RECOVERY OF THE FISH POPULATION OF A MUNICIPAL WASTEWATER DOMINATED, NORTH TEXAS CREEK AFTER A MAJOR CHLORINE DISTURBANCE

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This study evaluated the effects of a major chlorine disturbance on fish communities in Pecan Creek by the City of Denton's Pecan Creek Water Reclamation Plant. Fish communities in Pecan Creek were sampled using a depletion methodology during February, April, July, and November, 1999. February and April sampling events showed that the fish communities were severely impacted by the chlorine. Sampling during July and November showed fish communities recovered in Pecan Creek.

The first-twenty minutes of shocking and seining data were analyzed to mirror an equal effort methodology. This methodology was compared to the depletion methodology to see if the equal effort methodology could adequately monitor the recovery of Pecan Creek after the chlorine disturbance. It was determined that the equal effort methodology was capable of monitoring the recovery of Pecan Creek, but could not accurately represent the fisheries community as well as the depletion method.

These data using the twenty-minute study were compared to a previous study. Results of this study were similar to those found in a previous study, although fish communities were more severely impacted and took longer to recover.

ACKNOWLEDGMENTS

I would like to thank the following people for their contributions to this project: Jim Coulter and the City of Denton Water Reclamation Plant for funding this project and providing access to the study area; Ritchie Taylor for invaluable advice and help in the field; University of North Texas graduate students for volunteering their time in the field; professors Jim Kennedy and Tom Waller for their input and support; Ryan Lee for his motivation and strategy sessions; and most importantly, my major professor, Dr. Ken Dickson for his guidance and patience.

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CHAPTER 1

INTRODUCTION

Water Quality Legislation

Historically, protecting water quality was not a major concern of the federal government, and was largely defined by three acts: the Rivers and Harbors Act of 1899, the Public Health Service Act of 1912, and the Oil Pollution Act of 1924. These acts were not widely enforced and had very little impact on water quality. As the U.S. population increased and development expanded, so did the degradation to our nations waters. In response, Congress passed the Federal Water Pollution Control Act (FWPCA) of 1972, which mandated major changes in the way water quality would be controlled in the United States. Three subsequent amendments to the FWPCA, the Clean Water Act of 1977 (CWA), the Water Quality Act of 1987 (WQA), and the Oil Pollution Act of 1990 have resulted in a complex and comprehensive system of water pollution control. The objective of this legislation is clearly stated: "The objective of this Act is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters", with specific reference to providing for "the protection and propagation of fish, shellfish, and wildlife, and… recreation in and on the water." Essentially, all of the Nation's waters are to be fit for fishing and swimming.(Kubasek and Silverman, 1997)

Biological Criteria and Biological Assessments

With the passage of water quality legislation, gross contamination of surface waters in our Nation has virtually been eliminated. This has been the result of developing strict, chemically based standards for point-sources of pollution. Although effective in improving a major portion or our degraded surface waters, about forty percent of our nations surface waters are still not clean enough to support uses such as fishing and swimming (USEPA, 2000). One possible reason that we have not succeeded in cleaning these waters is that chemically based standards have their limitations. One limitation is that they only reflect the conditions of the water body at the time of sampling. Perturbations that occur during non-sampling times will be unobserved. Another limitation of chemical standards is that they only detect what one is looking for and at levels that can be detected. While this is valuable for investigating point sources where one has a good idea of what to sample for, for non-point sources where the causes of degradation are unknown, other stressors or low levels of toxic substances that can cause degradation to our aquatic environment will not, or can not be detected. Because of these limitations, the EPA has begun to require whole-effluent toxicity (WET) testing. Rather then attempting to identify all toxic pollutants, determine the effects of each pollutant individually, and then attempt to assess their aggregated effect, the toxicity of the effluent to biological organisms becomes a regulated parameter. Thus, WET testing can be a useful tool in examining the biological effects of a complex mixture found in discharges (Federal Register, 1995). Although useful in helping to identify and reduce toxic discharges, it is difficult to relate or extrapolate both chemical standards and WET limitations to the biological and ecological communities found in aquatic environments. To fully understand the impact of anthropogenic activities on aquatic environments, biological sampling is a necessary addition to chemical sampling.

To address the limitations of chemically based standards, the EPA is developing a more comprehensive program that incorporates the adoption of biological criteria as part of state water quality standards. Biological criteria, or biocriteria, are defined as numerical values or narrative expressions that describe the preferred biological condition of aquatic communities based on designated reference sites. This program basically consists of assessing the biological condition of the water body in question through biological sampling and comparing its condition with that of a minimally disturbed reference site. Biological assessments and criteria address the cumulative impacts of all stressors, especially habitat degradation and point and non-point sources of pollution, and help provide an ecologically based assessment of the status of a water body (U.S. EPA 1997).

Although current legislation has virtually eliminated gross contamination of our water bodies, many problems still exist and accidental releases causing major disturbances to aquatic systems do occur. Biological assessments and criteria can be used to monitor the recovery of the disturbed system. Monitoring recovery is important for several reasons. First, it allows one to more fully understand the impacts that the disturbance has on the system. Secondly, it allows the offending party to optimize the necessary resources to help remediate and/or mitigate the disturbance. Thirdly, it may help appease enforcement agencies by showing them that the biological communities have indeed returned to utilize the impacted area. Lastly, it can help regulatory authorities set limits on the frequency and severity that water quality criteria can be exceeded for a particular area (Dietenbeck et al., 1992).

CHAPTER 2

PROJECT SIGNIFICANCE AND BACKGROUND

Chlorine Disturbance

The City of Denton's Pecan Creek Water Reclamation Plant (PCWRP) discharges between 9 and 15 million gallons of secondarily treated, municipal wastewater into Pecan Creek each day. This water flows approximately 6,000 meters before it enters Lake Lewisville, a popular recreational reservoir. The City of Denton, in addition to their chemical monitoring, would like to establish a bio-monitoring program for Pecan Creek (Jim Coulter, personal communication). This information as well as information from a previous study (Wise, 1995) would be used to help the City develop appropriate management strategies for protecting the physical, chemical and biological integrity of the creek as mandated by federal legislation and to predict and manage the impacts of any future disturbances.

Unfortunately, on December 14, 1998, a maintenance malfunction caused an unknown amount of raw sewage to enter Pecan Creek at the PCWRP. For about eight and a half hours raw sewage was discharged to the creek. To protect the public health, chlorine was added to the creek during the discharge as a disinfectant with levels reaching 500 ppm as measured by city employees monitoring the discharge (Bill McCoullah, City of Denton Pretreatment Coordinator, personal communication). The addition of chlorine had the effect of "sterilizing" the stream. In the weeks immediately following the disturbance, casual observations by this and other researchers indicated that there were few if any fish present in Pecan Creek from below the discharge point to site

PC 5. Further casual observations of the substrate also indicated that few, if any aquatic insects were present in the stream.

Due to this disturbance, the project was modified to include monitoring the recovery of the fish population of Pecan Creek. This information could then be utilized by the City to plan for and mitigate any future disturbances.

Purpose of Study

The purpose of this study was to begin to provide information for the City of Denton to protect "the physical, chemical, and biological integrity" of Pecan Creek, and to provide for "the protection and propagation of fish, shellfish, and wildlife, and…recreation in and on the water."

Objectives

The objectives of this project were four-fold:

1. To monitor the recovery of Pecan Creek for one year after the disturbance,
2. to quantify the fish populations of Pecan Creek so as to have base-line data for future biomonitoring activities,
3. to apply a North Texas based Index of Biotic Integrity (Linam et al., 1999, Karr, 1981) to Pecan Creek, and…
4. to asses the fish community of Pecan Creek five years after implementation of de-chlorination.

The methods to achieve these goals were sampling of the fish community using depletion and unit effort methodologies, monitoring the physio-chemical components of the creek, evaluating the habitat found in Pecan Creek, comparing the community to past studies, and comparing Pecan Creek to a minimally impacted reference creek.

Hypotheses

After the objectives were determined, it was hypothesized that:

1. H_o: There will be no differences in the fish community between sites in Pecan Creek.

1. H_a: There will be differences in the fish community between sites in Pecan Creek.

2. H_o: There will be no differences in the fish community between Pecan Creek and a reference creek.

2. H_a: There will be differences in the fish community between Pecan Creek and a reference creek.

3. H_o: There will be no differences in the Index of Biotic Integrity between Pecan Creek and a reference creek.

3. H_a: There will be differences in the Index of Biotic Integrity between Pecan Creek and a reference creek.

4. H_o: There will be no differences in the fish community in Pecan Creek between one year after de-chlorination and five years after de-chlorination.

4. H_a: There will be differences in the fish community in Pecan Creek between one year after de-chlorination and five years after de-chlorination.

Scope of Study

Six sampling sites were chosen on Pecan Creek (Figure 2.1). These were labeled PC1 through PC6. The first five sites are the same as those sampled by Wise (1995) during her de-chlorination study. These five sites were chosen for this study for two reasons: 1) the sites have similar habitats consisting of a combination of pools and riffles; and 2) to make it easier to compare this study with the previous Wise (1995) study. PC1 is 340 meters and PC2 is 569 meters above the PCWRP outfall, with sites PC3, PC4, and

PC5, being 1719 meters, 1857 meters, and 2652 meters respectively, downstream of the outfall. A sixth site (PC6) was chosen in Pecan Creek in a slough area as Pecan Creek enters Lake Lewisville. This site represents the connection or transition from the stream habitat to the lake habitat and is 5550 meters downstream of the outfall. A seventh site was chosen on Wilson Creek and labeled WC7 (Figure 2.2). Wilson creek is considered a minimally impacted reference creek and was used to compare the fish communities of the impacted Pecan Creek to its own fish communities (reference). Wise (1995) also analyzed samples from Wilson Creek. Sampling occurred quarterly beginning February of 1999 and ending November of 1999.

Figure 2.1 Sampling Sites on Pecan Creek, Denton County, Texas.

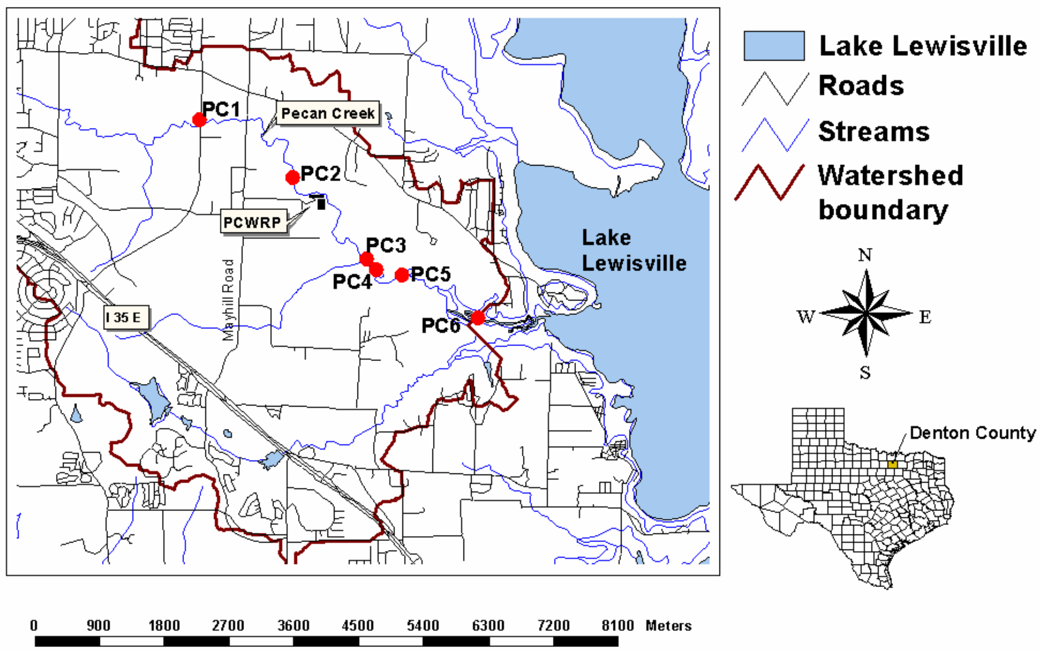
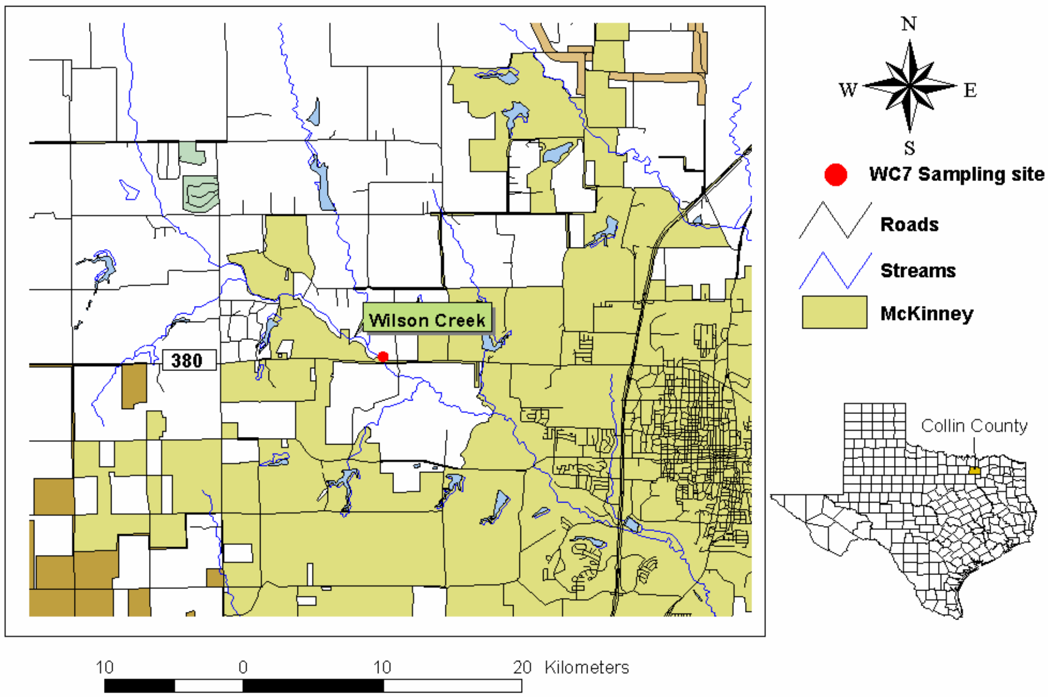


Figure 2.2 Sampling Site on Wilson Creek, Colin County, Texas.



CHAPTER 3

MATERIALS AND METHODS

Chemical, Physical, and Habitat Assessment

Temperature, dissolved oxygen, pH, and specific conductance were measured at each site at the time of sampling with a Hydrolab® multimeter. The operator's manual was followed for calibration and proper usage. Total residual and free chlorine was measured in the field at each site using a Hach® Digital Tritrator applying the DPD-FEAS method (Hach Company, 1998). For the chlorine analysis, three replicate samples were taken and averaged. Combined chlorine was calculated by subtracting the total residual from the free chlorine.

Flow was measured at selected sites using the cross sectional measurement technique (Gallagher and Stevenson, 1999). Discharge data from the Pecan Creek Water Reclamation Plant was also examined, and the discharge from the City of Denton Electric Utility plant was estimated as one fifth of their cooling water intake.

Habitat assessments for low gradient streams were evaluated at each site utilizing methods in Revision to Rapid Bioassessment Protocols for Use in Streams and Rivers: Periphyton, Benthic Macroinvertebrates, and Fish (USEPA, 1997).

Fish Collections

Fish were collected at each site by using a depletion and unit effort methodology. At all sites, one hundred meters of stream was blocked off using 0.25 inch mesh seines. At least two, usually three, and occasionally four passes moving upstream were performed with a Smith-Root Model 12b battery powered electro-shocker. Each pass consisted of shocking for approximately the same duration (usually 20 minutes) and six good seine hauls (approximately 15 meters of shoreline) above the upstream block net. Seine hauls that snagged or where the researchers stumbled were not counted. This methodology provided comparable sampling to the Wise (1995) study, but yet allowed us to quantify the fish community of Pecan Creek. After each pass, fish were identified (Pflieger, 1991; Hubbs et al., 1991; Robison and Buchanan, 1988; Eddy and Underhill, 1978), weighed, measured, and released downstream of the downstream block seine. Fish that could not be identified in the field were preserved in 15% formaldehyde and identified, weighed, and measured in the lab. After two weeks, preserved specimens were soaked in water for twenty-four hours, and transferred to 80% ethyl alcohol for final preservation. Voucher specimens were stored at the University of North Texas Limnology Laboratory.

Data Analysis

The data analysis was divided into three distinct phases. In phase I, data were analyzed using multiple analytical tools so that the fish community recovery could be examined. In phase II, data from the first twenty-minutes of shocking and six seine hauls were analyzed and compared to the phase I analysis. This was an attempt to mirror the sampling procedures used by Wise (1995) who sampled each site by using a 20 minute equal effort shocking protocol and six seine hauls. After comparing the sampling methodologies in phase II, the data were then compared to the Wise (1995) study in phase III.

The total abundance, percent abundance, and total species richness at each site and each sampling date was evaluated, and is represented by tables and appropriate graphics.

Community similarities were measured using the Percent Similarity (PS) index discussed by Bray and Curtis (1957). A value of 0.5000 or greater was chosen to identify sites with similar fish community structures.

Diversity and evenness, as measured by the Brillouin index (log base 2), was calculated with the Multivariate Statistics Package, M.V.S.P. (Kovach, 1986).

Karr's (1981) Index of Biotic Integrity, modified for north Texas by the Texas Parks and Wildlife (Linam et al, 1999), was calculated for each site and Pecan Creek as a whole, as well as Wilson Creek. The IBI attempts to incorporate the zoogeographic, ecosystem, community, and population aspects of the fish community into a single, ecologically based index.

The total fish populations in Pecan and Wilson Creeks were estimated using the MICROFISH 3.0 (Van Deventer and Platts, 1985) computer program. This program calculates maximum-likelihood population estimates based on data collected using a depletion method.

CHAPTER 4

RESULTS AND DISCUSSION – PHASE I

Phase I was designed to meet objectives one, two, and three of this study. The recovery of Pecan Creek was monitored, the fish populations were quantified, and a North Texas Index of Biotic Integrity was applied to Pecan Creek.

Chemical, Physical, and Habitat Assessment

Table 4.1 shows a summary of the water quality data taken during the study. Dissolved oxygen (DO) ranged from a high of 9.85mg/L to a low of 4.14mg/L. pH values ranged from a high of 7.74 to a low of 6.77. Conductivity ranged from a 1405 µs/cm to 296. Temperatures recorded ranged from a high of 28.29 C to a low of 12.09 C. At no point in the study did the above water quality measurements reach a level that could not sustain a fisheries community in Pecan or Wilson Creek.

Table 4.1 also shows the results from the free, total, and combined chlorine analysis. Traces of chlorine were found at most sites throughout the study. Free chlorine ranged from zero to 0.092 mg/L, and total residual chlorine ranged from zero to 0.13 mg/L, with most measurements being below 0.05 mg/L. It is well documented that chlorine has been found to negatively affect fish communities (Bellanca et al, 1977, Brungs, 1973 and Karr et al., 1985,). Arthur and Eaton (1971) found that as little as 0.001 mg/l chlorine killed amphipods and fathead minnows in three to five days, and Tsai (1973) found that 0.10 mg/L of chorine caused the fish species diversity index of small streams in Maryland, northern Virginia, and southeastern Pennsylvania to be reduced by 50%. It has also been shown by Bellanca et al. (1977), Paller et al. (1988), and Wise (1995) that fish communities improved upon the removal or reduction of chlorine in aquatic systems. The USEPA has adopted 0.019 mg/L total residual chlorine as the maximum one hour concentration and 0.011 mg/L as a maximum four day average concentraion as a criterion for protection of aquatic life (Szal et al. 1991). Clearly, the levels of chlorine found in this study could chronically, if not acutely, affect the fisheries community. Further investigation revealed that chlorine detected could be due to the methodology used to measure the chlorine. The amperometric titration method is considered to be a more accurate method then the DPD-FEAS method. Brungs (1973) stated that the DPD method is subject to gross interference from oxidizing agents, turbidity, and color. This was observed in the field when it was noticed that if the sediments were stirred up before the analysis, large chlorine values would be measured. Turbidity from sediment and organic substances in water could be a source of interference for some or all of the chlorine as measured by the DPD-FEAS methodology.

Table 4.2 shows discharges in million gallon days (mgd) for Wilson Creek, the Pecan Creek Water Reclamation Plant, City of Denton electric power plant, a background station upstream of the treatment plant, but downstream of site PC2, and other selected sites on Pecan Creek. Flows below the treatment plant are 90-99% treated effluent and typically vary from nine to fifteen mgd. Flows upstream of the treatment plant are from urban sources and the city of Denton power plant. At the background station, flows can range from zero to flooding levels during storm events, but typically range from 0.1 mgd to 1.0 mgd. Above site PC1 the city of Denton power plant discharged between 0.5 mgd and 0.6 mgd of cooling tower water into the creek. This practice was stopped on September 1, 1999. Flows at Wilson Creek showed wide variation typical of north Texas streams. The highest flow measured was about 9.5 mgd in February of 1999 and decreased throughout the hot dry summer to zero flow in November. A measurement taken in September, 1998, also had very low flow of 1.7 mgd, indicating that late summer and early fall may be periods of low flow for Wilson Creek.

Figure 4.1 shows the calculated habitat scores for Pecan and Wilson Creeks. Sites PC3 and PC5 scored the highest of all the sites studied (160.5 and 151 respectively). These sites were generally characterized by a combination of riffles, pools, snags and some undercut banks indicating a high quality aquatic habitat. A lack of epifaunal substrate cover, and pools with a hard clay substrate prevented the scores from being higher. Sites PC1 (score=119), PC6 (score=126.5), and WC7 (score=122) had relatively intermediate scores, but were different in habitat structure. Site PC1 was characterized by a long wide pool ending in a short riffle. Major factors that lowered the score were that epifaunal substrate was lacking, pool substrate was mostly sediment, and the stream was somewhat channelized (channel sinuosity) due to this site being just below a highway overpass and closest to the city. Although lacking in epifaunal substrate, this site did have undercut banks (undercutting a meter or more in several places) which provided abundant habitat for the sunfishes and bullheads. If more weight is given to this type of cover the overall score may be five to ten points higher. Site PC6 scored higher then expected. This site is characterized by a long straight run of deep pools with a sand and sediment bottom. This site lacked epifaunal substrate and undercut banks, pool substrate was mostly a soft and sandy sediment as was most of site, and the banks were relatively unstable. The site scored higher in the areas of channel structure where the stream is evaluated broader then the actual location of the site. Although site PC6 was scored; under "normal" lake conditions (lake at conservation pool) this site would be approximately five meters under water and would undoubtedly have a different habitat structure then the one sampled. Reference site WC7 scored lower then expected. This was also due to a lack of epifaunal substrate, and sediment deposition throughout the reach. The reason for the low score could be due the fact that the site was immediately upstream of a highway overpass that had been expanded to four lanes three years previously and seemed to be somewhat channelized. Further upstream of the site, Wilson Creek was characterized by a variety of riffles, runs, and pools indicating that Wilson Creek may possibly have a higher aquatic habitat value. Sites scoring the lowest were PC2, with a score of 107 and PC4 with a score of 108.5. The low score for PC 2 was surprising since it resembled site PC1. Cattle were present on the banks and in the stream channel at site PC2. Cattle activity reduced the vegetative protection, increased bank instability, and increased sediment deposition. This site also had very little epifaunal substrate, but did have considerably undercut banks that provided habitat for sunfishes and bullheads. Although present, cattle may not have impacted the habitat of the stream as the score indicates. PC4 obviously had the worst habitat of all the sites. This site is characterized by a narrow, deep, and fast run, with a hard clear substrate, and there was very little undercutting of the banks, which significantly reduced the available habitat. The score was higher then expected by the fact that there was a wide riparian zone, extensive vegetative protection, and no sediment deposition. The habitat analysis should have been modified beforehand to better represent the conditions found in Pecan Creek and to increase its sensitivity.

Presence/Absence and Species Richness

Table 4.3 summarizes the fish species captured throughout the study. Twenty-five species of fish were captured, including one hybrid bluegill sunfish, and one unidentified juvenile sunfish. Twenty-three species were found in Pecan Creek, while only 15 were found in Wilson Creek. Pecan and Wilson Creek had thirteen out of twenty-five fish species in common. Blackstripe topminnow and central stoneroller were the only two fish species found in Wilson Creek that were not also found in Pecan Creek. Although it appears that Pecan Creek is more species rich than Wilson Creek, this is more likely due to that fact that we sampled at six sites with varying habitats on Pecan Creek and only one site on Wilson Creek. The opportunity to collect more species was greater in Pecan Creek.

Figure 4.2 shows the species richness at each site. It can be seen that sites PC3, PC4, and PC6 were the only sites that ever had fewer then six species, and this was immediately after the disturbance. The recovery of species richness in Pecan Creek can be seen in Figure 4.2 with values generally increasing at sites PC3, PC4, and PC6 in the months following their exposure to chlorine. Species richness at site PC3 during the July and November sampling events even surpassed those at background sites and the reference site. WC7 maintained relatively high and consistent species richness throughout the study compared to other sites. This trend is not seen at site PC5 where species richness remained relatively constant. It is possible that PC5 was far enough downstream that all the species present before the disturbance were able to maintain at least some surviving members. Although if this were true, it would not explain the relative recovery trend of PC6 which is even further downstream from PC5, except that it is felt that other factors besides the chlorine disturbance are actually influencing site PC6. Site PC6 is sufficiently downstream of the outfall that it was probably not as influenced by the chlorine as other sites. 1999 was a dry year in North Texas and lake levels were much lower then in previous years. More then likely, the fish community at site PC6 was influenced more by lower lake levels then by the chlorine disturbance.

Total Abundance

Figure 4.3 shows the total abundance of fish captured at each site during each sampling date. Red shiner accounts for 167 fish captured at PC1 during November and 606 fish captured at PC2 during April. Even if these "outliers" were excluded, it can be seen that the background sites, PC1 and PC2, had higher total abundance's for all sampling dates than any of the downstream sites. The figure also shows that for sites PC3, PC4, and PC5, total abundance increased considerably during the July and November sampling events over the February and April sampling events. The increase in total abundance at these sites indicates that the fish communities in Pecan Creek were recovering. Site WC7 had comparatively lower total abundance's then sites PC1 and PC2 although they remained fairly consistent throughout the study. It should be emphasized that sites PC3, PC4, and PC5 had very low numbers of fish captured during the February and April sampling events. This should be considered when interpreting the results from all the analysis. Site PC6 did not follow the same trend that the other downstream sites and as discussed above is probably being influenced by factors other than the chlorine disturbance.

Percent Abundance

Figure 4.4 shows the percent abundance of fish captured during the February sampling event. All the sites have several abundant species, but no species accounted for more than fifty percent of the population except at site PC6. Seventy-two percent of the fish captured at site PC6 were western mosquitofish, although only western mosquitofish and red shiner were the only two species actually captured.

The percent abundance of fish captured during the April sampling event is represented in Figure 4.5. Four sites had one species that accounted for more than fifty percent of the population (PC1, green sunfish = 58%; PC2, red shiner = 79%; PC4, bluegill = 67%; PC6, red shiner = 50%), although site PC4 only had two species and a total of three fish captured. Sites PC3, PC5, and WC7 did not have any one species that was more then fifty percent abundant. At site PC2, 606 out of 769 fish captured were red shiner. This could be considered a sampling anomaly.

During the July sampling event, four sites had a single species that accounted for more than fifty percent of the population (PC1, yellow bullhead = 54%; PC3 yellow bullhead = 79%; PC4, yellow bullhead = 81%; PC6, bluegill sunfish = 50%), while sites PC2, PC5 and WC7 did not have any one dominant species (Figure 4.6). Although yellow bullhead was dominate at sites PC1, PC3, and PC4, most of these were juveniles, which is actually a positive indication of a successful spawn in Pecan Creek.

None of the sites during the November sampling event (Figure 4.7) had any species that was more then fifty percent abundant, although red shiners were forty-eight and forty-six percent abundant at sites PC1 and PC2, respectively, and sites PC4 and PC5 had longear sunfish at forty-three and forty-seven percent abundant, respectively. The lack of a dominant species could be considered a sign that the fish community is beginning to stabilize and recover, although in this case, without more data, it is unclear whether this is true or if it is just a coincidence.

Of sites that were greater then fifty-eight percent abundant, dominance can be explained by either low species richness, low total abundance, a sampling anomaly, or by the presence of large number of juveniles. One would expect a "healthy" ecosystem to have a community without a dominant species. Although the November sampling event did not have any species greater then fifty-percent dominant, no clear pattern of recovery can be seen using the percent abundance data.

Evenness

Figure 4.8 shows the Brillouin Evenness Index values for the study. Sites PC2 during April and PC3 and PC4 during July had unusually low evenness values compared to the rest of samples. The low evenness values at these sites can be attributed to the extreme dominance of one species at each site. Site PC2 during April was seventy-nine percent red shiner, and sites PC3 and PC4 during July were seventy-nine and eighty-one percent respectively yellow bullhead (mostly juveniles). This figure shows that evenness was reasonably comparable for all the sites during most of the study and no real trend can be deduced from these values. This would indicate that in this study, evenness would not be a useful tool in monitoring the recovery of Pecan Creek. Although, one could conclude that all the fish were equally affected by the impact and seemed to recover "evenly". In other words, no one particular fish recovered quicker than any other did.

Diversity

Figure 4.9 shows the diversity values calculated for Pecan and Wilson Creeks. The low diversity values at site PC2 during April and sites PC3 and PC4 during July can be explained, like the evenness values above, by the extreme dominance of one particular species. The low diversity values at site PC4 during the February and April sampling events can be explained by both low total abundance and low species richness. The low diversity at PC6 during February can be attributed to low species richness. The diversity values show the recovery of Pecan Creek with the impacted sites tending to have the lowest diversity after the impact and increasing over the sampling period. By November, all the impacted sites had rebounded, and the diversity values were comparable to the background sites and reference site WC7. Site PC5 had a relatively consistent diversity over the course of the study, this is another indication that possibly site PC5 was far enough downstream that the impacts were less severe. Although diversity did show the recovery trend, it was not as clear cut as that seen using species richness and total abundance.

Percent Similarity

The Bray-Curtis similarity index was used to compare the fish community structure in Pecan and Wilson Creek for the February sampling and is represented by the dendrogram in Figure 4.10. At the 0.5000 and above level of similarity two distinct clusters can be seen. The two upstream sites PC1 and PC2 are clustered together (similarity value = 0.83442) and two downstream sites PC3 and PC5 are clustered together (similarity value = 0.5000). This indicates that the sites within each cluster may have similar fish community structures. Sites PC4, PC6, and WC7 fall below the 0.5 level of similarity, which indicates that each of their fish community structures are different from each of the other sites.

The fish community similarities for the April sampling are shown in Figure 4.11. None of sites were clustered at the 0.5000 or above level of similarity, which indicates that the fish communities at all the sites were different from each other. Knowing that site PC2 had an unusually large number of red shiner (606), the similarity calculations were re-calculated using 150 red shiner to take into account this anomaly. This re-calculation resulted in a clustering of sites PC1 and PC2 at the 0.54018 level of similarity.

During the July sampling event, sites PC1 and PC3 are clustered at the 0.68217 level of similarity and sites PC1 and PC2 are clustered at the 0.56447 level of similarity (Figure 4.12). This indicates that sites PC1, PC2, and PC3 have similar fish communities and that the fish communities are beginning to show signs of recovery. Sites PC4, PC5, PC6, and WC7 do not cluster at the 0.5000 level and above and are considered to have dissimilar fish communities. The reason for PC3 clustering with sites PC1 and PC2 could be that fish from sites PC1 and PC2 moved downstream to take advantage of the open niches left by the disturbance.

Three distinct clusters are evident during the November sampling event. Sites PC1 and PC2 are clustered at the 0.61620 level of similarity, PC3, PC4, and PC5 are clustered at the 0.64865 level of similarity, and site WC7 is clustered by itself (Figure 4.13). This is more clustering then at any other sampling event. It can be seen from Figure 4.13 that the two upstream sites are similar to each other, but dissimilar from the downstream sites and site WC7, while the downstream sites are similar to each other but dissimilar from the upstream sites and site WC7. Similarity of the downstream sites indicates that recovery is continuing. A possible reason for sites PC3, PC4 and PC5 clustering together is that fish probably moved up from the lake and re-colonized Pecan Creek. A concrete spillway upstream from PC3 and downstream of the treatment plant outfall, may be acting as a barrier to fish movement and preventing fish from the lake from colonizing sites PC1 and PC2. Another explanation for this could be that although sites PC1 and PC2 are upstream of the outfall, they are not without stress. Fish communities at these sites are under stresses from low flows and urban runoff. It is possible that the fish communities here have reached a "climax" state. Downstream sites on the other hand receive a relatively high and constant flow of treated effluent that dilutes the urban stressors coming from upstream. These downstream communities could possibly surpassing the upstream sites in terms of their community health. As during the previous sampling dates, site WC7 is dissimilar from all the other sites.

Index of Biotic Integrity

The index of biotic integrity, modified for the North Texas region was calculated at each site for each sampling date and is presented in Figure 4.14. Scores for the disturbed sites, PC3 through PC6, during the February and April sampling events should be considered questionable, as very few fish were captured during these events. Site WC7 had the highest single score of forty-two giving it a high aquatic life use (ALU) rating during the April sampling. All other dates scored thirty-five (intermediate ALU) or less (limited ALU). Site PC2 had three sampling events achieve an intermediate ALU with the July sampling event scoring only a twenty-nine (limited ALU). Site PC3 had two sampling events achieve an intermediate ALU and two events achieve a limited

ALU. PC1 had one event score an intermediate ALU with the other events scoring a limited ALU. No sampling event scored higher then a limited ALU at sites PC4, PC5, and PC6. By examining all the sampling events, it appears that sites PC2 and WC7 had the highest scores, site PC6 had the lowest scores, and sites PC1, PC3, PC4, and PC5 had scores in between.

It can be seen from the figure that the IBI scores tended to decrease from February to July and then increase in November. This pattern occurred at all the sites except PC1, where the November sampling event yielded the lowest score (thirty), but was only one unit less then the July score (thirty-one), and WC7 where April had the highest score (forty-two) and November had the lowest score (twenty-five). The low score for November may be accounted for by its lack of flow or because the site was only qualitatively sampled or possibly by both factors. Although IBI scores tended to decrease from February to July, the figure shows that the background sites, especially PC2, tended to score higher then disturbed sites until November when the disturbed sites scored higher then the background and reference sites. This could be an indication that Pecan Creek is recovering.

Data from all sampling events were combined at each site to give an overall IBI score for each site, and is also represented in Figure 4.2 as “All Months.” Overall, PC2 had the highest score with forty-five. This score gave PC2 a high ALU rating. Sites PC3, PC5, and WC7 each had combined scores of thirty-five, which barely gives these sites an intermediate ALU rating. PC1, PC4, and PC6 yield a limited aquatic life use rating with scores of thirty-three, thirty-three, and thirty-one respectively.

Overall, the IBI analysis did not represent the fish community as clearly as species richness and total abundance, and was not as useful in showing the recovery of Pecan Creek. It can be seen in Figure 4.14 that the IBI scores for the disturbed sites, PC3, PC4, and PC5 during the February and April sampling events were relatively high compared to the July and November sampling events. This indicates that the IBI has limited application when the species richness and total abundance are low. The IBI may be more useful in distinguishing between high and moderate quality sites than for analyzing poor quality sites like those found in this study.

Population Estimates

Total fish population estimates, excluding minnows, are presented in Figure 4.15. Minnows were excluded for two reasons, one, their small size makes it difficult to quantitatively shock, and two, their schooling nature means that they are not theoretically randomly distributed throughout the reach, this violates two of the assumptions behind the removal method. The fish not included in the population estimates are as follows: red shiner, western mosquitofish, pugnose minnow, golden shiner, bullhead minnow, blackstripe topminnow, stoneroller, bluntnose minnow, threadfin shad, and inland silverside. Of these, only the red shiner and western mosquitofish were found in significantly large numbers.

Background sites PC1 and PC2, as well as reference site WC7, had larger total fish population estimates during the February sampling event then sites downstream of the treatment plant (Figure 4.15). Sites PC4 and PC6 had so few fish (one and zero, respectively) that population estimates could not be generated, so total catch was plotted instead. The total fish population at site PC5 was estimated to be forty fish, but because of a non-descending removal pattern this estimate cannot be considered reliable. A total catch of eight fish at site PC5 is probably a closer approximation of the true population at this site.

This same trend continued during the April sampling with the total fish population estimates at sites PC3, PC4, PC5, and PC6 increasing slightly from the February sampling. During the July sampling, the total fish population estimate for site PC3 surpassed both background sites and the reference site. The population estimates for sites PC4, PC5, and PC6 increased from the April sampling and surpassed the population estimate for the reference site WC7, but were still lower then the background sites PC1 and PC2. Reference site WC7 had the lowest total fish population estimate of all the sites during the July sampling. This reduction in total fish population estimates at site WC7 can most likely be contributed to the previous dry months, which caused the flow to be significantly reduced in the creek.

The recovery trend in Pecan Creek is well pronounced in the November sampling. Sites PC3, PC4, and PC5 had higher total fish population estimates than during the previous sampling events. These sites also had higher total fish population estimates then background site PC2, and PC5 had an even higher total fish population estimate then background site PC1. Forty-eight fish (excluding minnows) were qualitatively sampled (by shocking and seining) from site WC7.

In general, these data shows a definite trend in the recovery of the fish populations of Pecan Creek. Few if any fish were captured below the treatment plant approximately one month after the spill, but fish populations gradually increased during the duration of the study, and on several occasions surpassed one or both of the background sites.

Figure 4.16 presents the population estimates for bluegill sunfish. It can be seen that few bluegill were found at the sites below the treatment plant during the February and April sampling, and populations at background sites PC1 and PC2, and reference site WC7 decreased slightly. In July, bluegill populations began to show signs of recovery at sites PC5 and PC6, while background sites PC1 and PC2 had zero bluegills captured and reference site WC7 only had one bluegill captured. Sites PC3 and PC4 still had only three and zero bluegills respectively. Although site PC6 had a non-descending removal pattern, the true bluegill population is more likely closer to the total catch of sixteen then to the estimate. Recovery of bluegill populations is more pronounced in the November sampling with downstream sites PC3, PC4, and PC5 having higher bluegill population estimates then at any other sampling date. Site WC7 was qualitatively sampled during November and four bluegill were found.

It can be seen from Figure 4.16 that few bluegills were found below the treatment plant immediately after the spill but appear to show signs of recovery starting at site PC6 and moving upstream. Colonization is most likely from the lake where bluegills are known to be abundant. Bluegills cannot tolerate high turbidity or silt, so the bluegill populations were probably restricted at the background and reference stations by the low flow and conditions found there. The relatively higher numbers of bluegills found at the background and reference stations in February, could possibly have been leftovers from 1998 when conditions in Pecan Creek were more favorable to the bluegills.

Figure 4.17 presents the population estimates for the green sunfish. During the February and April sampling events relatively large populations of green sunfish were found at the background stations PC1 and PC2, with few to zero found below the treatment plant. In July, green sunfish populations were drastically reduced in the background stations, and remained few to zero in the downstream stations, except at station PC5 were populations were similar and a bit higher than at the background stations. Site PC1 had a non-descending removal pattern and based on the data it was determined that the total catch was more representative of the true population then the generated estimate. Green sunfish populations increased at the background stations PC1 and PC2 during November, but were still less then found in February and April. Small but definite populations of green sunfish continue at downstream site PC5 and begin to show at downstream sites PC3 and PC4 as well. Sites PC3 and PC5 did have non-descending removal patterns, but it too was determined that the total catch was a more realistic estimate of the true population. A small but relatively constant green sunfish population was maintained at WC7 throughout the study, and although no population estimates were generated for November, twenty-one green sunfish were collected at that time, more than at any other collection date.

The relatively high populations of green sunfish found at the background stations reflect the tolerant nature of the fish. Green sunfish can tolerate extreme conditions and are often the last fish found in drying streams and the first fish to populate streams that dry entirely. In contrast, the green sunfish is easily displaced by other sunfish such as the longear and does best where other sunfish don’t (Plieger, 1991). This could explain the relatively few green sunfish found in the lower reaches, even in November when recovery of the population in this area would be predicted. The relatively high numbers found at WC7 could be explained by the nature of green sunfish. The lack of flow caused the fish to concentrate in the last remaining pools where the green sunfish is know to survive while other fish perish.

Population estimates for the longear sunfish are presented in Figure 4.18. Background sites PC1 and PC2 and reference site WC7 have relatively sizable longear populations, while downstream sites have few to zero individuals during the February sampling. This same pattern continues during the April sampling, except with a few more individuals being added to the downstream sites PC3 and PC5, and site WC7 seeing a considerable decrease in longear populations. Site PC1 had a non-descending removal pattern and it was determined that a total catch of thirty-one was more reflective of the true population estimate. During the July sampling, sites PC1 and PC2 show a large drop in longear populations, most likely due to the low flow conditions of the summer months. Downstream sites PC3, PC4, PC5, and PC6 and reference site WC7 maintain small but steady longear populations, adding three more individuals during the July sampling event. November saw a considerable increase in longear populations at all sites indicating a possible recovery of longear sunfish downstream of the treatment plant. Longear populations at Sites PC4 and PC5 even surpassed those found in the background sites. Qualitative sampling of WC7 found a total of 5 individuals.

Figure 4.19 presents the population estimates for yellow bullhead. Small populations of yellow bullhead were found in the background sites PC1 and PC2 and in the reference stream during the February and April sampling events. No yellow bullheads were found at the downstream sites PC3, PC4, PC5, and PC6 during February or April. The July sampling event marked an increase in the number of yellow bullhead at all sites except PC6 (zero individuals), and WC7 (two individuals). Site PC3 had the largest population estimates, surpassing sites PC1 and PC2. Sites PC4 and PC5 had smaller, but still noteworthy population estimates. The majority of the populations at these sites were juvenile (young of the year) fish, although there was also an increase in the number of adults at these sites. PC1 had 54 juvenile and 16 adults, PC2 46 juvenile/23 adults, PC3 64 juvenile/37 adults, PC4 16 juvenile/14 adults, and PC5 1 juvenile/15 adults. November saw yellow bullhead populations remain relatively steady for sites PC1, PC4, and PC5, or decline somewhat for sites PC2 and PC3. Site PC2 had a non-descending removal pattern and it was determined from the data that total catch of nine individuals was a more realistic estimate of the population. This was the lowest estimate for November. Qualitative sampling of Wilson Creek, found two individuals. The July and November sampling events indicate that populations of yellow bullhead were recovering or recovered. The large numbers of juveniles during the July sampling are the result of successful spawning and also point to recovery.

Overall, the population estimates were useful in monitoring the recovery of Pecan Creek. Although, there were several instances where population estimates could not be generated because of a non-descending removal pattern and many of the confidence intervals were very broad. It was determined after the study that increasing the number of passes to five or six could alleviate this variability. Any future population studies on Pecan Creek should seriously consider increasing the number of passes beyond three.

Phase I Conclusions

Objective number one, to monitor the recovery of Pecan Creek, was achieved and it was determined that, overall, most of the analyses indicate that Pecan Creek was recovering or recovered from the chlorine disturbance. Therefore, null hypothesis number one is rejected; the chlorine did cause there to be a difference between the sites in Pecan Creek. Most of the analyses show the same general trend; sites downstream of the disturbance show a clear impact compared to the background and reference sites but steadily show recovery over the course of the study. The presence of juvenile yellow bullhead and flathead catfish are also a positive indication of recovery. It should be re-emphasized that very few fish were captured during the February and April sampling events at the disturbed sites. These low numbers of fish caused the diversity and IBI analysis to “break down” and give results that were not consistent with the species richness and total abundance analysis. This makes most of the analyses for these sites dubious at best. Regardless of this fact, it is clear that chlorine can have a dramatic impact on fish communities, but it is also clear that recovery from these events can occur.

Objective number two, to quantify the fish community in Pecan Creek, was also met. Total fish populations (excluding minnows) and total bluegill sunfish, green sunfish, longear sunfish, and yellow bullhead populations were estimated. Total populations increased over the course of the study. Bluegill sunfish populations increased at sites below the outfall and appear to have colonized from the lake, but did not make up a significant proportion of the population above the outfall. Green sunfish populations were highest above the outfall but did not achieve great numbers below the outfall. Both longear sunfish and yellow bullhead populations were found above and below outfall. As stated above, future studies should increase the number of shocking passes to tighten the confidence intervals.

A North Texas based Index of Biotic Integrity was applied to Pecan Creek. This met the third objective of this study. It was determined that the IBI had limited application in this study and null hypothesis number three accepted. There does not appear to be a difference in the Index of Biotic Integrity between Pecan Creek and Wilson Creek. The low numbers of fish captured due to the disturbance rendered the IBI inapplicable and gave results that were not consistent with the other analyses. However, the other analyses did show that there was a difference in the fish communities between Pecan and Wilson Creeks. Many more species of fish were found in Pecan creek then found in Wilson Creek, therefore, null hypothesis number two is rejected.

Table 4.1 Chemical data for Pecan and Wilson Creeks for each sampling quarter during the 1999 fish survey.

February (Winter)

	PC1	PC2	PC3	PC4	PC5	PC6	WC7
DO (mg/L)	9.52	9.2	8.57	8.19	7.72	9.61	9.85
pH	7.74	7.84	7.15	7.27	7.37	17.71	7.64
Conductivity (us/cm)	1018	1089	833	8.17	764	796	517
Temperature (Celcius)	12.09	11.38	17.31	16.27	20.35	17.71	13.01
Free Chlorine (mg/L)	0.07	0.12	0	0.1233	0	0.05	0.0533
Total Chlorine (mg/L)	0.08	0.45	0.05	0.38	0.03	0.933	0.18
Combined Chlorine (mg/L)	0.01	0.33	0.05	0.2567	0.03	0.0433	0.1267

April (Spring)

	PC1	PC2	PC3	PC4	PC5	PC6	WC7
DO (mg/L)	6.64	7.4	7.08	6.84	6.62	7.57	6.05
pH	6.77	7.64	7.08	7.22	7.28	7.41	7.61
Conductivity (us/cm)	629	1122	1233	1222	1307	1308	700
Temperature (Celcius)	17.74	20.2	19.03	22.13	23.71	26.13	25.4
Free Chlorine (mg/L)	0	0.03	0	0	0.01	0.03	0
Total Chlorine (mg/L)	0	0.03	0.02	0	0.03	0.13	0
Combined Chlorine (mg/L)	0	0	0.02	0	0.02	0.1	0

July (Summer)

	PC1	PC2	PC3	PC4	PC5	PC6	WC7
DO (mg/L)	4.5	4.12	5.02	5.42	6.01	7.52	4.14
pH	7.08	7.19	6.97	7.06	7.12	7.59	7.17
Conductivity (us/cm)	879	841	1405	1394	14.26	1485	836
Temperature (Celcius)	27.09	26.26	27.77	28.29	28.79	29.84	27.25
Free Chlorine (mg/L)	0.02	0.0633	0.02	0.01	0.02	0.1233	0.033
Total Chlorine (mg/L)	0.05	0.0633	0.03	0.05	0.04	0.14	0.067
Combined Chlorine (mg/L)	0.03	0	0.01	0.04	0.02	0.0166	0.034

November (Fall)

	PC1	PC2	PC3	PC4	PC5	PC6	WC7
DO (mg/L)	6.37	5.53	6.25	5.41	6.3	N/A	5.46
pH	7.14	*	6.88	*	7.3	N/A	7.5
Conductivity (us/cm)	407	296	595	624	587	N/A	368
Temperature (Celcius)	12.71	*	23.06	23.42	21.84	N/A	18.07
Free Chlorine (mg/L)	0.092	0	0.01	0.01	0.068	N/A	0.033
Total Chlorine (mg/L)	0.103	0.01	0.02	0.037	0.123	N/A	0.06
Combined Chlorine (mg/L)	0.011	0.01	0.01	0.027	0.055	N/A	0.027

*No data due to equipment failure.

Table 4.2 Discharge data for Pecan and Wilson Creeks.

Average Monthly Discharges in Million Gallons per Day from the Pecan Creek Water Reclamation Plant in Pecan Creek for 1999.

January	February	March	April	May	June	July	August	September	October	November	December
10.284	11.055	10.802	11.662	11.923	10.993	10.115	9.502	10.656	11.274	10.538	10.783

Average Monthly Discharges in Million Gallons per Day from the City of Denton Power Plant in Pecan Creek for 1999.

January	February	March	April	May	June	July	August	September	October	November	December
0.0842	0.0758	0.0306	0.083	0.0568	0.1566	0.194	0.5324	0	0	0	0

Background Flow Measurements (MGD) for Pecan Creek Above the Pecan Creek Water Reclamation Plant for 1999.

2-Feb-99	23-Mar-99	22-Apr-99	19-May-99	2-Sep-99	23-Sep-99	21-Oct-99	5-Nov-99	19-Nov-99	17-Dec-99
1.284	0.617	0.867	0.133	0.191	0	0.1	0.327	0.043	0.532

Flow Measurments (MGD) at Sites on Pecan Creek for 1999.

PC2	PC3	PC4	PC6	PC1
2-Feb-99	2-Feb-99	4-Feb-99	23-Jul-99	4-Nov-99
1.283	12.531	14.876	8.966	0.139

Flow Measurements (MGD) for Wilson Creek for 1998 and 1999.

28-Sep-98	18-Feb-99	16-May-99	24-Jul-99	10-Nov-99
1.663	9.541	6.878	0.285	0

Figure 4.1 Average habitat scores for Pecan and Wilson Creek in 1999.

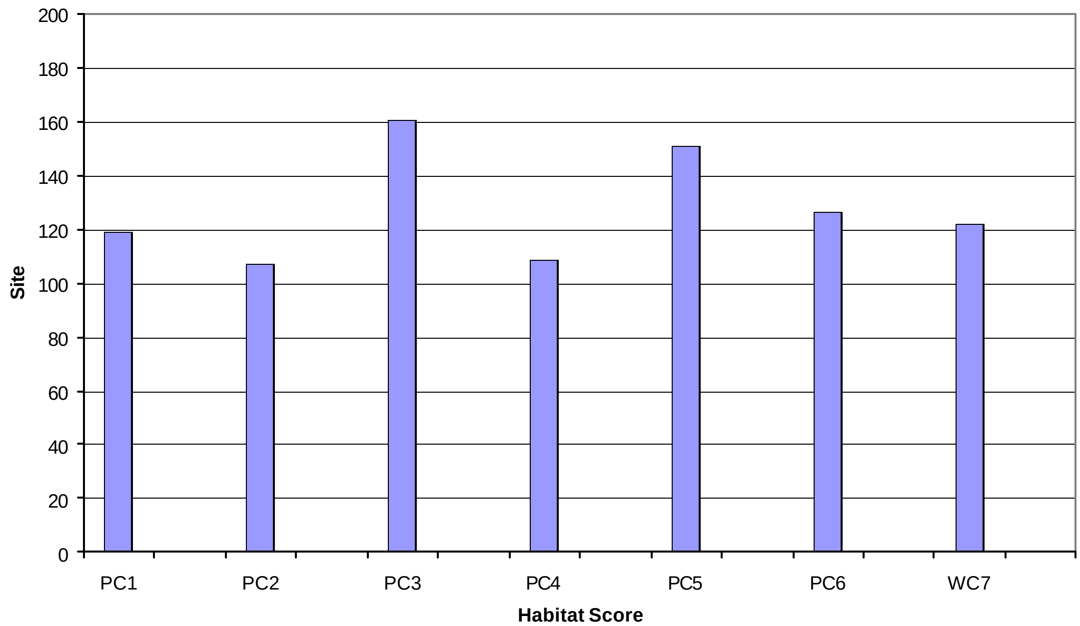


Table 4.3 List of fish species captured in the four 1999 surveys via shocking and seining in Pecan Creek (P), Denton County, Texas, and Wilson Creek (W), Colin County, Texas, and those captured in the 1993 and 1994 Wise study in Pecan Creek (p) and Wilson Creek (w).

FAMILY	SPECIES	COMMON	STREAM CAPTURED
Atherinidae	*Menidia beryllina*	Inland Silverside	P,p
Centrarchidae		Hybrid Bluegill Sunfish	P,p
Centrarchidae	*Lepomis gulosus*	Warmouth Sunfish	P,p
Centrarchidae	*Pomixis annularis*	White Crappie	P,p
Clupeidae	*Dorosoma petenense*	Threadfin Shad	P,p
Cyprinidae	*Pimephales notatus*	Bluntnose Minnow	P
Cyprinidae	*Notemigonus crysoleucas*	Golden Shiner	P,p
Ictaluridae	*Ictalurus punctatus*	Channel Catfish	P,p,w
Ictaluridae	*Pylodictis olivaris*	Flathead Catfish	P
Ictaluridae	*Noturus nocturnus*	Freckled Madtom	P
Centrachidae		Juvenile Sunfish	P,W,p
Centrarchidae	*Lepomis macrochirus*	Bluegill Sunfish	P,W,p,w
Centrarchidae	*Lepomis cyanellus*	Green Sunfish	P,W,p,w
Centrarchidae	*Micropterus salmoides*	Largemouth Bass	P,W,p,w
Centrarchidae	*Lepomis megalotis*	Longear Sunfish	P,W,p,w
Centrarchidae	*Lepomis humilis*	Orangespotted Sunfish	P,W,p,w
Cyprinidae	*Pimephales vigilax*	Bullhead Minnow	P,W,p,w
Cyprinidae	*Cyprinus carpio*	Common Carp	P,W,p
Cyprinidae	*Opsopoeodus emiliae*	Pugnose Minnow	P,W,p
Cyprinidae	*Cyprinella lutrensis*	Red Shiner	P,W,p,w
Ictaluridae	*Ameiurus melas*	Black Bullhead	P,W,p
Ictaluridae	*Ameiurus natalis*	Yellow Bullhead	P,W,p,w
Poeciliidae	*Gambusia affinis*	Western mosquitofish	P,W,p,w
Cyprinidae	*Campostoma anomalum*	Central Stoneroller	W,w
Cyprinodontidae	*Fundulus notatus*	Blackstripe Topminnow	W,w
Catostomidae	*Carpiodes carpio*	River Carpsucker	p
Centrachidae	*Lepomis punctatus*	Spotted Sunfish	p
Centrarchidae	*Lepomis microlophus*	Redear Sunfish	p
Cyprinidae	*Lythrurus umbratilis*	Redfin Shiner	p
Cyprinidae	*Notropis stramineus*	Sand Shiner	p
Percicthyidae	*Morone chrysops*	White Bass	p
Percidae	*Percina carbonaria*	Texas Logperch	p

Figure 4.2 Species Richness for Pecan and Wilson Creeks.

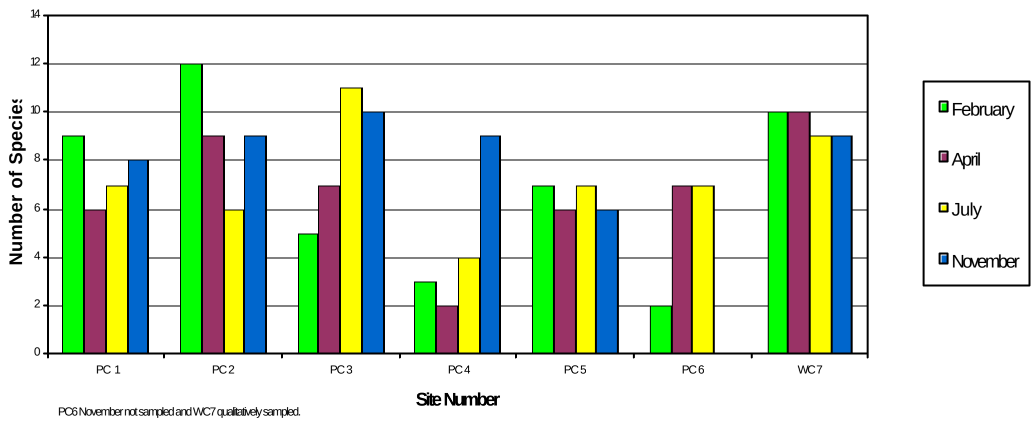
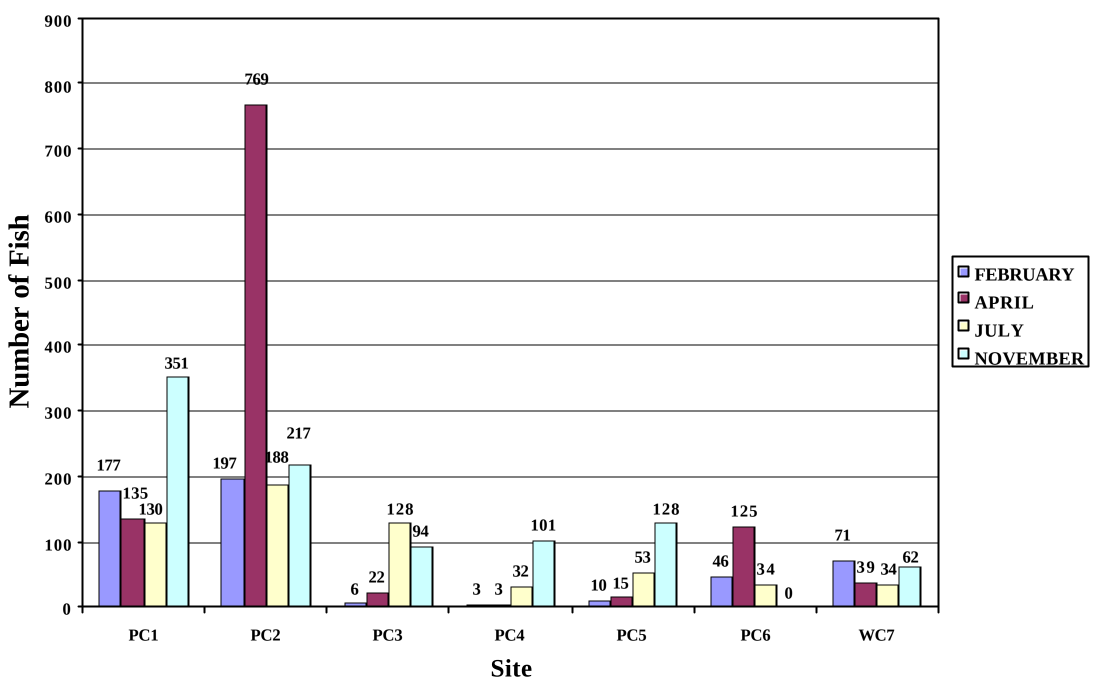


Figure 4.3 Total abundance of fish captured at each site.



PC6 November not sampled and WC7 November qualitatively sampled.

Figure 4.4 Percent abundance of fish species captured in the Pecan and Wilson Creek fish survey during February 1999.

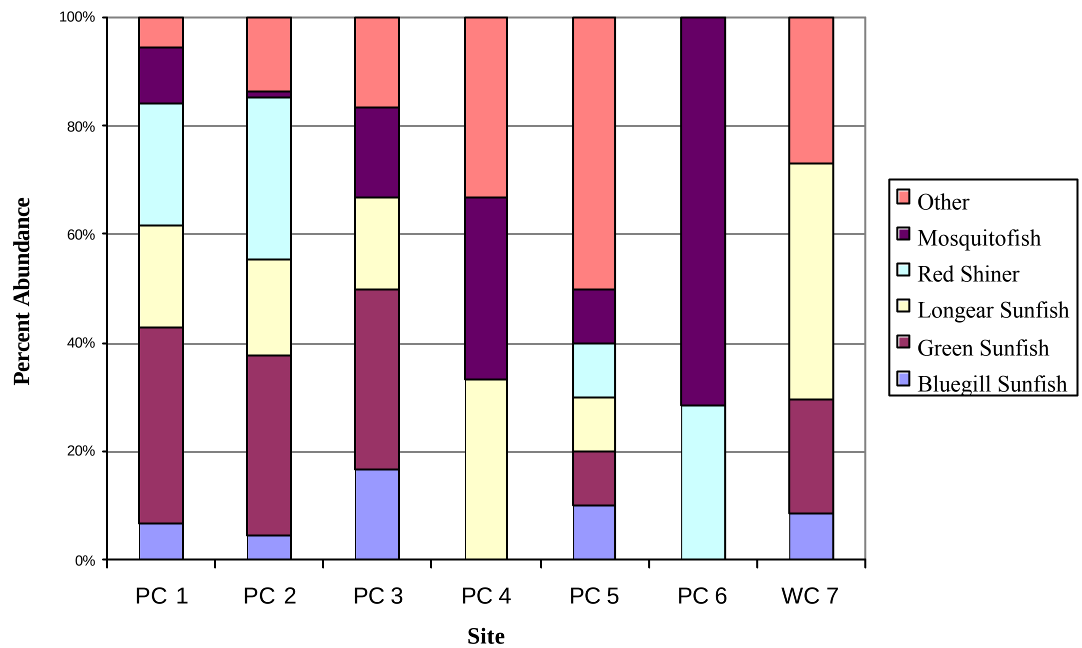


Figure 4.5 Percent abundance of fish species captured in the Pecan and Wilson Creek fish survey during April 1999.

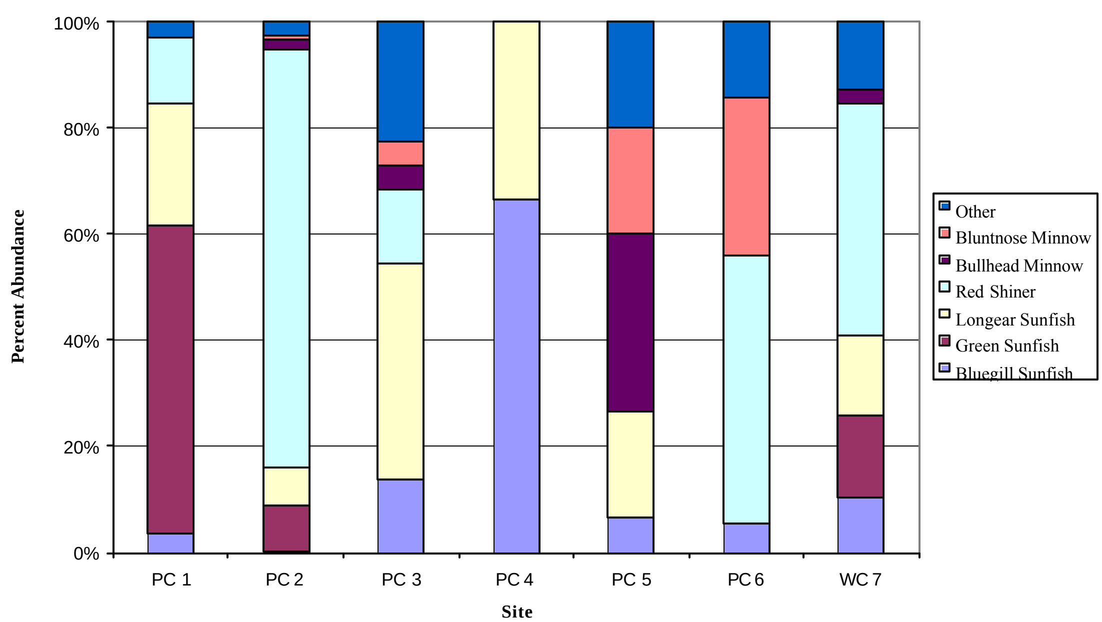


Figure 4.6 Percent abundance of fish species captured in the Pecan and Wilson Creek fish survey during July 1999.

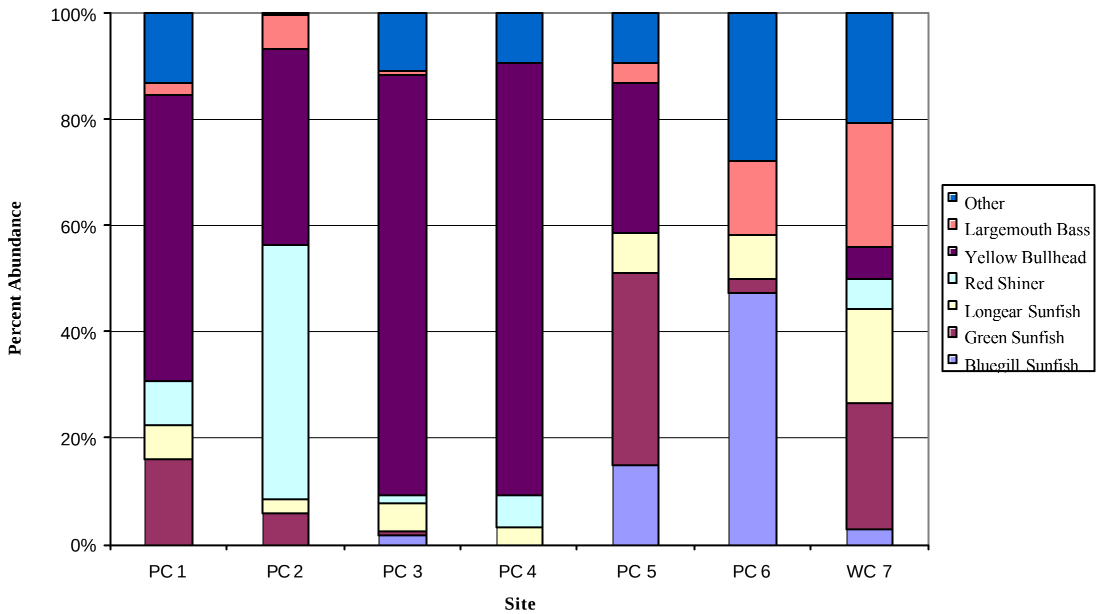


Figure 4.7 Percent abundance of fish species captured in the Pecan and Wilson Creek fish survey during November 1999.

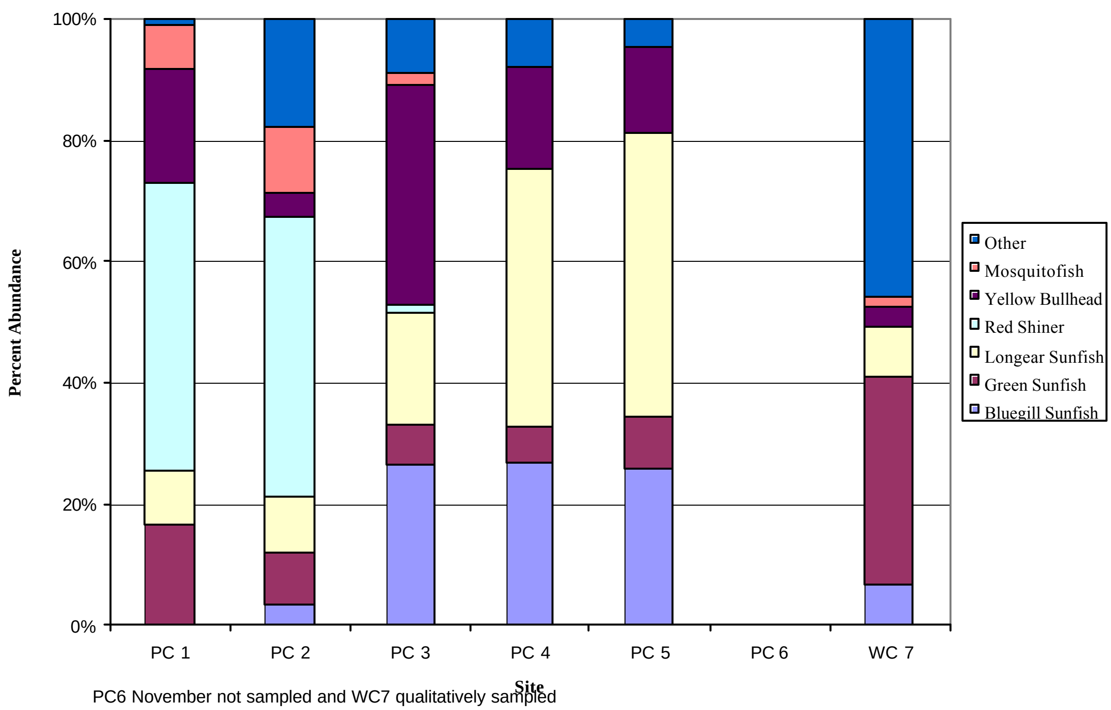


Figure 4.8 Brillouin evenness index (log base 2) for Pecan and Wilson Creeks during 1999.

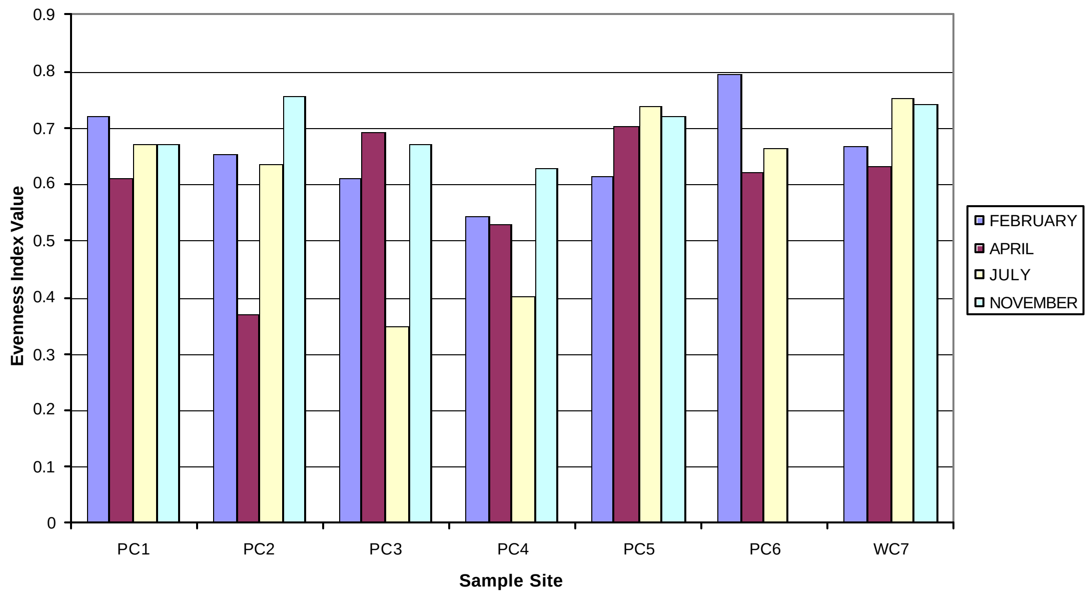


Figure 4.9 Brillouin diversity index values (log base 2) for Pecan and Wilson Creeks during 1999.

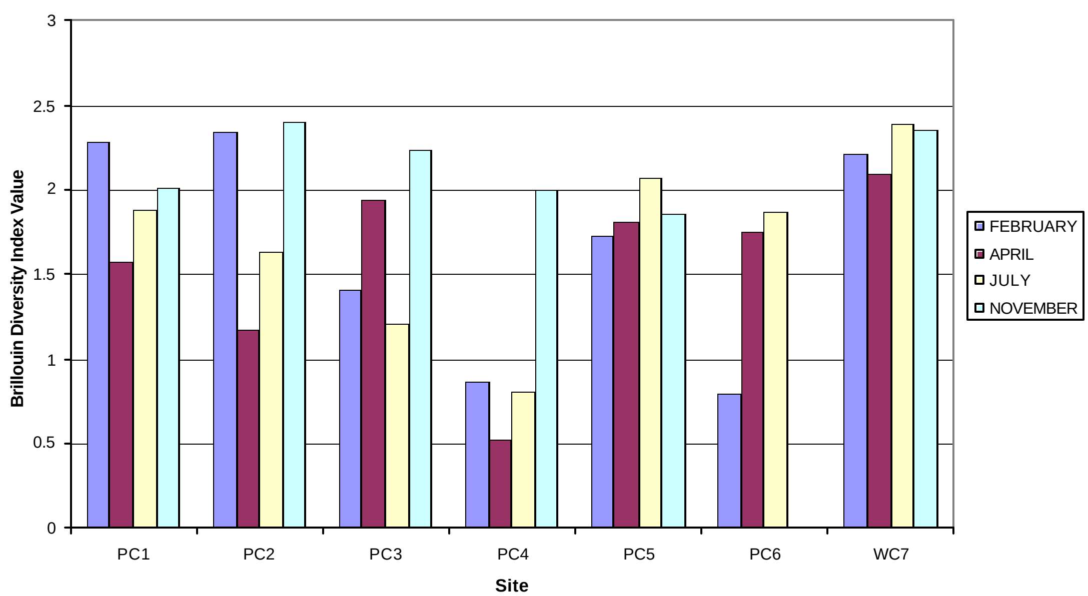


Figure 4.10 Bray-Curtis coefficient of similarity for Pecan and Wilson Creeks during February 1999.

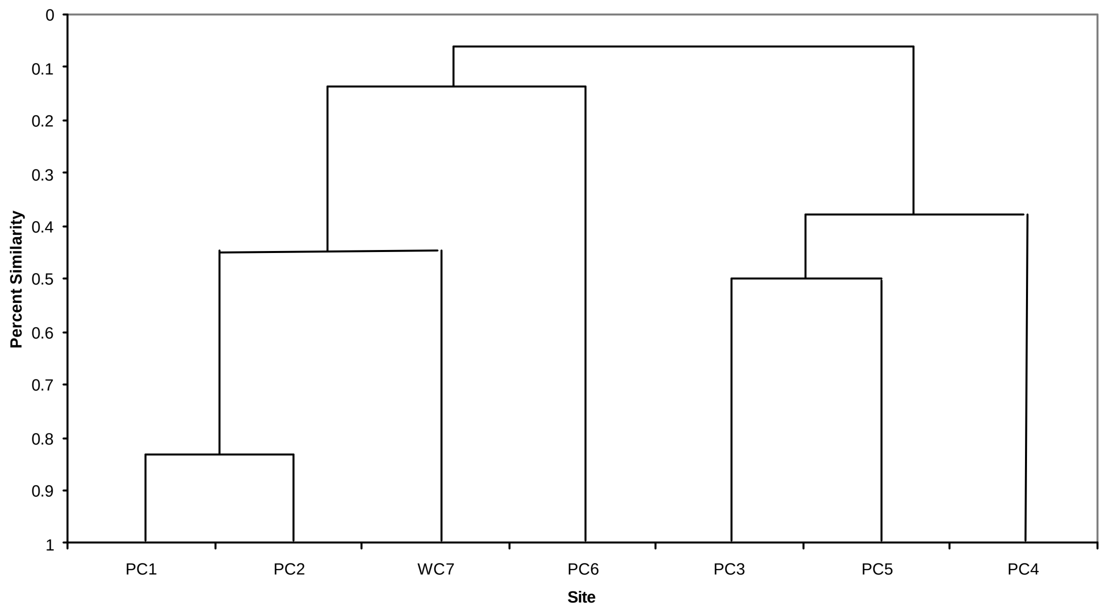


Figure 4.11 Bray-Curtis coefficient of similarity for Pecan and Wilson Creeks during April 1999.

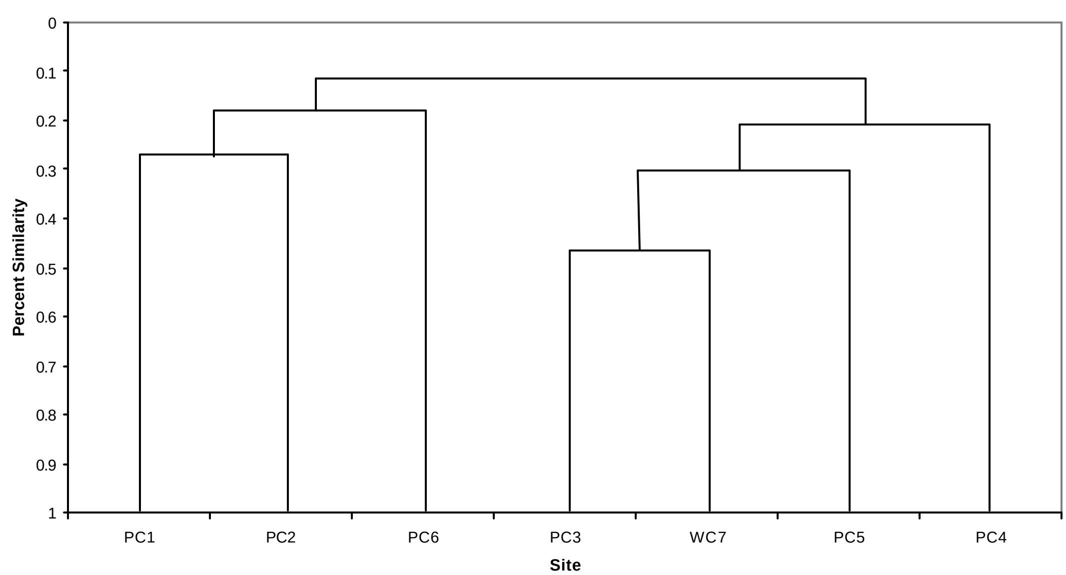


Figure 4.12 Bray-Curtis coefficent of similarity for Pecan and Wilson Creeks during July 1999.

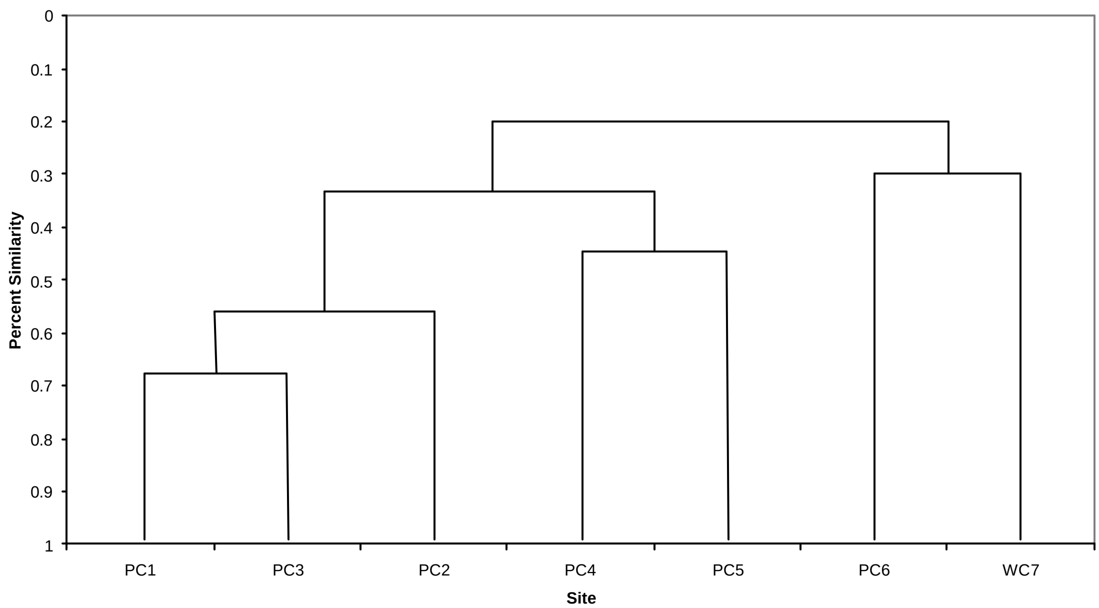


Figure 4.13 Bray-Curtis coefficient of similarity for Pecan and Wilson Creeks during November 1999.

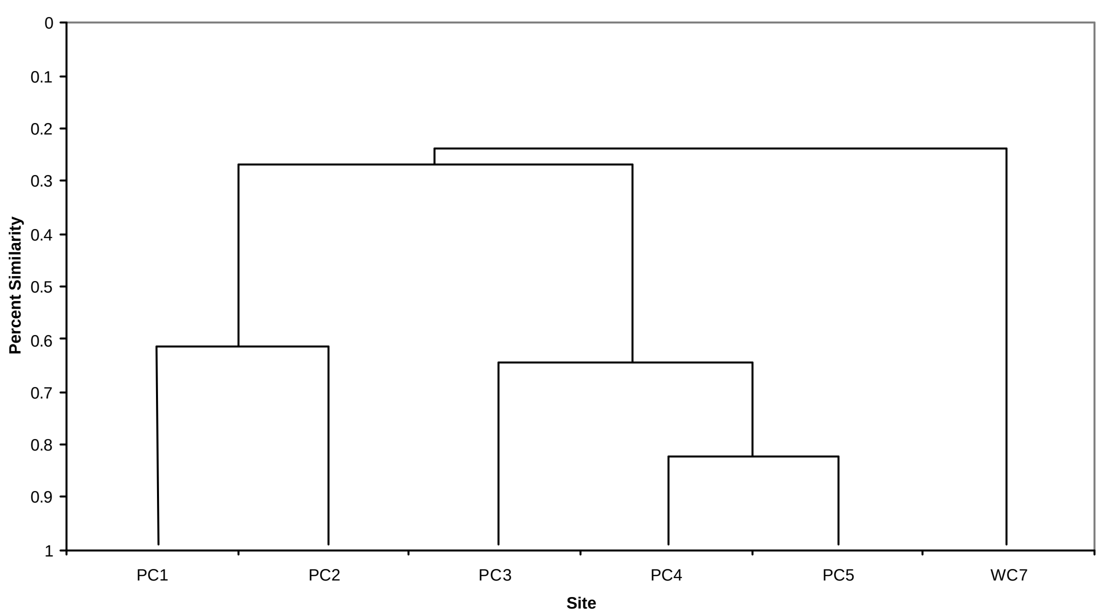


Figure 4.14 Index of biotic integrity for Pecan and Wilson Creeks.

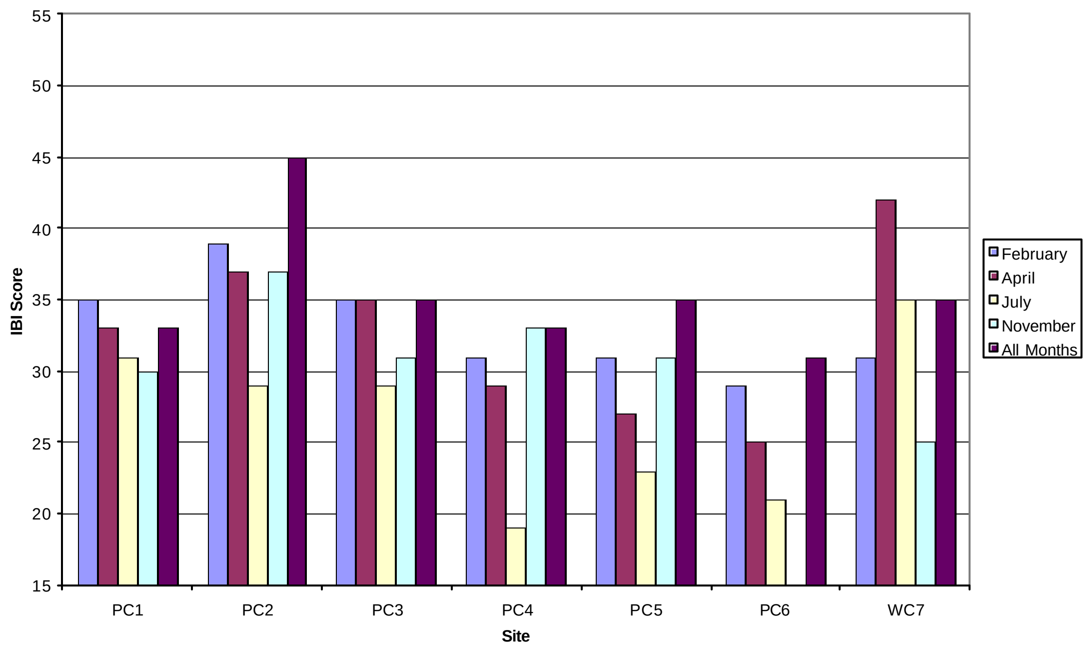
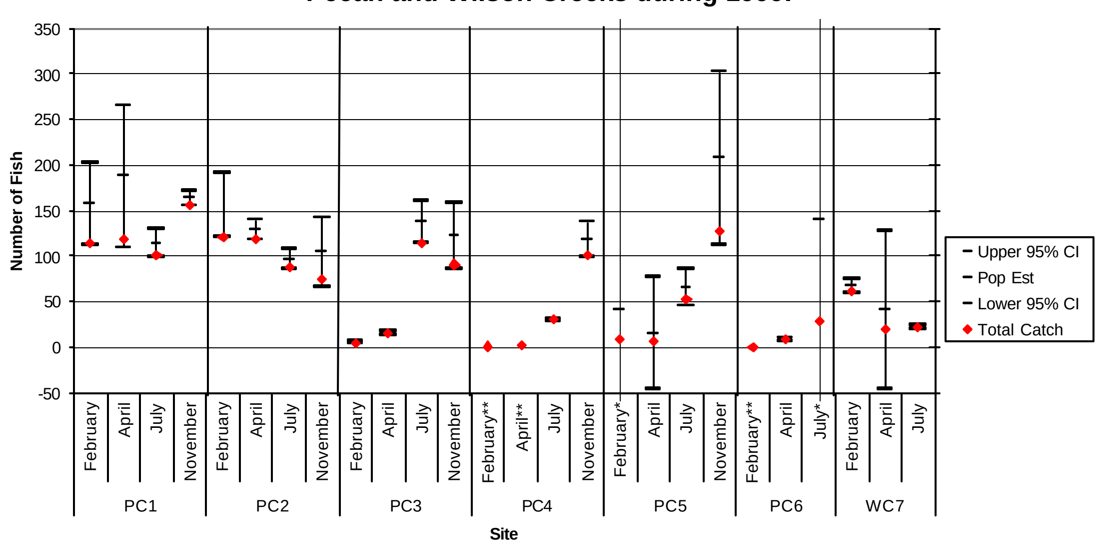
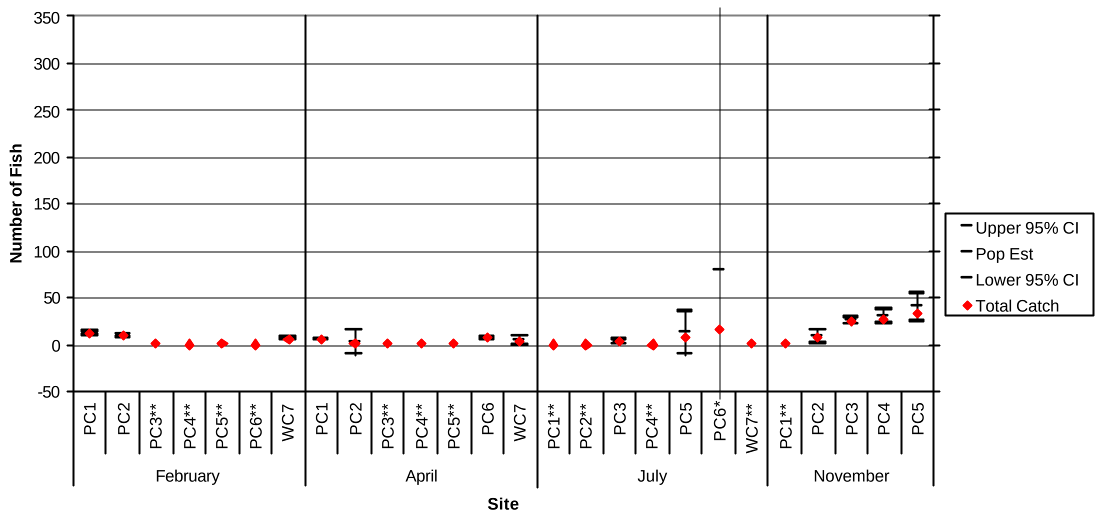


Figure 4.15 Total fish population estimates (excluding minnows) for Pecan and Wilson Creeks during 1999.



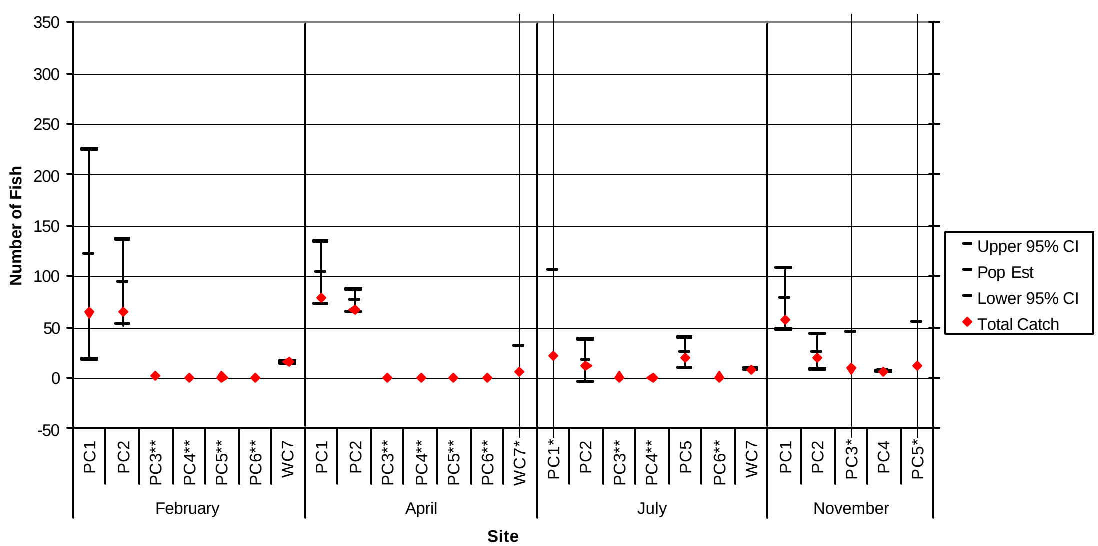
* Non descending removal pattern, population estimates set at five times the total catch. Results should not be considered reliable.
** Population estimate could not be generated because; no fish were caught, only one fish was caught, or all fish were caught on first pass.

Figure 4.16 Total bluegill population estimates for Pecan and Wilson Creeks during 1999.



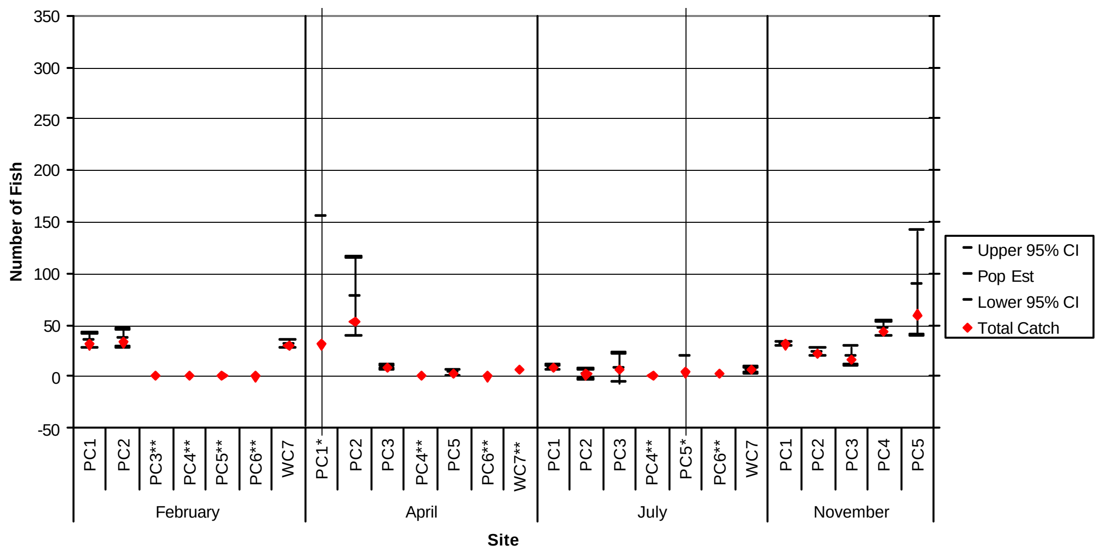
* Non descending removal pattern, population estimates set at five times the total catch. Results should not be considered reliable.
** Population estimate could not be generated because; no fish were caught, only one fish was caught, or all fish were caught on first pass.

Figure 4.17 Total green sunfish population estimates for Pecan and Wilson Creeks during 1999.



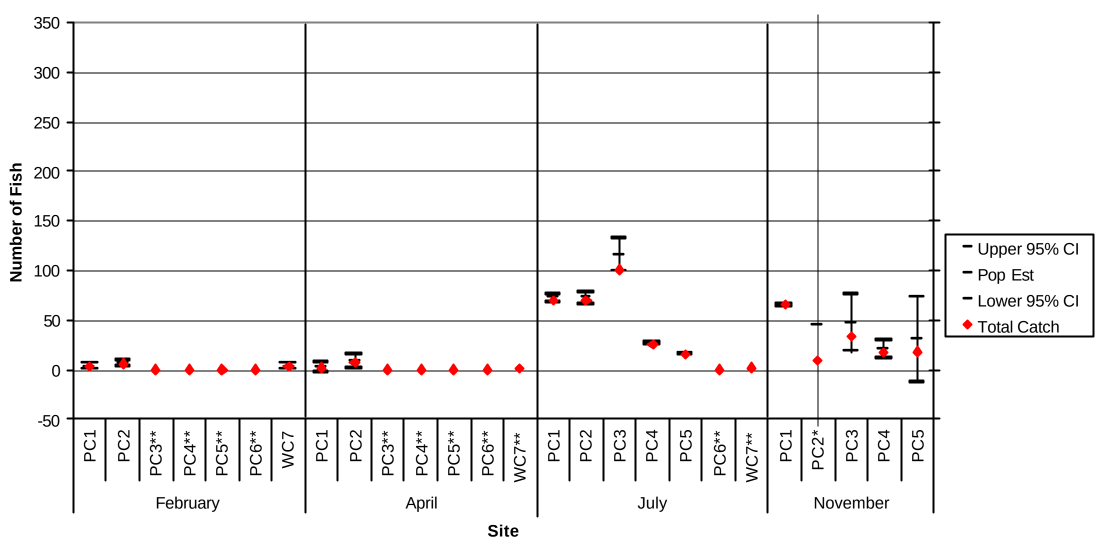
* Non descending removal pattern, population estimate set at five times the total catch. Results should not be considered reliable.
** Population estimate could not be generated because; no fish were caught, only one fish was caught, or all fish were caught on first pass.

Figure 4.18 Total longear sunfish population estimates for Pecan and Wilson Creeks during 1999.



* Non descending removal pattern, population estimate set at five times the total catch. Results should not be considered reliable.
** Population estimate could not be generated because; no fish were caught, only one fish was caught, or all fish were caught on first pass.

Figure 4.19 Total yellow bullhead population estimates for Pecan and Wilson Creeks during 1999.



* Non descending removal pattern, population estimate set at five times the total catch. Results should not be considered reliable.
** Population estimate could not be generated because; no fish were caught, only one fish was caught, or all fish were caught on first pass.

CHAPTER 5

RESULTS AND DISCUSSION – PHASE II

In the following phase II section, the first twenty-minutes of shocking and the seine haul results were analyzed. These data were compared to the above depletion strategy to determine if a reduced sampling effort could adequately represent the recovering of Pecan Creek and similarly represent the fisheries community as a whole. This was done so that the results could be compared to a previous study (Wise, 1995) that used a twenty-minute shocking and seining equal effort sampling strategy. Phase III of this study will make this comparison, and meet the fourth and final objective of assessing the fish community of Pecan Creek five years after implementation of de-chlorination.

Presence/Absence and Species Richness

All the species captured throughout the depletion study were captured during the first 20 minutes of shocking and seining and can also be represented by Table 4.3. This indicates that the twenty-minute sampling protocol would be an adequate protocol for a presence/absence study and could adequately represent the species composition of Pecan and Wilson Creeks.

The species richness at each site for each sampling date during the first twenty minutes of sampling is shown in Figure 5.1. If the twenty-minute sampling protocol could adequately sample all the species present, one would expect the same species richness as found in the depletion protocol. Comparing Figure 4.3 and Figure 5.1 we see that the species richness for the twenty-minute protocol underrepresented the species found in Pecan Creek during the depletion protocol. This indicates that the twenty-minute sampling protocol would not adequately represent the species richness for Pecan and Wilson Creeks. On the other hand, it does show the same general recovery trend seen in the depletion protocol for sites PC3 and PC4. Site PC5 on the other hand does not show the same consistent levels of species richness that it showed for the depletion protocol, and one could erroneously conclude that PC5 was more impacted then it really was.

Total Abundance

Figure 5.2 shows the total abundance for each site for the first twenty minutes of sampling. Like species richness, the total abundance was lower than for the depletion protocol, but this would be expected, since the sampling effort was reduced. What is important is that the same recovery trend is just as obvious for the twenty-minute sampling protocol as it is for the depletion. One would draw the same conclusions about the recovering of Pecan Creek using these data as they would using the depletion data. This indicates that total abundance could be used to adequately represent the recovery of Pecan Creek using a twenty-minute protocol.

Percent Abundance

Figure 5.3 shows the percent abundance of fish captured during the February sampling event for the first twenty minutes of sampling and six seine hauls. The results are similar to Figure 4.5 in that site PC6 was the only site that had a species that was more than fifty percent abundant (western mosquitofish, 68%). As above, this dominance is explained by the fact that only two fish species were captured. Unlike above, two additional sites, PC3 and PC4 had species that were fifty percent abundant, but this too can be explained by the fact that only three and two species were captured at these sites respectively.

Using the twenty minute sampling protocol resulted in six sites during the April sampling event (Figure 5.4) having one species more than fifty percent abundant (PC1, green sunfish = 73%; PC2, red shiner = 86%; PC4, bluegill sunfish = 67%; PC5, bullhead minnow = 63%; PC6, red shiner = 52%; WC7, red shiner = 57%) while the depletion protocol resulted in only four sites having one species fifty percent or more abundant (Figure 4.6). As above, the dominance at site PC2 can be explained by a large number of red shiner being captured, site PC4 having only two species with a total of three fish being captured, and site PC6 having only two species captured. Site PC1 was similar to the depletion protocol in having bluegill sunfish dominant, only in this case, at a larger percentage. Dominance at site PC5 can also be explained by having only three species captured.

Figure 5.5 shows the percent abundance for the July sampling event using the twenty minute protocol. Four sites had a single species that was over fifty percent abundant (PC1, yellow bullhead = 53%; PC2, red shiner = 56%; PC3, yellow bullhead = 79%; PC4, yellow bullhead = 84%. This was similar to the depletion protocol which also had four sites with over fifty percent except that PC2 did not have a single species that was greater than fifty percent dominate (although red shiner was close being the dominate species at forty-eight percent) and PC6 had bluegill that were fifty percent dominate (in this case bluegill were only thirty percent dominate).

The twenty-minute sampling protocol for November (Figure 5.6) yielded similar results as the depletion protocol except that PC2 was the only site to show a single species (red shiner) that was greater than fifty percent dominate and it was only fifty-three percent.

The percent abundance data show that the twenty-minute protocol adequately represented the fish community as compared to the depletion protocol. The twenty-minute protocol did tend to overstate the dominance compared to the depletion study but did not do so in a way that would change conclusions drawn from the data. Also, the sites that were overstated tended to be from the impacted sites during the February and April sampling events. As stated above, these sites had very few fish captured, which makes these data dubious at best. The twenty-minute protocol also adequately represented the fish community in that the same species that were dominant for the twenty-minute protocol were the same as in the depletion protocol.

Evenness

The evenness values (log base 2) were calculated for the twenty-minute protocol (Figure 5.7), and were similar to the values calculated for the depletion protocol. As for the depletion protocol, the sites with unusually low evenness values had an extremely dominant species that reduced the evenness values. Also, as above, no real recovery trend can be seen using the evenness index.

Diversity

The Brillouin diversity index (log base 2) for the twenty-minute protocol is shown in Figure 5.8. Like the depletion protocol, sites PC1, PC2 and WC7 tended to have higher diversity values than the impacted sites. Also, the impacted sites tended to have higher diversity values during the July and November sampling events than during the February and April sampling events. The same general conclusions could be drawn using the twenty-minute strategy as with using the depletion strategy, therefore, the twenty-minute strategy adequately represents the recovering of Pecan Creek. On the other hand, the diversity tends to be underestimated for the twenty-minute strategy compared to the depletion strategy. This indicates that the twenty-minute strategy does not adequately represent the fish community as a whole.

Percent Similarity

Two clusters at the 0.5000 or greater level of similarity during the February sampling event for the twenty-minute protocol can be seen in Figure 5.9. As in the depletion protocol, PC1 and PC2 are clustered together (similarity value = 0.77056). Unlike the depletion protocol where PC3 and PC5 were clustered together, PC4 and PC5 are clustered together at the 0.57143 level. Although there was some difference in how the sites were clustered, overall the clustering pattern for all the sites was very similar. This could indicate that the twenty-minute protocol, at least in this case, was representing the fish community almost as well as the depletion protocol.

The percent similarity during the April sampling event for the twenty-minute protocol is represented in Figure 5.10. Sites PC3 and WC7 were clustered together at the 0.52174 level of similarity with no other sites being clustered above the 0.5000 level. This was different from the depletion protocol where no sites were clustered above the 0.5000 level, although sites PC3 and WC7 were clustered at 0.45902. To take into account the large number of red shiner found at site PC2, similarity calculations were rerun with only 50 red shiner. This resulted in PC1 and PC2 clustering at the 0.5000 level of similarity, similar to the depletion protocol. Like the February sampling event, overall, the clustering pattern tended to be similar (except site PC1) to that found for the depletion protocol.

Percent similarity for the twenty-minute sampling protocol for the July sampling event is given in Figure 5.11. Sites PC1 and PC3 clustered together at the 0.71233 level and sites PC1 and PC2 clustered at the 0.52690 level. A separate cluster consisting of sites PC4 and PC5 came in just under the 0.5000 level at 0.49180. Sites PC6 and WC7 were well below the 0.5000 level of similarity. As during the February and April sampling events, the clustering pattern was very similar to that found in the depletion study.

Percent similarity for the twenty-minute protocol during the November sampling event is shown in Figure 5.12. PC4 and PC5 are clustered together at the 0.80597 level and PC4 and PC3 are clustered at the 0.61559 level of similarity. This is very similar to the results found using the depletion protocol. On the other hand, the twenty-minute protocol clustered together PC1 and WC7 at the 0.52252 level and PC1 and PC2 below the 0.5000 level of similarity at 0.39744. This is different from the depletion protocol that clustered PC1 and PC2 together and left WC7 clustered by itself. This was the only time that the twenty-minute protocol did not cluster PC1 and PC2 above the 0.50000 level of similarity.

In general, the twenty-minute protocol showed similar clustering patterns as those shown using the depletion protocol, with a few exceptions. The conclusions drawn from using the twenty-minute protocol are generally the same as those drawn from using the depletion methodology, although, it is felt that in this case the twenty-minute strategy did not represent the fish community as well as the depletion strategy.

Phase II Conclusions

Overall, the twenty-minute sampling strategy was capable of monitoring the recovery of Pecan Creek and would be adequate in monitoring any future disturbances. Using a twenty-minute strategy to examine the community structure of Pecan Creek would be questionable. In this study, the depletion strategy yielded results that more accurately reflects the true conditions of the fish community as a whole, while the twenty-minute strategy tends to fall short. Of the analysis compared, only the Presence/Absence data were comparable to the depletion strategy. Total abundance, percent abundance and percent similarity were comparable to the depletion study for monitoring the recovery of Pecan Creek, but were not comparable enough to adequately represent the fisheries community.

Evenness was not valuable in monitoring the recovery or examining the fish community in Pecan Creek. It was determined from these data that a species had to be seventy percent or more dominant to have any affect on the evenness value. Percent abundance would give a more complete picture of the evenness of each site. Diversity was determined to be useful in monitoring the recovery of Pecan Creek, but tended to be underestimated compared to the depletion strategy. These data also showed that diversity values could be relatively high for sites that had low species richness and low total abundance if the evenness was high. Good scientific judgement, along with species richness, total abundance, and percent abundance should be used, in addition to, diversity indices in analyzing fisheries data.

Figure 5.1 Species richness for the first twenty-minutes of shocking and seining in Pecan and Wilson Creeks, 1999.

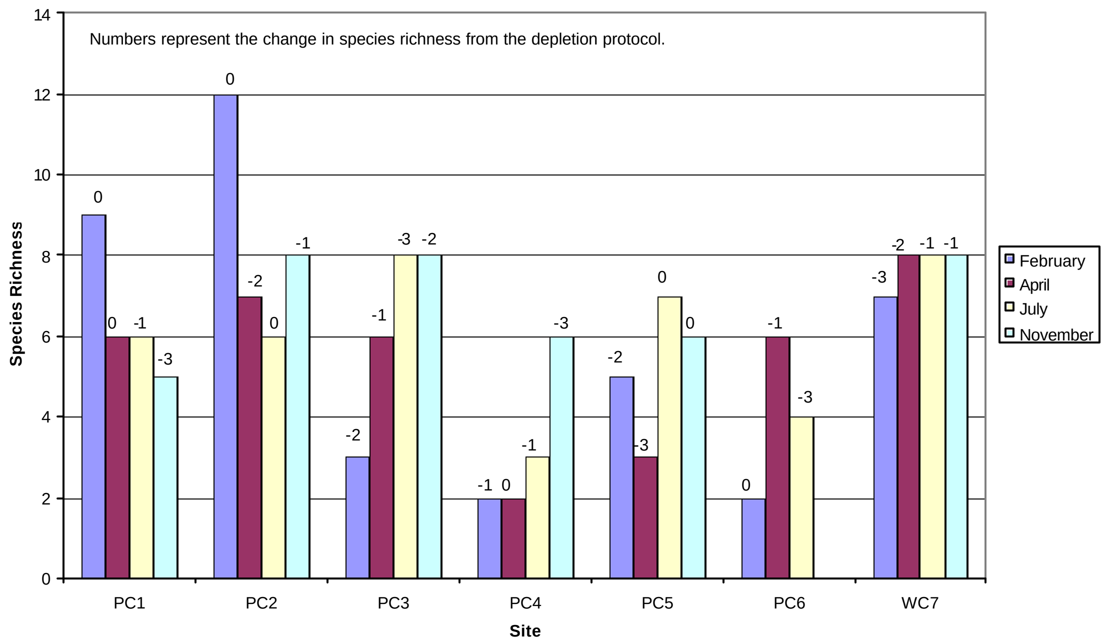


Figure 5.2 Total abundance of fish captured during the first twenty-minutes of shocking and seining in Pecan and Wilson Creeks, 1999.

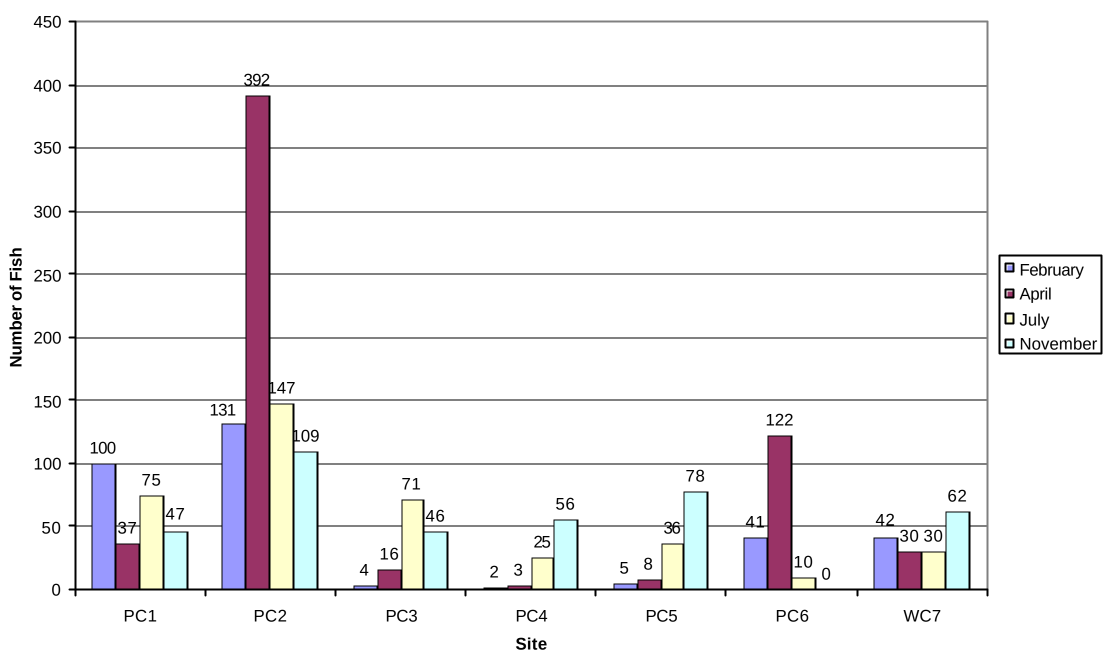


Figure 5.3 Percent abundance of fish captured during the first twenty-minutes of shocking and seining in Pecan and Wilson Creeks, February 1999.

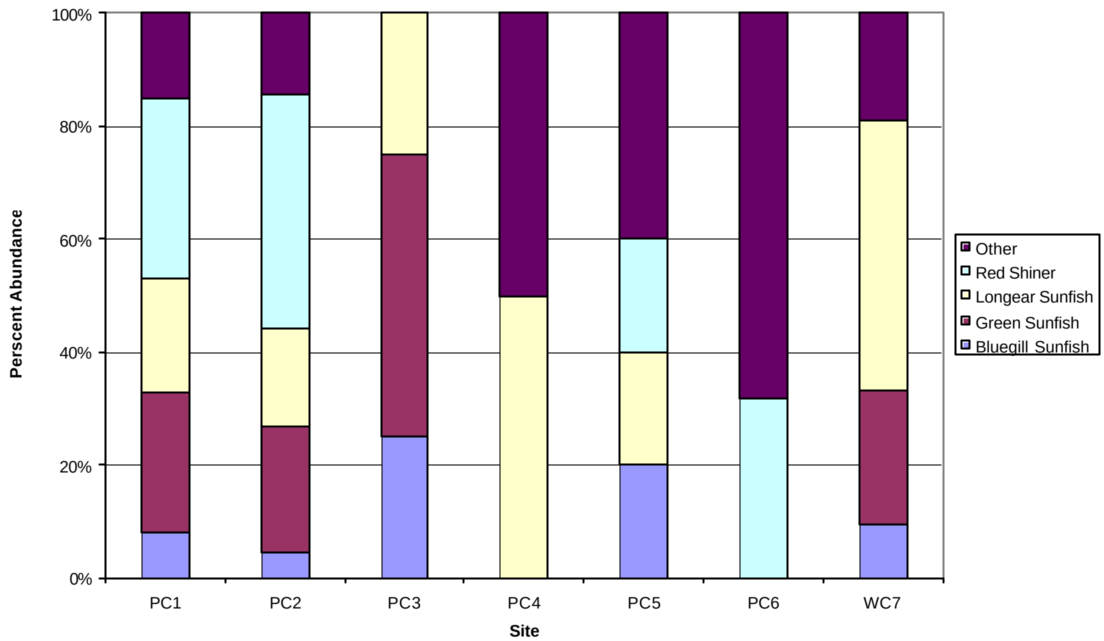


Figure 5.4 Percent abundance of fish captured during the first twenty-minutes of shocking and seining in Pecan and Wilson Creeks, April 1999.

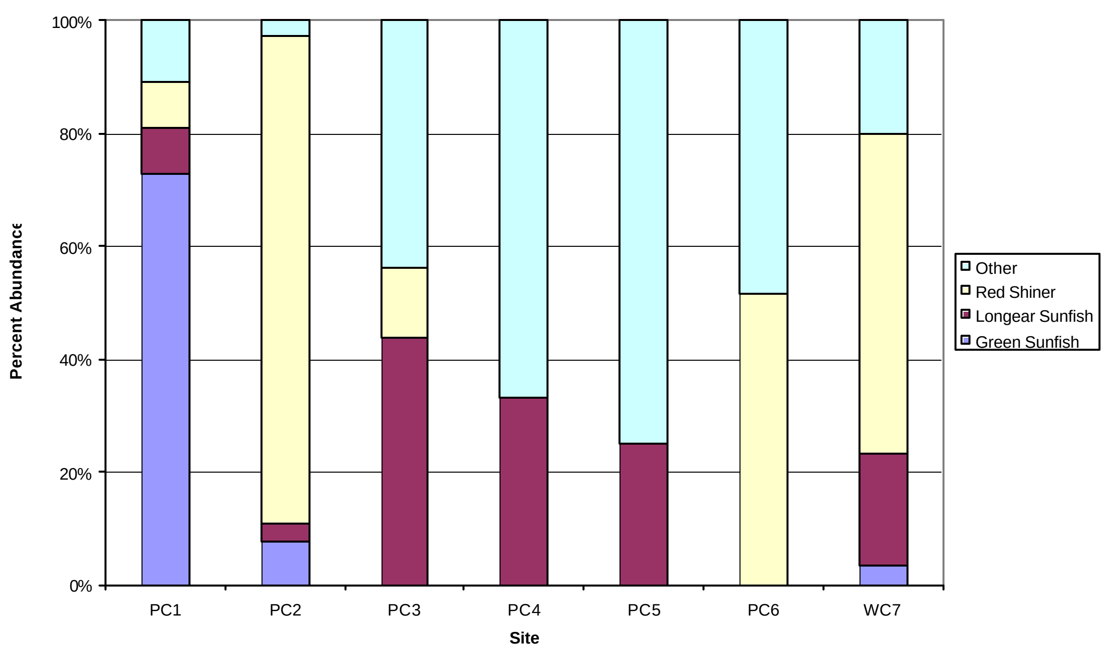


Figure 5.5 Percent abundance of fish captured during the first twenty-minutes of shocking and seining in Pecan and Wilson Creeks, July 1999.

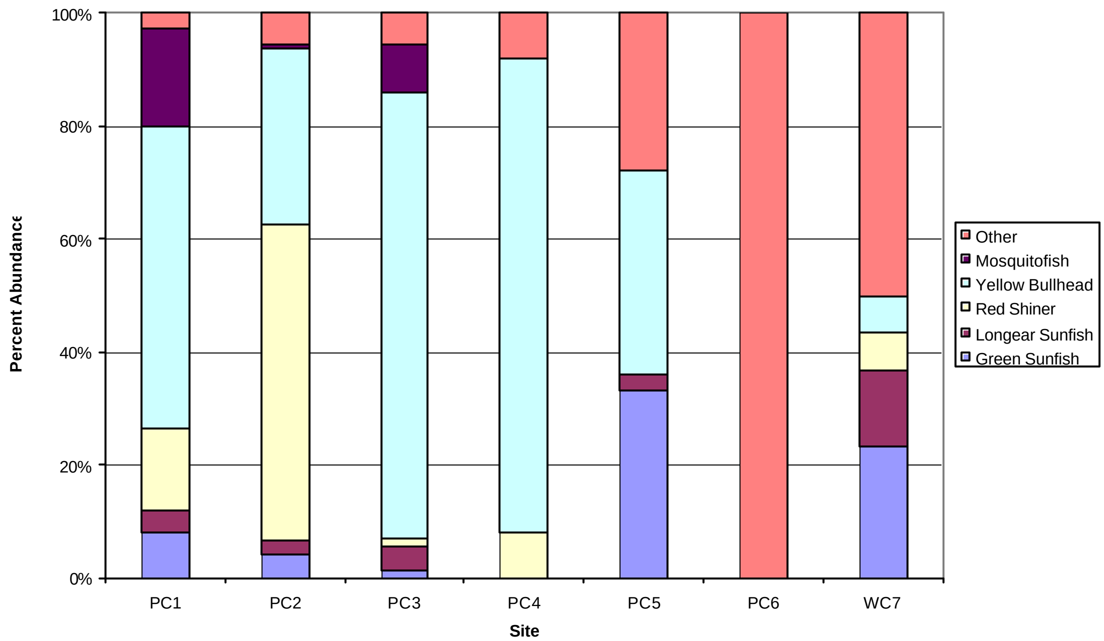


Figure 5.6 Percent abundance of fish captured during the first twenty-minutes of shocking and seining in Pecan and Wilson Creeks, November 1999.

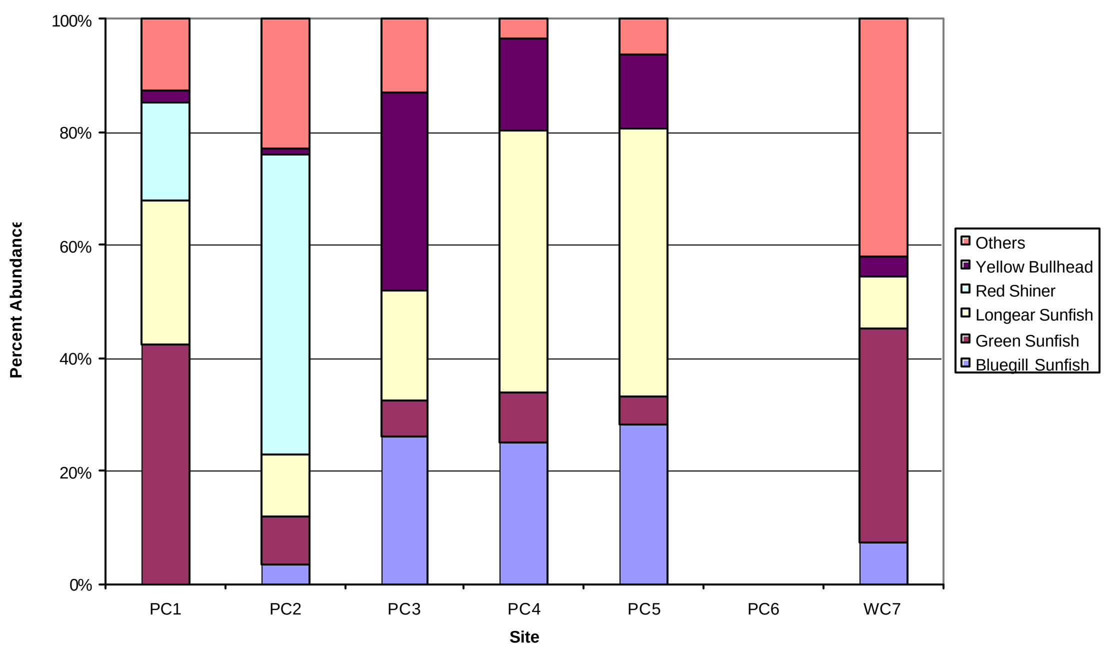


Figure 5.7 Brillouin evenness values (log base 2) for the first twenty-minutes of shocking and seining in Pecan and Wilson Creeks, 1999.

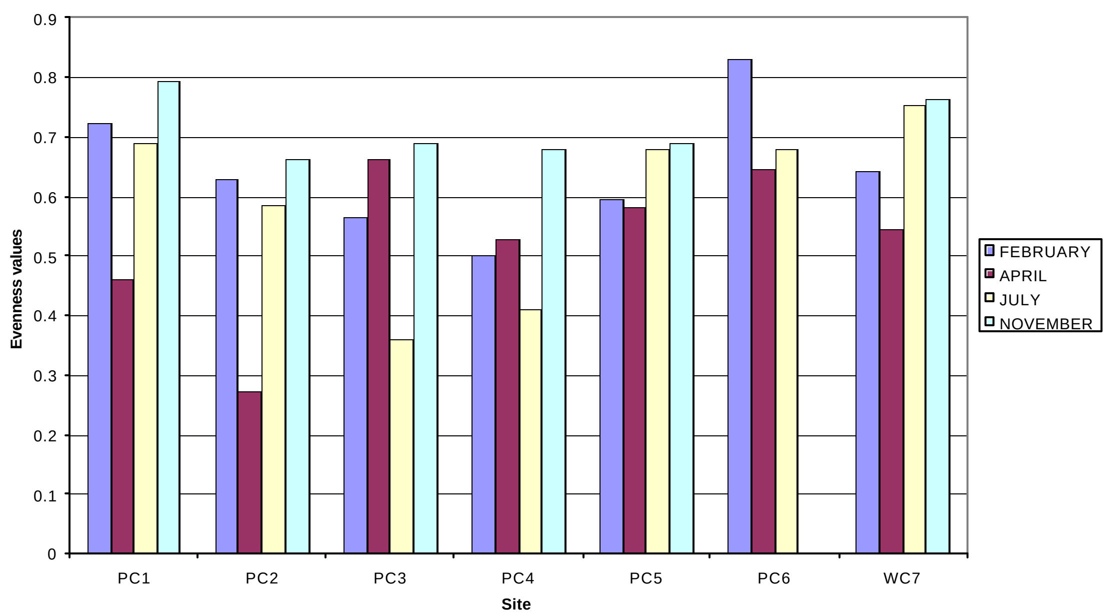


Figure 5.8 Brillouin diversity index values (log base 2) for the first twenty-minutes of shocking and seining in Pecan and Wilson Creeks, 1999.

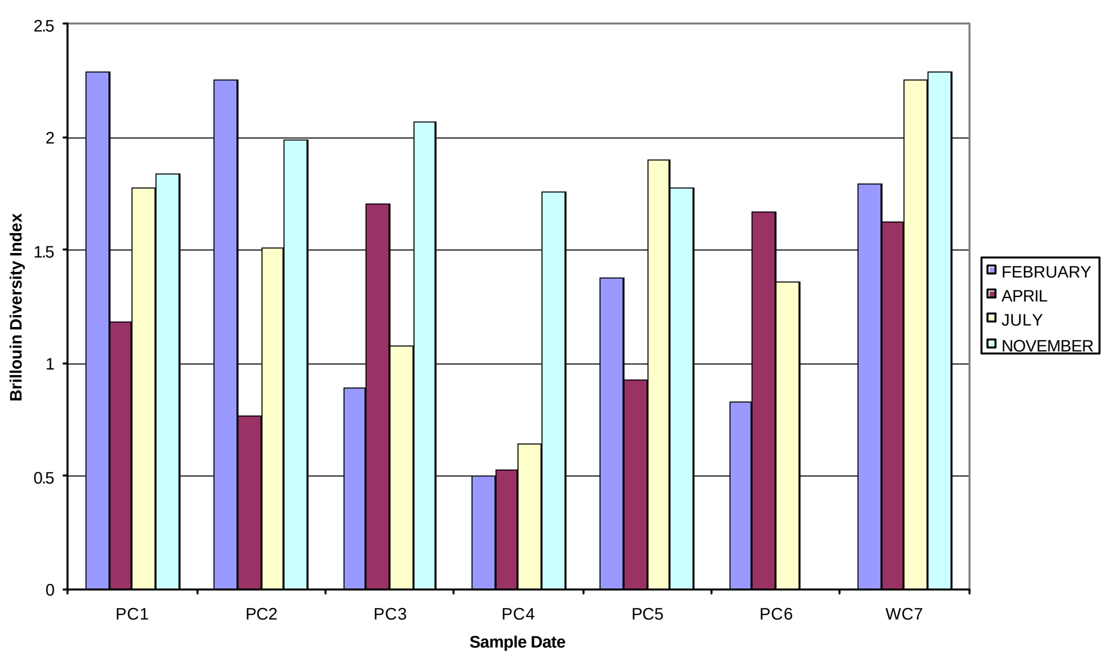


Figure 5.9 Bray-Curtis coefficient of similarity for the first twenty-minutes of shocking and seining in Pecan and Wilson Creeks, February 1999.

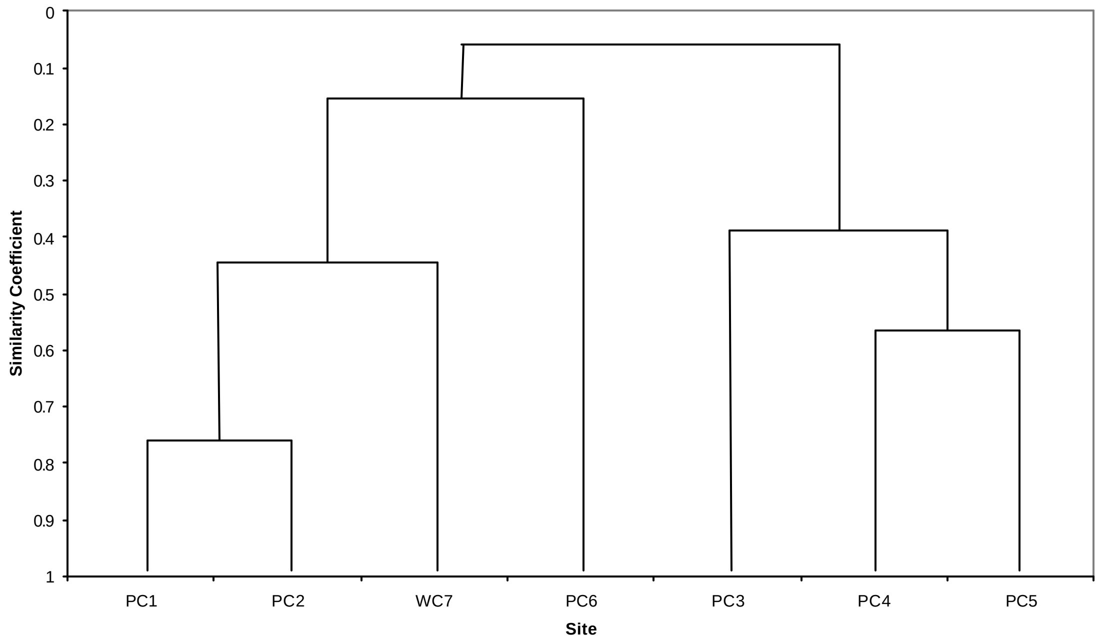


Figure 5.10 Bray-Curtis coefficient of similarity for the first twenty-minutes of shocking and seining in Pecan and Wilson Creeks, April 1999.

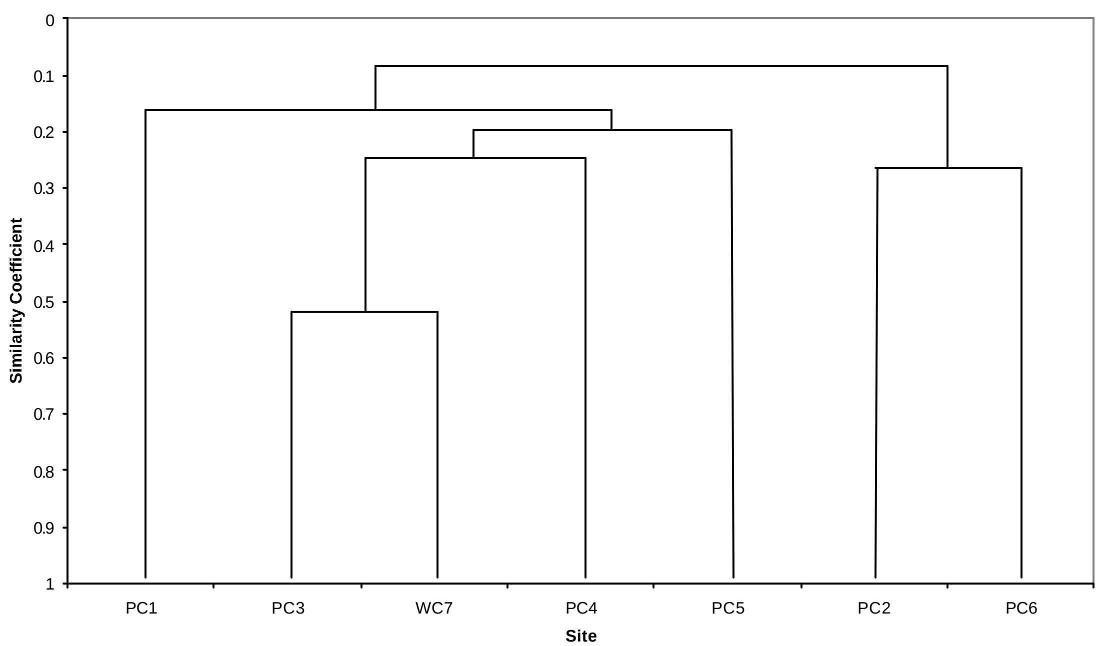


Figure 5.11 Bray-Curtis coefficient of similarity for the first twenty-minutes of shocking and seining in Pecan and Wilson Creeks, July 1999.

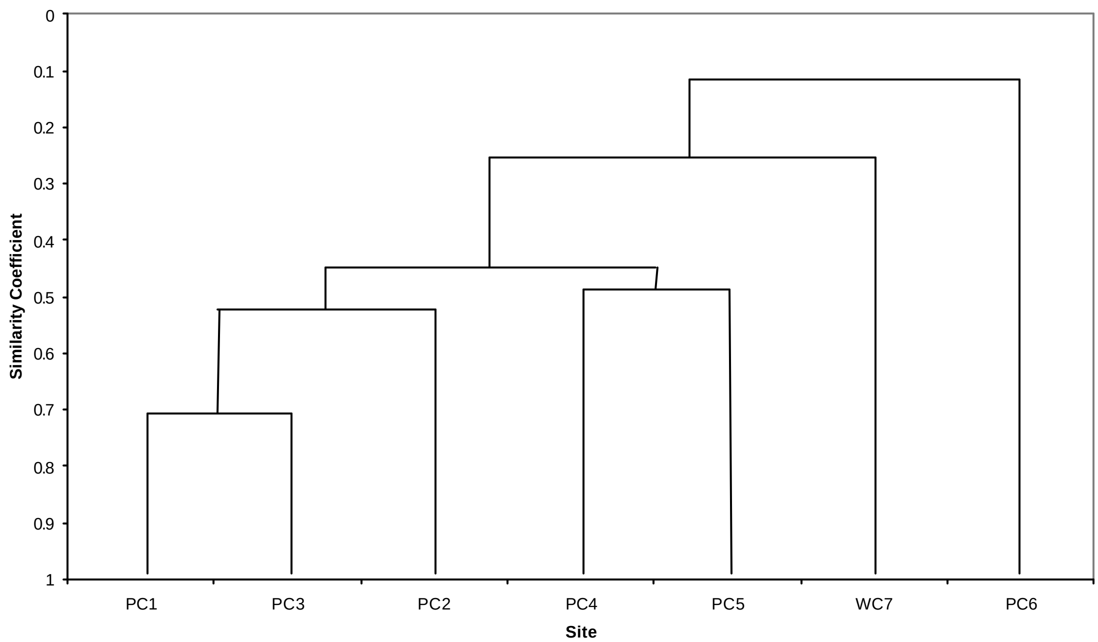
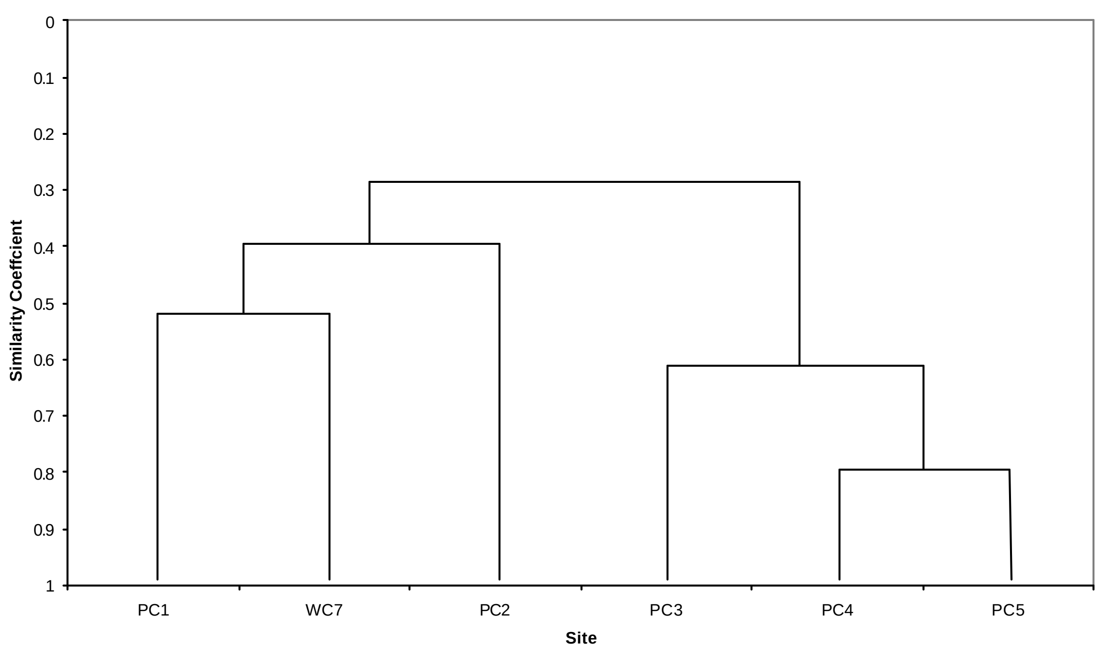


Figure 5.12 Bray-Curtis coefficient of similarity for the first twenty-minutes of shocking and seining in Pecan and Wilson Creeks, November 1999.



CHAPTER 6

RESULTS AND DISCUSSION – PHASE III

In Phase III, the twenty-minute data generated in Phase II was used to asses the fish community of Pecan Creek five years after implementation of de-chlorination (study objective number four). This was achieved by comparing the twenty-minute data with that of Wise (1995) who surveyed the fish community before and after de-chlorination of the PCWRP's discharge.

Chemical and Physical

Most of the chemical measurements in this study concur with Wise (1995) who did not find any extreme measurements that could have a negative impact on the fisheries community of Pecan Creek. Also, water quality data measured by Taylor (work in progress) on Pecan Creek before, during, and after this study was similar to that found in this study. On the other hand, chlorine measurements in this study are in contrast to Wise who found no traces of total residual chlorine in Pecan Creek after dechlorination. As stated above this could be the result of differing testing protocols. Wise used a Hach® 19300 Amperometric Titrator, while this study used a Hach® Digital Titrator applying the DPD-FEAS method. The DPD-FEAS method is less sensitive and prone to more interference than the amperometric method.

Discharge measurments by Wise (1995) were similar to those measured in this study, although she measured flows as high as 22 mgd. It should also be noted that her method generated a less precise estimate of discharge then those used in this study.

Presence/Absence and Species Richness

Fewer species of fish were found in this study than in the previous Wise (1995) study. Wise's study, reported thirty-one different species of fish in Pecan and Wilson Creek. Twenty-nine species were found in Pecan Creek and fourteen species were found in Wilson with twelve species in common. As in this study, Wise (1995) found that the blackstripe topminnow and the central stoneroller were the only two species found in Wilson Creek but not in Pecan Creek. Bluntnose minnow, flathead catfish, and freckled madtom were found in Pecan Creek in this study but were not found in Wise's study. Fish found in Pecan Creek during the Wise study but not in this study were river carpsucker, spotted sunfish, redear sunfish, redfin shiner, sand shiner, white bass, and texas logperch. Common carp, pugnose minnow, and black bullhead were found in Wilson Creek during this study but not in the Wise study, while channel catfish was the only fish found in Wilson Creek during the Wise study but not found in Wilson Creek during this study.

Comparing the species richness in this study with that of the Wise study, similar patterns can be seen. Prior to de-chlorination, Wise found that the background sites tended to have higher species richness then site PC3 immediately downstream of the out fall, such as found in this study. A difference between this study and the Wise (1995) study is that during the Wise study, sites PC4 and PC5 were less affected then site PC3, while in this study site PC4 was the most affected site. Site PC5 was also affected somewhat although it is less conclusive using only the species richness. Another pattern that can be seen is that during the Wise study, once the chlorine disturbance was removed the species richness at the downstream sites increased, sometimes surpassing the background sites. This is similar to this study in that the species richness also increased in the downstream sites after the disturbance. Another difference can be seen in that the species richness of sites PC4 and PC5 tended to be much greater during the Wise study then the species richness found at those sites during this study. Also, site PC3 was the most impacted site during the Wise study while site PC4 was the most impacted site during this study. One major difference in the species richness data is that species richness in the Wise study rebounded within two to three months of removing the chlorine, while in this study it took seven to eleven months to see the species richness rebound. There are several possible reasons for this, which will be discussed below.

Total Abundance

Comparing the total abundance in both studies we see that the same pattern develops. In the presence of chlorine, total abundance of organisms was very low in the downstream sites compared to the background sites. When chlorine is removed the total abundance at the downstream, impacted sites increase. As with species richness, total abundances in the Wise study immediately increased with the removal of chlorine, while in this study, the increases were more gradual taking place over seven to eleven months.

Percent Abundance

As in this study, Wise found many sites that had one species that was fifty percent or more dominant. In a majority of the instances, red shiner and sunfish were the dominant species. Wise also did not see a reduction in the number of sites with a species that was greater then fifty-percent dominant after chlorine was removed. Wise did find that the fish community downstream of the out fall shifted from tolerant sunfish to shiners, sunfish, minnows, and livebearers. This pattern was not evident in this study. A possible explanation for this could be that in the Wise study, the ecosystem was under a low level, chronic stress, which allowed the sunfish to survive in the impacted area where other fish could not. In our study, the ecosystem was under a high level, acute stress, which essentially wiped out the entire fish community. Once the chlorine dissipated, all species returned at approximately the same speed.

Percent Similarity

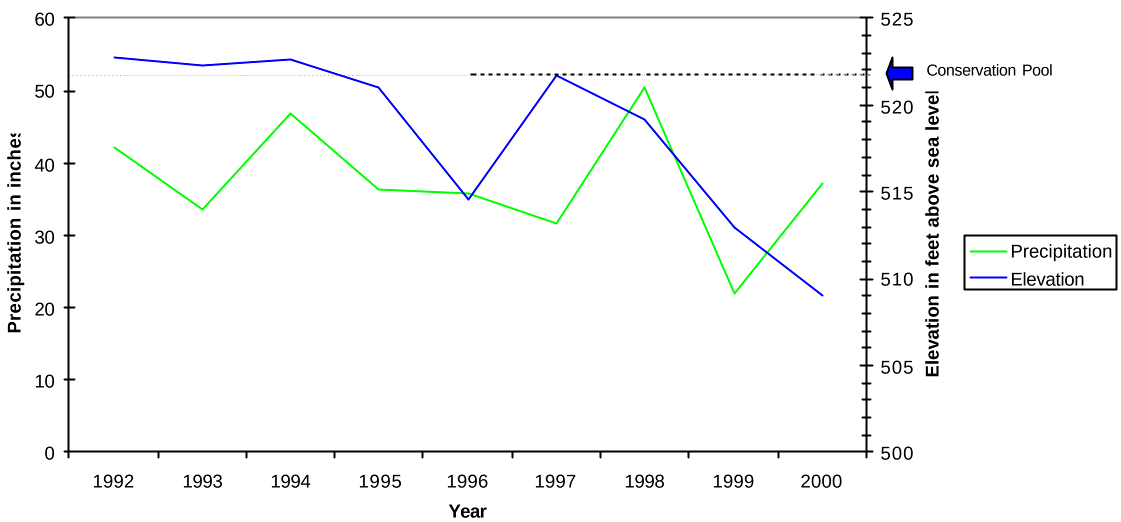
The results of Wise were not specifically the same as those found in this study, but several patterns found in the Wise study were similar to this study. In the Wise study prior to de-chlorination, background sites PC1 and PC2 tended to cluster, while the downstream impacted sites tended to cluster together, but apart from the background sites. During the second to the last sampling event after de-chlorination, Wise found that the downstream sites began to cluster with the background sites indicating that recovery of the impacted sites was occurring. For her last sampling event, the sites began to uncluster. This study had similar results in that immediately after the disturbance, the background sites clustered together and the downstream sites clustered together but apart from the background sites. As recovery progressed, the background sites and the downstream sites clustered together, and by the November sampling event, the background and downstream sites were again clustered apart.

Another similarity between this study and the Wise study is the clustering of the furthest downstream site. In the Wise study site PC5 (her furthest downstream site) always clustered by itself. She attributed this to the fact that the chlorine had dissipated before reaching site PC5 and to the fact that Lake Lewisville backed all the way up to site PC5. This gave site PC5 a nearby colonizing community and different habitat. In this study site PC6 (this study's furthest downstream site) also always clustered by itself, while site PC5 often clustered with site PC4. It is believed that the reason for this difference is that the high chlorine levels were able to reach and affect site PC5, but not site PC6. Also, 1999 was a low water year for Lake Lewisville (Figure 6.1). Figure 6.2 are aerial photographs of the cove during 1994 and 1999. The lake was so low that the water did not even reach the cove that Pecan Creek flows into. This put the colonizing community much further downstream and slowed the recovery of the upstream sites.

Phase III Conclusions

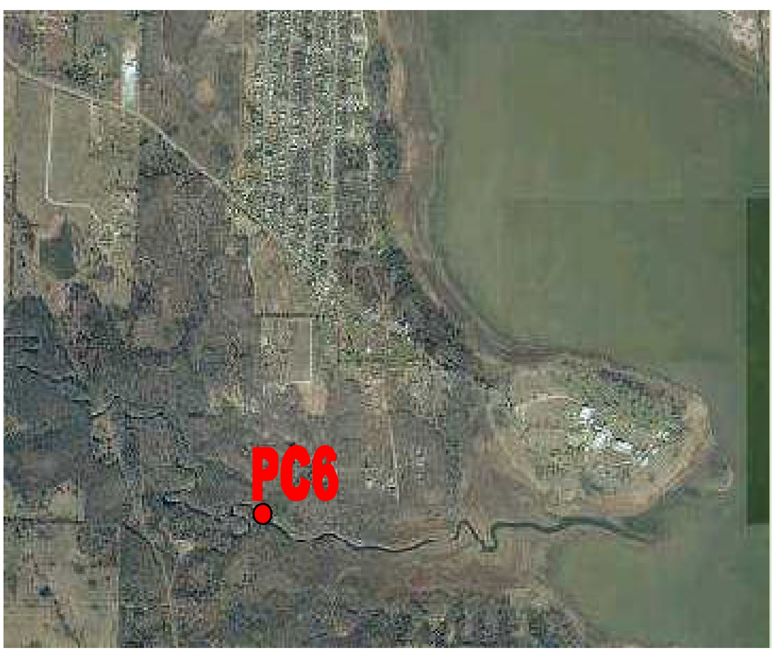
Objective number four, to assess the fish community of Pecan Creek five years after implementation of de-chlorination, was met. This study found similar patterns as those found in the Wise study. Chlorine had a strong impact on the fisheries community with the fisheries community recovering once the chlorine was removed. Differences between this study and the Wise study were also found. The fish community recovered slower and was impacted further downstream in this study than in the Wise study. This was most likely caused by the high concentrations of chlorine used to remediate the spill. Wise also found more species in Pecan Creek in her study then was found in this study. This indicates that possibly Pecan Creek was still recovering beyond the last sampling event in this study, and that another sampling event should have been performed. Considering these differences, it was concluded that null hypothesis number four is rejected. There were differences in the fish community one-year after de-chlorination and five years after de-chlorination as a result of the chlorine disturbance.

Figure 6.1 Yearly total precipitation and yearly average lake elevation at Lake Lewisville, Texas.



* Precipitation data not available for Lake Lewisville in 1996. Lake Grapevine precipitation data was used instead.

Figure 6.2 Aerials of Pecan Creek entering the Camp Copass cove of Lake Lewisville during 1994, top (TxDOT: North Central Texas Council of Governments), and 1999, bottom (NCTCOG, Eyemap™ Aerial Image Maps Courtesy of Vargis LLC).



CHAPTER 7

SUMMARY

This study showed that chlorine has a negative impact on the fisheries community of Pecan Creek. It also showed that recovery can occur once the chlorine has been removed from the system. The analyses used in this study were able to quantify the recovery although some were better than others. This underscores the importance of using a variety of tools and sound judgement when analyzing scientific data.

The twenty-minute sampling strategy was also capable of monitoring the recovery of Pecan Creek with nearly the same conclusions being drawn as with the depletion strategy. On the other hand, the twenty-minute strategy did not accurately represent the fish community as a whole and would not be a useful strategy to examine the fisheries ecology of Pecan Creek.

The results found in this study were similar to that found by Wise (1995) with a couple of slight differences. Species richness and total abundance were initially low at the disturbed sites and rose to and above the background sites after the chlorine was removed. The differences' being that the recovery was slower and the affects felt further downstream in this study than in the Wise study.

In this study four hypotheses were tested and it is concluded that:

Null hypothesis number one is rejected. The chlorine did cause there to be a difference between the sites in Pecan Creek. Most of the analyses showed that background sites had a stronger fish community then the downstream disturbed sites for the first two sampling events. The downstream sites did show recovery and were even comparable to, and sometimes surpassing, the background sites during the last two sampling events.

Null hypothesis number two is rejected. The fish communities in Pecan Creek and Wilson Creek are different with many more species of fish being found in Pecan Creek than Wilson Creek. This is probably the result of differing flow regimes and the proximity of Pecan Creek to Lake Lewisville.

Null hypothesis number three is accepted. There does not appear to be a difference in the Index of Biotic Integrity between Pecan Creek and Wilson Creek. This could be due to the fact that the IBI breaks down when low species richness and low total abundances are found. The IBI is probably better for examining more subtle differences between higher quality sites than between lower quality sites.

Null hypothesis four one is rejected. There were differences in the fish community one-year after de-chlorination and five years after de-chlorination as a result of the chlorine disturbance. Fewer species were found in this study than in the Wise study.

APPENDIX A

FISHERIES DATA

Pecan and Wilson Creek fish species and number captured in fish survey in February 1999.

	PC 1					PC 2					PC 3					PC 4				
SPECIES	Pass 1	Pass 2	Pass 3	Seine	Total	Pass 1	Pass 2	Pass 3	Seine	Total	Pass 1	Pass 2	Pass 3	Seine	Total	Pass 1	Pass 2	Pass 3	Seine	Total
Black Bullhead	2	1	1		4	2	1	2		5			N/S					N/S		
Bluegill Sunfish	8	2	2		12	6	1	2		9	1				1					
Green Sunfish	25	23	16		64	29	22	14		65	2				2					
Longear Sunfish	18	8	5	2	33	21	4	8	2	35	1				1	1				1
Red Shiner	2	5	3	30	40	10	1	4	44	59										
Yellow Bullhead	2		1		3	3	2	1		6										
Mosquitofish	6	9	1	2	18	1		1		2		1			1		1			1
Pugnose Minnow				2	2				1	1										
Golden Shiner				1	1															
Largemouth Bass						1			1	2										
Bullhead Minnow						6	3		1	10						1				1
White Crappie									1	1		1			1					
Warmouth Sunfish						2				2										
Freckled Madtom																				
Common Carp																				
Orangespotted Sunfish																				
Blackstripe Topminnow																				
Stoneroller																				
Bluntnose Minnow																				
Threadfin Shad																				
Channel Catfish																				
Inland Silverside																				
Hybrid Bluegill Sunfish																				
Flathead Catfish																				
Juvenile Sunfish																				
TOTALS	63	48	29	37	177	81	34	32	50	197	4	2	0	0	6	2	1	0	0	3

	PC 5					PC 6					WC 7				
SPECIES	Pass 1	Pass 2	Pass 3	Seine	Total	Pass 1	Pass 2	Pass 3	Seine	Total	Pass 1	Pass 2	Pass 3	Seine	Total
Black Bullhead		4	N/S		4			N/S					1		1
Bluegill Sunfish	1				1						4	2			6
Green Sunfish		1			1						10	5			15
Longear Sunfish	1				1						19	8	3	1	31
Red Shiner				1	1				13	13					
Yellow Bullhead											1	2			3
Mosquitofish	1				1	4	5		24	33					
Pugnose Minnow															
Golden Shiner															
Largemouth Bass												1	1		2
Bullhead Minnow															
White Crappie															
Warmouth Sunfish															
Freckled Madtom	1				1										
Common Carp											1	2	1		4
Orangespotted Sunfish											1				1
Blackstripe Topminnow											5	1			6
Stoneroller												2			2
Bluntnose Minnow															
Threadfin Shad															
Channel Catfish															
Inland Silverside															
Hybrid Bluegill Sunfish															
Flathead Catfish															
Juvenile Sunfish															
TOTALS	4	5	0	1	10	4	5	0	37	46	41	23	6	1	71

Pecan and Wilson Creek fish species and number captured in fish survey in April 1999.

	PC 1					PC 2						PC3					PC 4				
SPECIES	Pass 1	Pass 2	Pass 3	Seine	Total	Pass 1	Pass 2	Pass 3	Pass 4	Seine	Total	Pass 1	Pass 2	Pass 3	Seine	Total	Pass 1	Pass 2	Pass 3	Seine	Total
Black Bullhead	2				2	1	2		1		4			N/S					N/S		
Bluegill Sunfish	4	1			5		1	1			2	3				3	2				2
Green Sunfish	37	26	15		78	31	22	4	10		67										
Longear Sunfish	6	14	11		31	11	25	13	4	1	54	7	2			9	1				1
Red Shiner	12	1	1	3	17	23	84	126	57	316	606	2	1			3					
Yellow Bullhead	1	1			2	1	4	1	1		7										
Mosquitofish						5	4				9		1		1	2					
Pugnose Minnow																					
Golden Shiner																					
Largemouth Bass																					
Bullhead Minnow						3	8	4			15	1				1					
White Crappie																					
Warmouth Sunfish																					
Freckled Madtom																					
Common Carp																					
Orangespotted Sunfish												2	1			3					
Blackstripe Topminnow																					
Stoneroller																					
Bluntnose Minnow									5		5		1			1					
Threadfin Shad																					
Channel Catfish																					
Inland Silverside																					
Hybrid Bluegill Sunfish																					
Flathead Catfish																					
Juvenile Sunfish																					
TOTALS	62	43	27	3	135	75	150	149	78	317	769	15	6	0	1	22	3	0	0	0	3

		PC 5					PC 6					WC7			
SPECIES	Total	Pass 1	Pass 2	Pass 3	Seine	Total	Pass 1	Pass 2	Pass 3	Seine	Total	Pass 1	Pass 2	Pass 3	Seine
Black Bullhead				N/S					N/S				1	N/S	
Bluegill Sunfish	2		1			1	6	1			7	2	2		
Green Sunfish												1	5		
Longear Sunfish	1	2	1			3						6			
Red Shiner										63	63				17
Yellow Bullhead													1		
Mosquitofish							2	1		7	10				
Pugnose Minnow															1
Golden Shiner															
Largemouth Bass															
Bullhead Minnow		5				5									1
White Crappie															
Warmouth Sunfish															
Freckled Madtom															
Common Carp		1	1			2									
Orangespotted Sunfish			1			1						1			
Blackstripe Topminnow															1
Stoneroller															
Bluntnose Minnow			3			3	2			35	37				
Threadfin Shad							6				6				
Channel Catfish								1			1				
Inland Silverside										1	1				
Hybrid Bluegill Sunfish															
Flathead Catfish															
Juvenile Sunfish															
TOTALS	3	8	7	0	0	15	16	3	0	106	125	10	9	0	20

Pecan and Wilson Creek fish species and number captured in fish survey in July 1999.

	PC 1					PC 2					PC 3					PC 4				
SPECIES	Pass 1	Pass 2	Pass 3	Seine	Total	Pass 1	Pass 2	Pass 3	Seine	Total	Pass 1	Pass 2	Pass 3	Seine	Total	Pass 1	Pass 2	Pass 3	Seine	Total
Black Bullhead			1		1															
Bluegill Sunfish												2			2					
Green Sunfish	7	5	9		21	6		5		11	1				1					
Longear Sunfish	5	2	1		8	1	1		3	5	2	2	2	1	7		1			1
Red Shiner				11	11	9	5	3	73	90		1		1	2				2	2
Yellow Bullhead	45	22	3		70	46	15	8		69	56	30	15		101	21	5			26
Mosquitofish	1	3		12	16				1	1			1	6	7					
Pugnose Minnow																				
Golden Shiner																				
Largemouth Bass		1		2	3	1	3	1	7	12				1	1					
Bullhead Minnow											2	1			3					
White Crappie																				
Warmouth Sunfish																				
Freckled Madtom																				
Common Carp												1	1		2	2	1			3
Orangespotted Sunfish																				
Blackstripe Topminnow																				
Stoneroller																				
Bluntnose Minnow																				
Threadfin Shad																				
Channel Catfish																				
Inland Silverside																				
Hybrid Bluegill Sunfish											1				1					
Flathead Catfish													1		1					
Juvenile Sunfish																				
TOTALS	58	33	14	25	130	63	24	17	84	188	62	37	20	9	128	23	7	0	2	32

	PC 5					PC 6					WC 7				
SPECIES	Pass 1	Pass 2	Pass 3	Seine	Total	Pass 1	Pass 2	Pass 3	Seine	Total	Pass 1	Pass 2	Pass 3	Seine	Total
Black Bullhead			N/S										N/S		
Bluegill Sunfish	4	4			8	2	9	5	1	17	1				1
Green Sunfish	12	7			19		1			1	7	1			8
Longear Sunfish	1	3			4		3			3	4	2			6
Red Shiner														2	2
Yellow Bullhead	13	2			15						2				2
Mosquitofish															
Pugnose Minnow															
Golden Shiner															
Largemouth Bass	2				2	1	1		3	5	2	1		5	8
Bullhead Minnow											2				2
White Crappie															
Warmouth Sunfish															
Freckled Madtom															
Common Carp	3				3	1		1		2					
Orangespotted Sunfish															
Blackstripe Topminnow											1			2	3
Stoneroller															
Bluntnose Minnow															
Threadfin Shad															
Channel Catfish	1	1			2		4			4					
Inland Silverside									2	2					
Hybrid Bluegill Sunfish															
Flathead Catfish															
Juvenile Sunfish											2				2
TOTALS	36	17	0	0	53	4	18	6	6	34	21	4	0	9	34

Pecan and Wilson Creek fish species and number captured in fish survey in November 1999.

	PC 1					PC 2					PC 3					PC 4				
SPECIES	Pass 1	Pass 2	Pass 3	Seine	Total	Pass 1	Pass 2	Pass 3	Seine	Total	Pass 1	Pass 2	Pass 3	Seine	Total	Pass 1	Pass 2	Pass 3	Seine	Total
Black Bullhead																		1		1
Bluegill Sunfish		1			1	3	2	2	1	7	12	11	1		24	14	10	3		27
Green Sunfish	27	18	12		57	9	5	5		19	3	1	5		9	5	1			6
Longear Sunfish	20	10	1		31	12	6	2		20	9	4	4		17	26	11	6		43
Red Shiner	15	92	53	7	167	39	20	22	19	100			1		1					
Yellow Bullhead	59	1	5		65	1	5	3		9	16	8	9		33	9	4	4		17
Mosquitofish	1	9	13	4	27	9	7	5	2	23	1	1			2					
Pugnose Minnow																				
Golden Shiner																				
Largemouth Bass	2				2	9	4	4	2	19	1	1			2					
Bullhead Minnow						2	8	7		17										
White Crappie																				
Warmouth Sunfish																		1		1
Freckled Madtom																	1			1
Common Carp											1				1	1	1			2
Orangespotted Sunfish												1			1					
Blackstripe Topminnow																				
Stoneroller																				
Bluntnose Minnow																				
Threadfin Shad																				
Channel Catfish																1		2		3
Inland Silverside																				
Hybrid Bluegill Sunfish																				
Flathead Catfish											3		1		4					
Juvenile Sunfish				1	1	1	2			3										
TOTALS	124	131	84	12	351	85	59	50	24	217	46	27	21	0	94	56	28	17	0	101

	PC 5					PC 6					WC 7				
SPECIES	Pass 1	Pass 2	Pass 3	Seine	Total	Pass 1	Pass 2	Pass 3	Seine	Total	Pass 1	Pass 2	Pass 3	Seine	Total
Black Bullhead			N/S			N/S	N/S	N/S	N/S	N/A	7				7
Bluegill Sunfish	22	11			33					N/A	2			2	4
Green Sunfish	4	7			11					N/A	6			15	21
Longear Sunfish	37	23			60					N/A	3			2	5
Red Shiner										N/A					
Yellow Bullhead	10	8			18					N/A				2	2
Mosquitofish										N/A				1	1
Pugnose Minnow										N/A					
Golden Shiner										N/A					
Largemouth Bass										N/A				8	8
Bullhead Minnow										N/A					
White Crappie										N/A					
Warmouth Sunfish										N/A					
Freckled Madtom										N/A					
Common Carp	2	1			3					N/A					
Orangespotted Sunfish	3				3					N/A					
Blackstripe Topminnow										N/A				13	13
Stoneroller										N/A					
Bluntnose Minnow										N/A					
Threadfin Shad										N/A					
Channel Catfish										N/A					
Inland Silverside										N/A					
Hybrid Bluegill Sunfish										N/A					
Flathead Catfish										N/A					
Juvenile Sunfish										N/A	1				1
TOTALS	78	50	0	0	128	0	0	0	0	0	19	0	0	43	62

APPENDIX B

INDEX OF BIOTIC INTEGRITY METRICS

Index of Biotic Integrity scores for Pecan and Wilson Creeks during the February sampling.

METRIC				SCORE			
	PC1	PC2	PC3	PC4	PC5	PC6	WC7
Total number of fish species	3	5	1	1	3	1	5
Number of native cyprinid species	3	3	1	1	1	1	1
Number of benthic invertivore species	1	1	1	1	3	1	1
Number of sunfish species	3	5	5	1	3	1	5
% of individuals as tolerant species	1	1	3	5	1	3	3
% of individuals as omnivores	5	5	5	5	1	5	3
% of individuals as invertivores	3	3	3	5	3	5	5
% of individuals as piscivores	5	5	5	1	5	1	5
Number of individuals in sample	1	1	1	1	1	1	1
% of individuals as non-native species	5	5	5	5	5	5	1
% of individuals with disease or other anomaly	5	5	5	5	5	5	1
IBI SCORE	35	39	35	31	31	29	31
AQUATIC LIFE USE	Intermed.	Intermed.	Intermed.	Limited	Limited	Limited	Limited

AQUATIC LIFE USE
>48 = Exceptional
41-48 = High
35-40 = Intermediate
<35 = Limited

Index of Biotic Integrity scores for Pecan and Wilson Creeks during the April sampling.

METRIC	SCORE						
	PC1	PC2	PC3	PC4	PC5	PC6	WC7
Total number of fish species	3	3	3	1	3	3	5
Number of native cyprinid species	1	3	3	1	3	3	3
Number of benthic invertivore species	1	1	1	1	1	1	1
Number of sunfish species	3	3	3	3	3	1	5
% of individuals as tolerant species	1	1	3	1	3	1	1
% of individuals as omnivores	5	5	5	5	1	1	5
% of individuals as invertivores	3	5	5	5	5	3	5
% of individuals as piscivores	5	3	1	1	1	1	5
Number of individuals in sample	1	3	1	1	1	1	2
% of individuals as non-native species	5	5	5	5	1	5	5
% of individuals with disease or other anomaly	5	5	5	5	5	5	5
IBI SCORE	33	37	35	29	27	25	42
AQUATIC LIFE USE	Limited	Intermed.	Intermed.	Limited	Limited	Limited	High

AQUATIC LIFE USE
>48 = Exceptional
41-48 = High
35-40 = Intermediate
<35 = Limited

Index of Biotic Integrity scores for Pecan and Wilson Creeks during the July sampling.

METRIC	SCORE						
	PC1	PC2	PC3	PC4	PC5	PC6	WC7
Total number of fish species	3	3	5	1	3	3	3
Number of native cyprinid species	1	1	3	1	1	1	3
Number of benthic invertivore species	1	1	1	1	1	1	1
Number of sunfish species	3	3	5	1	3	3	5
% of individuals as tolerant species	5	1	5	5	1	1	3
% of individuals as omnivores	1	1	1	1	1	1	5
% of individuals as invertivores	1	3	1	1	1	3	3
% of individuals as piscivores	5	5	1	1	5	5	5
Number of individuals in sample	1	1	1	1	1	1	1
% of individuals as non-native species	5	5	3	1	1	1	5
% of individuals with disease or other anomaly	5	5	3	5	5	1	1
IBI SCORE	31	29	29	19	23	21	35
AQUATIC LIFE USE	Limited	Limited	Limited	Limited	Limited	Limited	Intermed.

AQUATIC LIFE USE
>48 = Exceptional
41-48 = High
35-40 = Intermediate
<35 = Limited

Index of Biotic Integrity scores for Pecan and Wilson Creeks during the November sampling.

METRIC	SCORE						
	PC1	PC2	PC3	PC4	PC5	PC6	WC7
Total number of fish species	3	3	5	3	3	N/A	3
Number of native cyprinid species	1	3	1	1	1	N/A	1
Number of benthic invertivore species	1	1	1	3	1	N/A	1
Number of sunfish species	3	3	5	5	5	N/A	3
% of individuals as tolerant species	1	1	3	3	3	N/A	1
% of individuals as omnivores	1	5	1	1	1	N/A	1
% of individuals as invertivores	3	5	3	5	5	N/A	3
% of individuals as piscivores	5	5	5	3	3	N/A	5
Number of individuals in sample	2	1	1	1	1	N/A	1
% of individuals as non-native species	5	5	5	3	3	N/A	5
% of individuals with disease or other anomaly	5	5	1	5	5	N/A	1
IBI SCORE	30	37	31	33	31	N/A	25
AQUATIC LIFE USE	Limited	Intermed.	Limited	Limited	Limited	N/A	Limited

AQUATIC LIFE USE
>48 = Exceptional
41-48 = High
35-40 = Intermediate
<35 = Limited

Index of Biotic Integrity scores for Pecan and Wilson Creeks combining all sampling dates and some sites.

METRIC	SCORE								
	PC1&PC2	PC3,PC4,PC5&PC6	PC1	PC2	PC3	PC4	PC5	PC6	WC7
Total number of fish species	5	5	5	5	5	5	5	5	5
Number of native cyprinid species	5	3	3	5	5	3	3	3	5
Number of benthic invertivore species	1	3	1	1	1	3	3	1	1
Number of sunfish species	5	5	3	5	5	5	5	3	5
% of individuals as tolerant species	1	3	1	1	5	3	3	1	3
% of individuals as omnivores	3	1	1	5	1	1	1	1	3
% of individuals as invertivores	5	3	3	5	3	3	3	5	3
% of individuals as piscivores	5	3	5	5	3	3	5	1	5
Number of individuals in sample	1	1	1	3	1	1	1	1	1
% of individuals as non-native species	5	3	5	5	3	1	1	5	3
% of individuals with disease or other anomaly	5	5	5	5	3	5	5	5	1
IBI SCORE	41	35	33	45	35	33	35	31	35
AQUATIC LIFE USE	High	Intermediate	Limited	High	Intermed.	Limited	Intermed.	Limited	Intermed.

AQUATIC LIFE USE
>48 = Exceptional
41-48 = High
35-40 = Intermediate
<35 = Limited

APPENDIX C

UTM COORDINATES OF SAMPLE SITES

Universal Transverse Mercator (UTM) Zone 14 coordinates of Pecan Creek, Denton County, Texas, and Wilson Creek, Collin County, Texas, site locations.

SITE	EASTING (m)	NORTHING (m)
PC1	677,976	3,675,648
PC2	679,245	3,674,901
PC3	680,318	3,673,679
PC4	680,525	3,673,497
PC5	680,701	3,673,471
PC6		
WC7	714,919	3,677,649
USACOE Survey Mark P243W 1968	680,394	3,673,373

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