Etheostoma vitreum	2007	Control	6
Percidae	Etheostoma vitreum	2008	Control	1
Percidae	Percina notogramma	2006	AD1	0
Percidae	Percina notogramma	2007	AD1	0
Percidae	Percina notogramma	2008	AD1	2
Percidae	Percina notogramma	2006	AD2	0
Percidae	Percina notogramma	2007	AD2	0
Percidae	Percina notogramma	2008	AD2	0
Percidae	Percina notogramma	2006	AD3	1
Percidae	Percina notogramma	2007	AD3	1
Percidae	Percina notogramma	2008	AD3	0
Percidae	Percina notogramma	2006	BD1	0
Percidae	Percina notogramma	2007	BD1	0
Percidae	Percina notogramma	2008	BD1	0
Percidae	Percina notogramma	2006	BD2	0
Percidae	Percina notogramma	2007	BD2	0
Percidae	Percina notogramma	2008	BD2	0
Percidae	Percina notogramma	2007	Control	0
Percidae	Percina notogramma	2008	Control	0
Percidae	Percina peltata	2007	AD1	0
Percidae	Percina peltata	2008	AD1	0
Percidae	Percina peltata	2007	AD2	0
Percidae	Percina peltata	2008	AD2	0
Percidae	Percina peltata	2007	AD3	2
Percidae	Percina peltata	2008	AD3	0
Percidae	Percina peltata	2007	BD1	1
Percidae	Percina peltata	2008	BD1	1
Percidae	Percina peltata	2007	BD2	0
Percidae	Percina peltata	2008	BD2	0
Percidae	Percina peltata	2007	Control	0

Percidae	Percina peltata	2008	Control	0
Percidae	Percina roanoka	2006	AD1	0
Percidae	Percina roanoka	2007	AD1	0
Percidae	Percina roanoka	2008	AD1	43
Percidae	Percina roanoka	2006	AD2	0
Percidae	Percina roanoka	2007	AD2	0
Percidae	Percina roanoka	2008	AD2	4
Percidae	Percina roanoka	2006	AD3	0
Percidae	Percina roanoka	2007	AD3	0
Percidae	Percina roanoka	2008	AD3	10
Percidae	Percina roanoka	2006	BD1	119
Percidae	Percina roanoka	2007	BD1	49
Percidae	Percina roanoka	2008	BD1	4
Percidae	Percina roanoka	2006	BD2	99
Percidae	Percina roanoka	2007	BD2	25
Percidae	Percina roanoka	2008	BD2	31
Percidae	Percina roanoka	2007	Control	0
Percidae	Percina roanoka	2008	Control	0
Percidae	Percina sp.	2007	AD1	0
Percidae	Percina sp.	2008	AD1	0
Percidae	Percina sp.	2007	AD2	0
Percidae	Percina sp.	2008	AD2	0
Percidae	Percina sp.	2007	AD3	0
Percidae	Percina sp.	2008	AD3	0
Percidae	Percina sp.	2007	BD1	1
Percidae	Percina sp.	2008	BD1	1
Percidae	Percina sp.	2007	BD2	0
Percidae	Percina sp.	2008	BD2	0
Percidae	Percina sp.	2007	Control	0
Percidae	Percina sp.	2008	Control	0
Percidae	Unidentified juvenile etheostoma	2007	AD1	0
Percidae	Unidentified juvenile etheostoma	2008	AD1	0
Percidae	Unidentified juvenile etheostoma	2007	AD2	0
Percidae	Unidentified juvenile etheostoma	2008	AD2	0
Percidae	Unidentified juvenile etheostoma	2007	AD3	3
Percidae	Unidentified juvenile etheostoma	2008	AD3	0
Percidae	Unidentified juvenile etheostoma	2007	BD1	6
Percidae	Unidentified juvenile etheostoma	2008	BD1	1
Percidae	Unidentified juvenile etheostoma	2007	BD2	1
Percidae	Unidentified juvenile etheostoma	2008	BD2	0
Percidae	Unidentified juvenile etheostoma	2007	Control	0
Percidae	Unidentified juvenile etheostoma	2008	Control	0
Petromyzontidae	Petromyzon marinus	2008	BD2	7
Petromyzontidae	Petromyzon marinus	2008	Control	0
Poeciliidae	Gambusia holbrooki	2006	AD1	0
Poeciliidae	Gambusia holbrooki	2007	AD1	0
Poeciliidae	Gambusia holbrooki	2008	AD1	0
Poeciliidae	Gambusia holbrooki	2006	AD2	0

Poeciliidae	Gambusia holbrooki	2007	AD2	0
Poeciliidae	Gambusia holbrooki	2008	AD2	0
Poeciliidae	Gambusia holbrooki	2006	AD3	2
Poeciliidae	Gambusia holbrooki	2007	AD3	0
Poeciliidae	Gambusia holbrooki	2008	AD3	0
Poeciliidae	Gambusia holbrooki	2006	BD1	0
Poeciliidae	Gambusia holbrooki	2007	BD1	0
Poeciliidae	Gambusia holbrooki	2008	BD1	0
Poeciliidae	Gambusia holbrooki	2006	BD2	0
Poeciliidae	Gambusia holbrooki	2007	BD2	0
Poeciliidae	Gambusia holbrooki	2008	BD2	0
Poeciliidae	Gambusia holbrooki	2007	Control	0
Poeciliidae	Gambusia holbrooki	2008	Control	0
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