THE INFLUENCE OF URBANIZATION ON STREAMS: THE USE OF GIS SPATIAL ANALYSIS TO STUDY LAND USE INFLUENCE ON FISH COMMUNITIES, WATER QUALITY AND PHYSICAL HABITATS IN SOUTHEAST TEXAS

by

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ABSTRACT

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Streams throughout the U.S. have been historically subjected to degradation due to urbanization, agriculture and industry. The influence of urbanization on stream ecosystems is difficult to evaluate, due to many interacting variables. Previous studies have found that the degree of urbanization influences flow regime, pollutant loading and resulting fish community structure. Our study investigated the influence of urbanization on hydrology, physical habitat, water quality, and resulting fish community structure at 8 coastal streams located in Southeastern Texas. Streamflow, physical habitat, water quality and fish community data were collected at these sites during 2011. The stream sites were selected to represent a variety of land uses ranging from highly urbanized, to minimally urbanized or reference conditions. In order to determine the degree of urbanization within each watershed

ArcGIS software was used to assess land use. Total impervious area (TIA) and percent impervious area (PIA) was used for each watershed as a simple index of urbanization. TIA and PIA were estimated using 2006 impervious surface data obtained from the United States Geological Survey. Various fish community metrics including the Index of Biological Integrity (IBI), Shannon-Weiner diversity index, Pielou's evenness and species richness, were used to evaluate the impact of urbanization on fish community structure. Estimated land use data was compared to IBI scores, fish community metrics, water quality, and physical habitat. Several statistical analysis methods including Pearson correlation analysis, Analysis of Variance (ANOVA), principle component analysis and cluster analysis were used to evaluate the response of fish communities to land use and associated hydrology, physical habitat, and water quality. We found that IBI scores and stream fish diversity were negatively correlated with PIA. We also observed positive correlations between PIA/TIA and orthophosphate and combined nitrate and nitrite concentrations among the sites. We did not observe any strong correlations between the amount of impervious area within the upstream watershed and physical habitat metrics, with the exception of a negative correlation between TIA with mean instream cover, riparian width and tree canopy cover. Our study suggests that future management plans could include a threshold of impervious area for a watershed, in order to protect or promote biological integrity and water quality.

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INTRODUCTION

Management overview

Harris County, Texas contains the City of Houston, which is currently the 4th largest city in the nation (U.S. Census 2010a). Harris County has experienced rapid population growth, increasing from a little over a million people in 1960 to over 4 million people in 2010 (U.S. Census 2010b). The Texas Water Development Board (2011) estimated that Harris County will increase to over 6.2 million people by 2050 at current population growth rates. Exponential population growth, in Southeast Texas and across the country, has resulted in waterways becoming severely impacted due to increased agricultural activity, urbanization and industrialization (Copeland 2010). Anthropogenic stress on aquatic environments throughout America caused many waterways to become highly polluted (Carpenter et al. 1998). Copeland (2010) explained that as a result, water became unsafe to drink, fish became unfit for human consumption and areas available for recreational activities were restricted.

The Clean Water Act (CWA) was passed in 1972 out of urgent need for remediation,. The CWA regulates pollutants released from point and non-point source pollution and thus helps to restore the physical, chemical and biological communities of surface waters (Copeland 2010). Section 303d of the CWA mandates states to determine water bodies as impaired or unimpaired (TCEQ 2010a). Impaired is defined as water quality parameters in noncompliance with state water quality standards. Water quality standards in Texas are based on, but are not limited to, a water body's designated uses, numerical criteria, narrative criteria and an antidegredation clause. Designated uses refer to providing quality water for aquatic life, recreational activities and public water supply. While narrative criterion has been developed for all water bodies, numerical criteria have only been developed for water bodies with sufficient data. Lastly, water bodies determined to be of intermediate, high or exceptional quality, fall under the antidegredation policy in which they receive additional protection. The antidegredation policy requires states to develop guidelines that protect the current uses of waterways and thus preventing additional degradation. The policy also provides rigorous protection to the highest quality waters of the state.

The state must also determine a Total Maximum Daily Load (TMDL) for impaired bodies of water. A TMDL is the amount of a single pollutant, a body of water can receive without violating state water quality standards (TCEQ 2010a). However, TMDL have been criticized by researchers including Stow (2003) since they are based on crude mathematical models simulating very complex environments. A review by USEPA (2000) explained that streams and rivers have benefited greatly from the passing of the CWA, however many are continuing to degrade due to anthropogenic stressors, while others may never recover from the initial degradation. Continued degradation, in some cases, is due to heavy metals and natural and synthetic organic compounds which are persistent in aquatic environments (USEPA 2000). On the other hand, Hubbs et al. (2008) documented that due to anthropogenic stressors, sensitive species have become threatened or extinct which leaves some Texas waterways indefinitely altered.

Water quality and urbanization

Water quality monitoring is the most common method to evaluate pollution. Conventionally analyzed parameters include water temperature, pH, alkalinity, dissolved oxygen (DO), nitrogen, phosphorus, conductivity, chlorophyll-*a*, total suspended solids (TSS) and turbidity (USEPA 2000). Countless studies have documented anthropogenic impacts to watersheds (Reviewed by Paul and Meyer 2001). Based on multiple studies (Booth and Jackson, 1997; Roy et al. 2003; Schoonover et al. 2005), increased urbanization surrounding aquatic habitats often resulted in elevated nutrients, increased erosion and sedimentation, changes in flow regimes and decreased natural riparian corridor habitat. The reduction of riparian habitat often leads to higher levels of TDS, nitrogen, phosphorus, and conductivity (Roy et al. 2003; Schoonover et al. 2005). It is imperative to manage water quality to maintain these variables within a range of concentrations that will support a healthy ecosystem in order for the native inhabitants to successfully survive and reproduce. However, the ranges of variables vary across aquatic habitats and geographically (Dodson 2005).

Temperature is very important to aquatic life processes because it influences reaction rates and due to differential physiological tolerances of diverse organisms (Brower et al. 1998). Temperature can be influenced by urbanization due to reduction in canopy cover as a result of lost or loss of riparian habitat. The main cause of riparian habitat loss is deforestation caused by agricultural activities and urbanization (Roth and Allen 1996; Sweeney et al. 2004).

Turbidity is a measure of the clarity of water which both affects and is influenced by algae growth depending on the original causes of the turbidity. Turbidity can be caused by dissolved chemicals, microbes (including algae) and suspended particulates (Brower et al. 1998). Roy et al. (2003) explained how turbidity can be influenced by human disturbances such as elevated nutrients and increased erosion and runoff (Roy et al. 2003). Studies by Newcombe and Jensen (1996) determined that increased turbidity influences fish in many ways including reduced feeding rates, physiological stress, reduced growth rates, increased predation and decreased reproduction.

Commonly examined forms of nitrogen include nitrate, nitrite, and ammonia. Nitrogen containing compounds enter bodies of water from municipal and industrial waste water, effluent, land runoff and agricultural activities (Dodson 2005). These forms are readily assimilated by primary producers and are indicators of potential over-enrichment (Brower et al. 1998). High levels of nutrients often result in hypoxic conditions due to algal and plant community decomposition, which are symptoms of eutrophication (Dodson 2005). Hypoxic conditions commonly result in fish kills (Heath 1995). Eutrophic conditions are also usually correlated with high phosphorus concentrations in freshwater symptoms since it is a limiting nutrient (Dodson 2005). Phosphorus, unlike nitrogen, is normally scarce and not replenished by biological processes such as nitrogen fixation (Dodson 2005).

Ammonia often enters the water though effluent and decomposition of organic matter (Heath 1995). In addition to serving as a nutrient, the unionized form of ammonia is directly toxic to fish (Heath 1995). Urban watersheds and fish inhabitants may be at higher risk to the toxicity of the non-ionized form of ammonia, due to excessive plant growth which commonly occurs in these systems. The non-ionized form of ammonia increases in concentration due to elevated pH levels, which is a result of high rates of photosynthesis causing an uptake of carbon dioxide (Heath 1995).

Biotic response to urbanization

While many early studies focused primarily on water quality response to urbanization and associated pollution, recently researchers have investigated biotic responses (Fitzpatrick et al. 2004; Helms et al. 2005). Biotic sampling differs from a water quality sample which is a mere snapshot in time and therefore is only a glimpse at the stream's health. For this reason, examinations of biotic communities in aquatic ecosystems became popular. Since aquatic organisms are exposed over generations to their physical environment, they integrate affects from various stressors over long periods of time (Helms et al. 2005). Biological studies have primarily focused on fish and macroinvertebrate communities as indicators of stream and river health. Biological community structure can be used as an ecological indicator since they exhibit differential tolerance to habitat stressors. Numerous studies have documented decreases in diversity, increases in exotics and homogenization of fish communities as streams become impacted (Reviewed by Helms et al. 2005). There are inherent difficulties in determining the direct influence of urbanization on biotic and abiotic factors. As a result, researchers have developed several biological indices, sampling methods and land use analysis to clarify the relationships between stressors and biological community response.

The use of geographical information system tools to study urbanization

Past studies have employed a wide variety of methods to estimate the influence of urbanization on physical habitats and biological communities. These studies have used computer modeling programs, population density, state land use maps overlaid with watershed boundaries and more recently computerized geographic information systems (GIS) (Wang et al. 2001; Fitzpatrick 2004; Helms et al. 2005). The use of GIS has rapidly increased in biological studies since it provides a visual and spatial representation of land use data (Fitzpatrick 2004). The United States Geological Survey (USGS) provides National Land Cover Data (NLCD) as well as an impervious surface layer, which allows the quantification of total impervious area (TIA) and percent impervious area (PIA). Impervious areas are defined by Booth and Jackson (1997) as areas in which water cannot penetrate the ground due to pavement, buildings or asphalt. They also explained that TIA and PIA have been widely adapted and used as a means to estimate the degree of urbanization. High amounts of impervious area have been correlated with increased flooding, stream bank erosion and decreased biodiversity and water quality (Booth and Jackson 1997; Wang et al. 2001). The use of GIS to determine the TIA and PIA of a catchment provides a comprehensive method to compare biological, physical and chemical data.

Fish community alterations, IBI and urbanization

Many studies have documented the response of fish communities to increased urbanization (reviewed by Allen 2004; Walsh et al. 2005). The techniques used to analyze fish community health in streams are wide-ranging. Studies commonly examine fish diversity, abundance, and health and their relationship to altered physical, hydrological and water quality conditions. Once data is collected researchers use statistical methods to examine correlations between biological factors and urbanization. However, Karr (1981) developed a new method, termed the Index of Biological Integrity (IBI), which is a quantitative and comprehensive scoring system that reflects community structure and perceived quality. The scoring of IBI's are based on species richness and composition, trophic composition, proportion of tolerant and intolerant species, occurrence of non-native species and fish abundance and condition (TCEQ 2007b). In general, IBI's characterize fish communities based on richness (adjusted for watershed size), proportions of specific trophic guilds, abundance, non-native species and fish health. The application of IBI's has become very popular throughout the U.S. and other countries as a cost effective method to evaluate the response of fish communities to changes in stream quality. Studies have found IBI's to be highly correlated with the degree of urbanization and agriculture (Wang et al. 2001). Wang et al. (2001) also found that some streams contained an altered fish community at a threshold value of 8-12 PIA.

One concern with IBI's is whether they are applicable to a variety of stream types and locales. As a result, a variety of modified IBI's were developed by different agencies across the United States (Linam et al. 2002; Roy et al. 2003). IBI's have been modified according to warm and cool water streams, as well as by ecoregions which can contain diverse fish communities. Initially, the Texas Commission on Environmental Quality (TCEQ), formerly called the Texas Natural Resource Conservation Commission (TNRCC), developed a state wide IBI for Texas in 1999 (Twidwell and Davis 1989). Researchers did not find this method suitable since fish community distribution differs greatly regionally and according to water parameters.

Texas has a general trend of decreasing fish diversity from east to west (Hubbs et al. 2008). As a result, Linam et al. (2002) conducted additional studies and developed a regionalized IBI for Texas streams. Their study was state wide and analyzed 62 reference sites at 11 of the 12 aquatic ecoregions of Texas. The study analyzed reference streams ("least impaired sites") in order to establish specific IBI's parameters for ecoregions. The regionalized IBI provides a systematic method to administer site specific IBI's. Results of new stream fish community studies conducted in these ecoregions can be compared to the "expected" IBI and individual component metrics to determine the degree of degradation in the community.

IBI's assign numeric values according to abundance, taxa, and trophic guilds, which are summed and placed into stream quality classes (excellent, good, fair, poor and very poor). In Ecoregions 34 and 35, the Western Gulf Coastal Plain, IBI scoring systems are divided into three main categories including species richness and composition, trophic composition and fish abundance and condition (Linam et al. 2002). Species richness and composition are further divided into six categories including abundance of species, native cyprinids, benthic invertivore, sunfish, intolerant, and tolerant species. Trophic composition is divided into omnivores and invertivores. Fish abundance and condition are separated into abundance in individuals seined and/or, electrofished, number of fish collected per minute electrofishing, non-native species, and number of individuals with disease or anomalies.   These metrics were chosen by professionals on a regional basis, based on an analysis of least impacted streams as the best portrayal of fish diversity, abundance, feeding guilds, tolerance, health condition and non-native species of a stream. Although IBI's are an insightful method to evaluate the fish community; physical habitat and water quality assessments are completed in association to investigate potential interrelated causal variables and possible sources of fluctuating IBI scores.

Physical habitat alterations and urbanization

Habitat alteration has often been associated with urbanization. There are a variety of methods established to evaluate the physical habitats of streams. Commonly studied attributes include riparian buffer, bottom sediment type, the amount and types of instream cover, stream flow and channel sinuosity. In order to establish statewide comprehensive methods to evaluate physical attributes of a stream, TCEQ published the Surface Water Quality Monitoring (SWQM) Volume 2 chapter 9 Physical Habitat of Aquatic Ecosystems (TCEQ 2007b). These standardized methods are based on countless years of studies of stream dynamics and theory. TCEQ (2007b) also developed a Habitat Quality Index which is based on a combination of these attributes; however for our study we only examined critical physical habitat attributes.

The physical habitat characteristics we assessed included stream flow, instream cover, substrate stability, bank stability and riparian buffer width. These variables can provide useful insight when evaluating potential effects on biological communities. Streamflow is based on the amount of water a drainage basin receives which in turn flows into streams and is dependent on precipitation, seasonal variation and anthropogenic influences. A study by Poff et al. (1997) referred to streamflow as “the master variable” because it influences almost all other stream variables including water quality, physical habitats and ultimately aquatic organisms. A study by Booth and Jackson (1997) found that increases in impervious surface area can alter stream flow and lead to high flow events that can erode stream banks and increase sedimentation. The erosion of stream banks and deposition of organic matter increases levels of nitrogen and phosphorus which can lead to eutrophic conditions (Wetzel 2001). Eutrophic conditions, as stated earlier, can have negative effects on fish communities and may influence IBI scores overtime.

Instream cover is habitat used by fishes for refuge including boulders, submerged vegetation, undercut banks and large woody debris. A study by Proboszcz and Guy (2006) determined instream cover to be important for protection from predators, especially for juvenile fish. As a result, instream cover is an important aspect to assess in stream studies and is it often a restoration technique as well.

Riparian buffer is the terrestrial area surrounding a stream which may be covered in shrubs, grasses or trees (Dodson, 2005). A study by Zaimes et al. (2008) showed that an intact riparian zone can filter pollutants from water before entering streams. However, riparian zones are often deforested which can lead to increased erosion, widening of streams and loss to the natural filtration process (Sweeney et al. 2004).

Project significance

As stated earlier, streams that receive water from urban land often exhibit an altered flow regime, elevated nutrients, altered physical habitats, reduced biotic diversity and increases in tolerant species. A study by Walsh et al. (2005) discussed these occurrences, commonly called the “urban stream syndrome” and the need for a cure. Only through further research will we be able to understand the influence of urbanization on streams and approaches to prevent impacts on flow regimes, water quality, physical habitats and fish communities.

Hubbs et al. (2008) reported that 44% of freshwater fish species in Texas had attained a status of “conservation concern”. Anderson et al. (1995) compared fish species in a 33 year state wide study in Texas and found significant decreases in ictalurids, cyprinids, catostomids, and percids. They also documented increases in tolerant species like *Gambusia affinis* and *Menidia beryllina* which is related to habitat alteration (Anderson et al. 1995). Hubbs et al. (2008) reported many fish species are imperiled throughout Texas due to impaired water quality, decreased water quantity, loss of habitat quality and introduced species. In order to create and administer fish conservation programs we must first have comprehensive methods to determine the level of degradation in a watershed. The use of IBI’s and impervious area provide useful methods to determine the quality of the fish community and habitat, respectively at the watershed scale. Although many studies have reported the negative influences of urbanization on aquatic habitats, few studies have quantified urbanization through GIS to obtain impervious area and compare these data with IBI’s, physical habitat evaluations and water quality data. Studies and data of this kind are lacking in the Western Gulf Coastal Prairie of Texas.

Our study was conducted during one of the worst droughts in Texas’ history (NOAA 2012). As a result of the drought, many reservoirs were at drastically low levels, base flows dropped and wildfires were prevalent. The drought most likely influenced our study in several ways including decreased flows, decreased fish habitat and perhaps increased levels of water quality variables concentration, as a result of drying down effects (Golladay and Battle 2002). Due to the drought, one study site had to be dropped since it was reduced to a series of shallow pools, covered in emergent vegetation and algae. Overall the drought may have influenced our study in many unforeseen ways.

Project objectives

1. Quantify Total Impervious Area and Percent Impervious Area for each of the eight stream study sites located in Southeast Texas using GIS.

2. Statistically compare Total Impervious Area and Percent Impervious Area data with site specific measurements of water quality, physical habitat, streamflow and fish community metrics.

3. Using results of this study, evaluate the role of impervious land cover and urbanization on Southeast Texas stream fish communities.

METHODS

Background and sites

The Southeastern region of Texas has been historically subjected to high population growth, industry and agriculture. The stream sites selected for this study represent a range of land use types including forested, agricultural, moderately urbanized and highly urbanized. This was done purposely to represent a spectrum from urbanized to reference sites. Selected sites were located in the ecoregions described by Texas Parks and Wildlife Department as the Western Gulf Coastal Plain of Texas (TPWD 2011). Fish community and water quality sampling were conducted at eight stream sites located in Harris, Brazoria, Galveston, and Montgomery counties of Southeastern Texas (Figure 1). GPS sample location, TCEQ stream segment number, watershed size, hydrological unit code and ecoregions for each site are presented in Table 1. Physical habitats and streamflow at each study site were evaluated using several methods including 1) visual inspections, 2) flow meter and 3) measurements of bank slope and riparian buffer width. The area, total number of waste water outfalls, PIA and TIA of each stream site's watershed were calculated using ArcGIS 9.3. Lastly, we conducted a literature review of each stream's status of impairment, according to the 303d listings of 2010. A detailed description of each method is provided below.

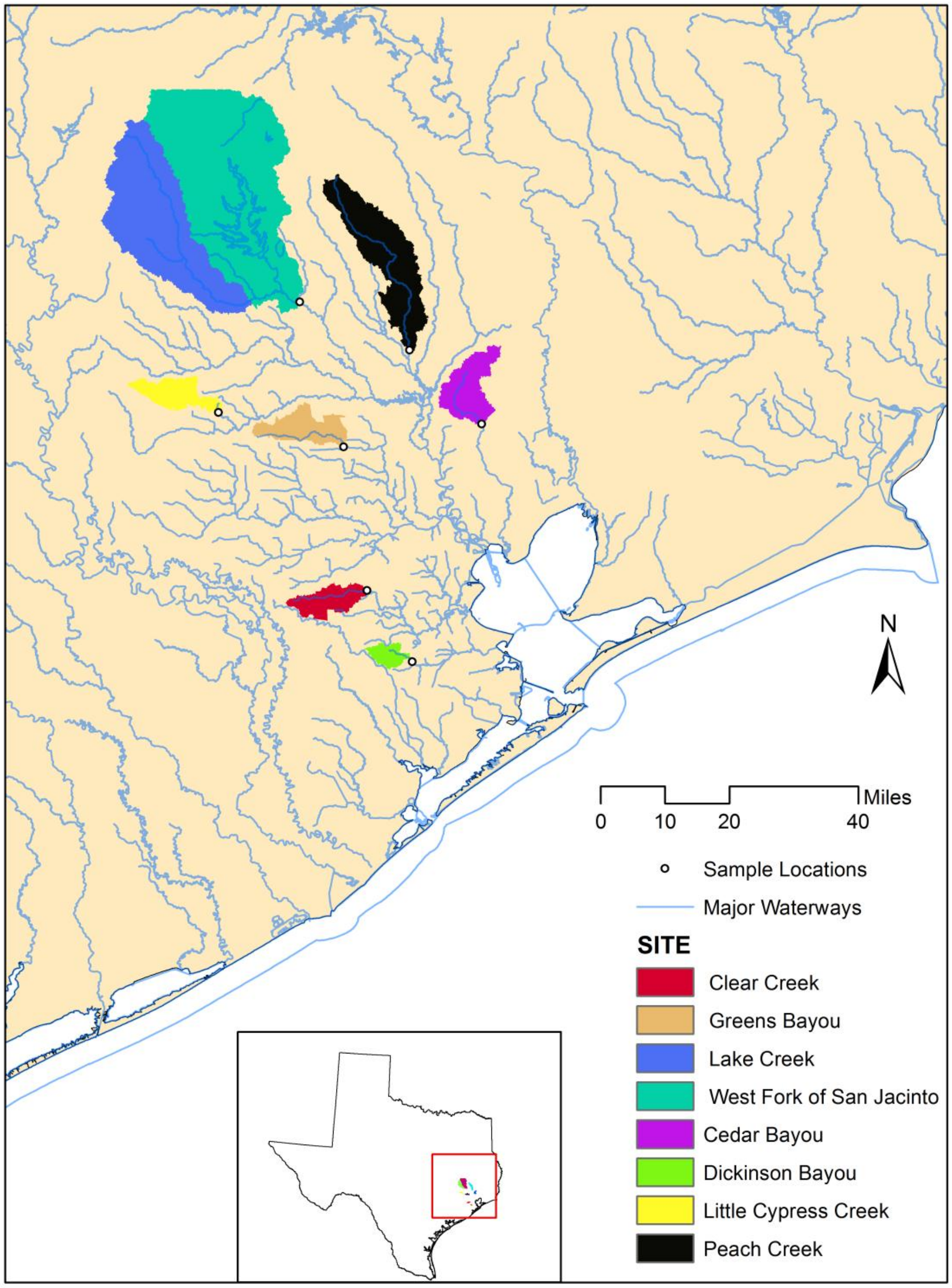

Figure 1. Map depicting the location of sampling sites in Southeastern Texas.

Table 1. Summary of site GPS location, TCEQ stream segment number, watershed size, hydrological unit code and ecoregion (TPWD 2011).

Site	Latitude	Longitude	TCEQ Segment #	Watershed Size (km^2)	HUC 8 Name	Ecoregion
Dickinson Bayou	29.43407	-95.16968	1104_01	44.5095	West Galveston Bay	34
Clear Creek	29.59755	-95.28609	1102_02	103.896	West Galveston Bay	34
Cedar Bayou	29.97216	-94.98531	902_01	167.9985	North Galveston Bay	34
West Fork of the San Jacinto	30.24476	-95.45567	1004_02	1329.9706	West Fork San Jacinto	35
Lake Creek	30.25253	-95.58187	1015	754.7895	West Fork San Jacinto	35
Greens Bayou	29.92139	-95.34256	1016_03	139.12381	Buffalo-San Jacinto	35
Peach Creek	30.13828	-95.17014	1011_02	403.4727	East Fork San Jacinto	34
Little Cypress Creek	30.00053	-95.66554	1009E	116.1999	Spring	34

Fish community sampling, water quality sampling and physical habitat evaluation closely followed the procedures outlined in the TCEQ SWQM Procedures Volumes 1 and 2 (TCEQ 2007a, 2007b). Fish community sampling, water quality sampling and physical habitat evaluation were conducted twice within the TCEQ index period (March 15 to October 15). TCEQ developed the index period in order to provide the most standardized accurate representation of fish communities, water quality, and physical habitat evaluation during the most stressful period of the year when water temperature is typically the highest and dissolved oxygen levels are usually lower (TCEQ 2007a, 2007b). The first sampling event was conducted during the spring Index period between April 26 and June 14, 2011 and the second event was conducted during the summer index period between July 14 and August 3, 2011(TCEQ 2007a). Sampling was conducted during base flow conditions to facilitate safe sampling of fish communities and representative water quality and physical habitat evaluations (TCEQ 2007a, 2007b). The stream segments were determined by measuring the five transects and determining an average stream width (TCEQ 2007b). This average stream width was multiplied by 40 to determine the length of the stream segment to be sampled (TCEQ 2007b).

Geographical information systems analysis

Watershed area, total impervious area and percent impervious area were evaluated for each of the eight sites using ArcGIS 9.3. All layers were projected in the NAD83 (North America Datum 83). Data used for this analysis included the National Elevation Data (NED) and impervious surface layer (ISL) which were both downloaded from the United States Geological Survey (USGS) seamless website (http://seamless.usgs.gov/). The most recently completed impervious surface layer was categorized from the National Land Cove Data 2006 (NLCD). The NED and NLCD were pixilated at a resolution of approximately 30 x 30 meter (1 arc second) and 30 x 30 meter, respectively.

A watershed is defined as the upslope area that contributes water to a specific outlet or pour point. The watersheds above the lowest transect at each site were delineated using the NED. The watershed area above the lowest transect was used since it represents the area which influences the water quality, fish and physical habitat within our stream reach. The NED was imported into ArcGIS and converted into a depressionless raster digital elevation model (DEM) through a series of steps (Smith et al. 2009). In order to delineate a watershed in a GIS, two functions were completed including flow direction and filling of sinks (Smith et al. 2009). The flow direction function uses algorithms to determine the direction of water flow based on the DEM or NED (Smith et al. 2009). The flow direction of the DEM is altered by sinks (Smith et al. 2009). Sinks are low elevation areas in the DEM that could be natural features (i.e. vernal pools, reservoirs) or errors in the data (Smith et al. 2009). As a result we filled the sinks in order to achieve a depressionless DEM. Lastly, the watersheds were delineated by inputting the GPS (Global Positioning System) points at the bottom transects of each stream site and the depressionless flow direction (Smith et al. 2009).

The impervious area of each site was calculated using the delineated watersheds and the impervious surface layer (ISL). The ISL is a raster data layer divided into 30 x 30 meter pixels which are categorized by USGS through algorithms as a value of 0 to 100 percent impervious area. We used the zonal statistics tool in ArcGIS to calculate each watersheds mean percent of impervious area.

We also calculated the number of municipal and industrial wastewater outfalls located within each delineated watershed. The feature GIS layer titled municipal and industrial wastewater outfalls was downloaded from the TCEQ website (http://www.tceq.texas.gov/gis/sites.html). Outfalls in the layer are point source discharge from domestic and industrial facilities or stormwater based. This layer was analyzed in ArcGIS 9.3 using zonal statistics to determine the total number of wastewater outfalls located within each watershed.

Physical habitat evaluation

The habitat evaluation followed several of the TCEQ SWQM methods of Volume 2 chapter 9 Physical Habitat of Aquatic Ecosystems (TCEQ 2007b). Five transects were evaluated at each stream site. Each of the transects included three meters upstream and downstream resulting in a six meter width sample area (TCEQ 2007b). At each transect several physical habitat characteristics were examined including instream cover, substrate stability, stream bank stability and slope, riparian buffer vegetation and canopy cover (TCEQ 2007b). Instream cover was assessed visually as a percent of the six meter wide transect in which fish could use as refuge. Instream habitat types including woody debris, submerged vegetation, undercut banks and cobble. Substrate stability was determined within the six meter wide sample area as percent gravel or larger. Gravel was classified as greater than 2 mm (TCEQ 2007b). Bank erosion potential was assessed as a percentage of the bank that could be easily eroded and therefore the bank was lacking intact vegetation. A low percentage was associated with stable banks showing little sign of erosion (TCEQ 2007b). Bank slope was measured with a clinometer on each bank of each transect. Bank stability in streams is associated with high erosion, bank failure, and steep bank angles (TCEQ 2007b). An unstable bank was classified as an average of transect angles higher that 60 degrees (TCEQ 2007b). Riparian buffer vegetation was measured as meters of vegetation extending from the edge of the stream (TCEQ 2007b). An extensive riparian buffer was classified as greater than 20 meters and a narrow buffer was less than 5 meters (TCEQ 2007b). Canopy cover was measured with a densitometer at each transect and followed TCEQ (2007b) methodologies. This data was used to make interpretations of IBI scores, water quality and TIA. It should be noted that the classifications stated were for basic site description and were not used in statistical analysis.

Streamflow was measured in an area with laminar flow and very few obstructions with a SonTek flow meter (Doppler method). We followed TCEQ (2007b) methods in which the stream width must be measured and divided into equally sized cells or segments. Streams 5 to 10 feet wide were divided it into 10 cells, while streams greater than 10 feet were divided into 20 cells. Measurements were taken at the midpoint of each cell at 6/10 of the depth. If the stream depth was greater than 2.5 feet we took flow measurements at two depths at 2/10 and 8/10 of the depth. We recorded the depth, velocity and width of each cell and computed the stream flow. The flow meter's inboard computer calculated the flow and we compared our handwritten results to assure accuracy. See appendix A for streamflow data sheet.

Water quality sampling

Multiple water quality variables were analyzed for each of the eight sites during both sampling events. Variables included water temperature, dissolved oxygen (DO), pH, specific conductivity, combined nitrite and nitrate, ammonia, chlorine, total orthophosphate, chlorophyll-*a*, pheophytin-*a*, turbidity and total suspended solids (TSS). Dissolved oxygen, pH, temperature, and specific conductivity were analyzed in the field using data sonde YSI model 600xl. These measurements were taken at the stream thalweg at a depth of one foot. Water samples for combined nitrite and nitrate, ammonia, chlorine, orthophosphate, turbidity, and total suspended solids (TSS) were collected in 1000 ml plastic bottles, placed in an ice cooler and analyzed in the lab using a HACH or standard methods. Samples for chlorophyll-*a* analysis were collected in 1000 ml amber bottles to prevent degradation due to sunlight. Chlorophyll-*a* was analyzed since it is the main pigment in photosynthetic organisms and can indicate the degree of primary production occurring (Wetzel 2001). Pheophytin-*a* was measured since it provides information on the physiological health of the Chlorophyll-*a* sample. This is due to portions of degraded photosynthetic organisms being converted from chlorophyll-*a* to pheophytin-*a as* they lose magnesium (Eaton et al. 2005). Free chlorine was measured with a test kit in the field due to its quick degradation. Free chlorine was measured since it is the active form of chlorine that waste water treatment plants use to disinfect water and is harmful to aquatic organisms (Wetzel 2001). The parameters and methods used in the lab (Field test kit for chlorine) are listed in Table 2.

Table 2: Summary of parameters analyzed in the lab including combined nitrate and nitrite, orthophosphate, turbidity, chlorophyll-*a* and TSS (Chlorine in field test kit). Also displayed is the maximum holding time, detection limit and the HACH or standard method used for each parameter listed.

Parameter	Holding Time	Detection Limit	HACH or Standard Method
Ammonium (NH_3^- as N)	28 Days	0-2.5 mg/L	HACH 8038
Nitrate + Nitrite ($N0_3^-$ + $N0_2^-$ as N)	48 Hours	0-0.5 mg/L (low range) 0-5.0 mg/L (mid range)	HACH 8192
Orthophosphate	28 Days	0-2.5 mg/L	HACH 8048
Turbidity	48 Hours	0.01 NTU	SM 2130 B
Chlorophyll-*a* & pheophytin-*a*	24 Hours/28 Days	0.001 mg/L	SM 10200 H
Chlorine (Free)	Immediate	0-2.00 mg/L	HACH 8021
TSS	7 Days/NA	0.001 mg/L	SM 2040 D
Total (T or M) Alkalinity mg/L as $CaCO_3$	14 Days	10-400 mg/L	Field Test Kit

Fish community sampling and indices

Fish community sampling followed procedures described in the TCEQ SWQM Procedures Volume 2, chapter 3: Freshwater fish (TCEQ 2007b). The main objective in fish sampling was to achieve a representative sample of the stream fish community. Fish sampling consisted of two active methods including seining and electrofishing. The type of seines used depended on the type of habitat sampled. Wider areas in the sample sites were sampled with a 15 x 4 feet seine with 1/8 inch mesh size and narrower areas were sampled with 6 x 4 feet seine with 1/8 inch mesh size. The length, width and mesh size were selected to collect the most representative sample of fish while reducing drag in the water column. The selected seine size collected any fish larger than 1/8 of an inch, however larger fish are known to evade seine capture. In this case electrofishing gear may be more efficient for capture of larger fish. A minimum of six functioning seine hauls were completed covering a minimum of 60 meters (TCEQ 2007b). Functioning seine hauls required that the seine is kept securely on the bottom and sides, not allowing fish escape (TCEQ 2007b). If it was suspected that a significant number of fish escaped, the corresponding seine haul was not counted and was repeated.

Electrofishing was conducted with the Smith-Root LR-24 electrofishing backpack. The electrofishing backpack was powered by a 24 volt, 400 watt battery (Smith-Root 2011). Electrofishing is inherently dangerous and as a result individuals participating wore neoprene waders and rubber gloves to prevent electric shock. Electrofishing was conducted in an upstream direction to reduce turbidity caused by stirred up sediment and facilitate capture of stunned fish (TCEQ 2007b). The electrofishing team was made up of a minimum two individuals, but three was preferred. One individual operated the electrofishing backpack and the others netted and transported fish. The voltage was dependent on the conductivity of the water with the general rule of lower voltage in higher conductivity waters (TCEQ 2007b). The electrofishing team sampled all different habitat types including large woody debris, riffles, boulders, aquatic plants, and undercut banks (TCEQ 2007b). The shocking time was recorded with a minimum of 900 seconds and was increased if new species were continuing to be found (TCEQ 2007b).

Fish greater than 30 centimeters were measured and identified in the field (released once sampling was completed). All fish collected (less than 0.3 meters) were euthanized with tricaine methanesulfonate (MS-222) and preserved in 10% formalin. Collected fish were identified, measured and counted at the University of Houston Clear Lake fish lab.

IBI's were calculated for each of the stream sites for both sampling events by compiling electrofishing and seining data. The regionalized (Ecoregion 34 and 33/35) IBIs developed by Linam et al. (2002) were used to calculate IBI scores (Figures 2 and 3). There are three main categories when calculating the regionalized IBI including species richness and composition, trophic composition, and fish abundance and condition (Linam et al. 2002). These categories are further broken down into thirteen metrics and are presented in the IBI worksheet in Figure 2. The raw numbers for the thirteen metrics were established by completing the scoring criteria sheet (Figures 4 and 5). Once all fish were identified, measured, counted and briefly examined for disease/abnormalities the IBI worksheets were completed for each site with scores ranging from 0 to 60 (Linam et al. 2002). IBI scores are divided into six broad categories ranging from exceptional to limited (Linam et al. 2002).

We also calculated other fish community indices including the percent tolerant species, percent intolerant species, Shannon Weiner diversity index, Pielou's evenness and species richness. In these calculations we combined electrofishing and seining data for each site since this was the method used for the IBI and thus comparable. Percent tolerant and intolerant were simply the number of tolerant or intolerant individuals divided by total number of individuals. Tolerance levels used in our study were categorized by Linam et al. (2002). The species

Gambusia affinis (Western mosquitofish) was removed from the percent tolerance index since it is known to skew results (Linam et al. 2002). Shannon-Weiner diversity index was used as another index of fish community quality. The Shannon-Weiner diversity index is one of the most applied diversity index and works with both large and small sample sizes (Dyke 2003). We also used Pielou's evenness as a method to interpret fish community features. Pielou's evenness index is a ratio of the diversity index to the total number of species in the community which ranges from zero to one (Dyke 2003). Commonly, the Shannon-Weiner diversity index and Pielou's evenness are used together to help interpret results. Lastly, we also used species richness as a fish community metric since it is often associated with disturbance. Richness is simply the number of species present at a site.

Stream Name:			Location:		Date:
Collector:			County:		
No. seine hauls:		Electrofishing effort (min):			
Metric Category	**Intermediate Totals for Metrics**		**Metric Name**	**Raw Value**	**IBI Score**
Species richness and composition	Drainage basin size (km^2)				
	Number of fish species		Number of fish species		
	Number of native Cyprinid species		Number of native Cyprinid species		
	Number of benthic invertivore species		Number of benthic invertivore species		
	Number of sunfish species		Number of sunfish species		
	Number of intolerant species		Number of intolerant species		
	Number of individuals as tolerants[a]		% of individuals as tolerant species		
Trophic composition	Number of individuals as omnivores		% of individuals as omnivores		
	Number of individuals as invertivores		% of individuals as invertivores		
Fish abundance **and condition**	Number of individuals (seine)		Number of individuals in sample		
	Number of individuals (electrofishing)		Number of individuals/seine haul		
	Number of individuals in sample		Number of individuals/min electrofishing		
	# of individuals as non-native species		% of individuals as non-native species		
	# of individuals with disease/anomaly		% of individuals with disease/anomaly		
			Index of biotic integrity numeric score:		
			Aquatic life use:		

Figure 2. Worksheet used to determine the IBI scores for ecoregion 34.

Stream Name:		**Location:**		**Date:**	
Collector:			**County:**		
No. seine hauls:		**Electrofishing effort (min):**			
Metric Category	**Intermediate Totals for Metrics**		**Metric Name**	**Raw Value**	**IBI Score**
	Drainage basin size (km^2)				
Species richness and composition	Number of fish species		Number of fish species		
	Number of native Cyprinid species		Number of native Cyprinid species		
	Number of benthic invertivore species		Number of benthic invertivore species		
	Number of sunfish species		Number of sunfish species		
	Number of intolerant species		Number of intolerant species		
	Number of individuals as tolerants[a]		% of individuals as tolerant species		
Trophic composition	Number of individuals as omnivores		% of individuals as omnivores		
	Number of individuals as invertivores		% of individuals as invertivores		
	Number of individuals as piscivores		% of individuals as piscivores		
Fish abundance and condition	Number of individuals (seine)		Number of individuals in sample		
	Number of individuals (electrofishing)		Number of individuals/seine haul		
	Number of individuals in sample		Number of individuals/min electrofishing		
	# of individuals as non-native species		% of individuals as non-native species		
	# of individuals with disease/anomaly		% of individuals with disease/anomaly		
			Index of biotic integrity numeric score:		
			Aquatic life use:		

Figure 3. Worksheet used to determine IBI scores developed for ecoregions 33 and 35

	Metric	Scoring Criteria 5	3	1
1	Total number of fish species		See Figure B-7	
2	Number of native cyprinid species	> 2	2	< 2
3	Number of benthic invertivore species	>1	1	0
4	Number of sunfish species	>3	2-3	<2
5	Number of intolerant species	≥1	-	0
6	% of individuals as tolerant species (excluding western mosquitofish)	<26%	26-50%	>50%
7	% of individuals as omnivores	<9%	9-16%	>16%
8	% of individuals as invertivores	>65%	33-65%	<33%
9	Number of individuals in sample			
	a. Number of individuals/seine haul	>174.7	87.4-174.7	<87.4
	b. Number of ind/min electrofishing	>7.7	3.9-7.7	<3.9
10	% of individuals as non-native species	<1.4%	1.4-2.7%	>2.7%
11	% of individuals with disease or other anomaly	<0.6%	0.6-1.0%	>1.0%

Aquatic life use: ≥49 Exceptional; 39-48 High; 31-38 Intermediate; <31 Limited

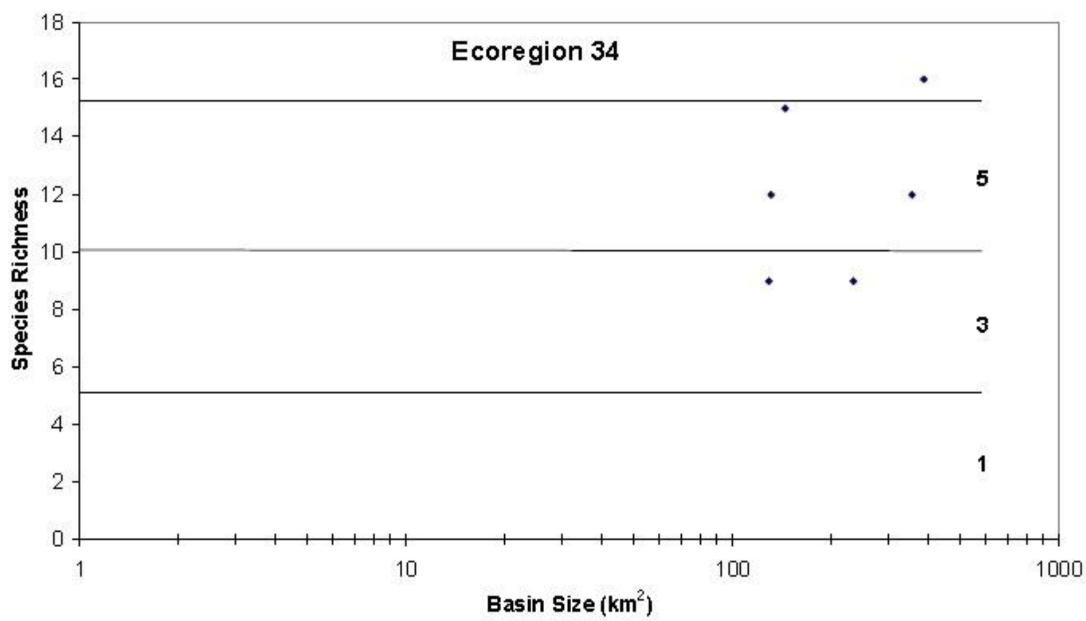

Figure 4. Scoring criteria for ecoregion 34 used to complete the IBI.

		5	3	1
1	Total number of fish species		See Figure B-6	
2	Number of native cyprinid species	> 4	2-4	< 2
3	Number of benthic invertivore species	> 4	3-4	<3
4	Number of sunfish species	>4	3-4	<3
5	Number of intolerant species	>3	2-3	<2
6	% of individuals as tolerant species (excluding western mosquitofish)	<26%	26-50%	>50%
7	% of individuals as omnivores	<9%	9-16%	>16%
8	% of individuals as invertivores	>65%	33-65%	<33%
9	% of individuals as piscivores	>9%	5-9%	<5%
10	Number of individuals in sample			
	a. Number of individuals/seine haul	>28	14-28	<14
	b. Number of ind/min electrofishing	>7.3	3.9-7.3	<3.6
11	% of individuals as non-native species	<1.4%	1.4-2.7%	>2.7%
12	% of individuals with disease or other anomaly	<0.6%	0.6-1.0%	>1.0%

Aquatic life use: ≥52 Exceptional; 42-51 High; 36-41 Intermediate; <36 Limited

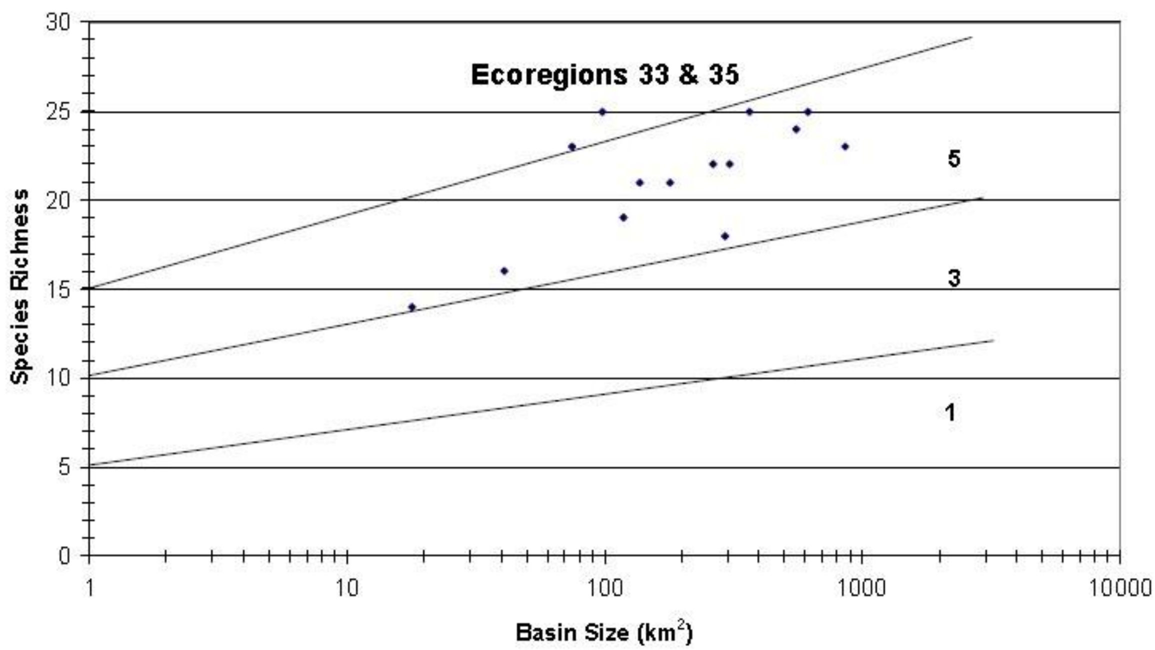

Figure 5. Scoring criteria for ecoregions 33 and 35 used to complete the IBI.

Statistical analysis

We visually assessed trends in data through bar graphs using Minitab 15®. Statistical analysis including analysis of variance (ANOVA), Pearson correlation, regression analysis, principle component analysis and cluster analysis, were completed in Minitab 15®. We established an a-priori level of statistical significance of a 95 confidence level ($p< 0.05$) for all statistical test results. Due to the high number of variables which might influence fish communities in the study, data analysis began by first plotting data in bar graphs to view spatial trends.

A two-way ANOVA, general linear model was used to determine significant differences between sites and sampling events for replicated data. Replicated water quality parameters included orthophosphate, combined nitrate and nitrite, TSS, ammonia, chlorophyll-a, turbidity, and alkalinity. Replicated physical habitat data included slope, erosion potential, instream cover, percent gravel or larger, riparian width and canopy cover. If significant interaction was found between sites and sampling events we ran a one way ANOVA across collections (Site and event combined). Tukey's multiple comparison was used to determine specific significant differences in sites, dates or collections as appropriate.

Pearson correlation analysis was used to evaluate relationships between physical habitat, water quality variables, TIA, PIA and fish community metrics (IBI scores, Shannon-Weiner diversity index, evenness, richness). When significant correlations were found, simple linear regressions were used to evaluate relationships between independent and dependent variables. In general, land use derived variables were considered independent variables when used in models with other variables. Streamflow was considered an independent variable when used in models with all other variables except landuse. Water quality and habitat was considered independent variables when used in regression models with all other variables except streamflow and land use. Biological metrics related to fish communities are considered dependent variables in all regression models. For statistical analysis of water quality, concentrations that read zero were treated as half of the minimum detection limit. Previous studies have determined using half of the detection limit is a reasonable depiction of actual values and decreases biases in statistical analysis (McBean et al. 1984).

Principle component analysis (PCA) was performed using MINITAB 15® on physical habitat and water quality to assess relationships. PCA is an unconstrained ordination technique that can condense large data sets into fewer dimensions (i.e. principal components) (McGarigal et al. 2000). Variables used to create the principal component are weighted according to their influence on the created principal component, indicating a higher influence (McGarigal et al. 2000). Principal components are graphically displayed in a biplot. Biplots represent the scores of each site as points and coefficients of the original data matrix as vectors (McGarigal et al. 2000). Points that are closer together represent sites with similar scores on the components (McGarigal et al. 2000). Vectors can be interpreted by length and direction (McGarigal et al. 2000). The length represents the amount of whatever the variable measures (i.e. concentration, meters of riparian habitat, percent impervious surfaces) (McGarigal et al. 2000). The direction the vector points represents the variable (McGarigal et al. 2000). Therefore, if two vectors point in the same direction they have similar meaning in the context of the data (McGarigal et al. 2000). It should be mentioned that we excluded single variables that were similar (i.e. measuring the same trait), for example turbidity and secchi disk depth are both measures of water clarity, so we only used turbidity since it was less subjective. We then investigated the relationship between the principal components and fish community metrics (IBI, Shannon-Weiner diversity index, evenness, and number of species) using a linear regression analysis with principal components (first or second) as the independent variables and the fish community metrics as the dependent variables.

Minitab 15® and Clustan® were used to conduct cluster analysis. Cluster analysis was used to classify collections based on similarity of fish communities (species attributes) across sites and sampling events. We expected to find sites with higher degree of urbanization to have similar fish communities and therefore be grouped together. Methods selected for the cluster analysis were Squared Euclidean Distance and Ward's Linkage method. In order to run the cluster analysis we averaged the number of each species collected per seine haul or per electrofishing run. It should be noted that since we had variable seine distance and electrofishing time we examined the data set with regression analysis to assure that sites with a higher degree of effort did not bias results. We also excluded species that were only captured at one or two sites since they were not a significant part of the fish communities and would only confound results. A dendrogram (tree diagram) was used to display similarity between sites based on community composition. Initially we ran our cluster analysis in the statistical program Clustan®, in order to determine the number of clusters within our dendrogram. Clustan® uses a statistical tool called “best cut” which uses variance reduction algorithms to determine the most significant differences between groups and define the most reasonable number of groups (Wishhart, 2006).   We reran the data set using the same cluster analysis algorithm in Minitab 15®, but with the final number defined by Clustan® to produce higher quality, easy to read graphics. Lastly, we used boxplots to graphically depict if cluster groupings based on both seining and electrofishing results exhibited an obvious difference based on the amount of impervious surfaces in the contributing watershed.

RESULTS

Geographical information systems

The eight study sites were located in the Western Gulf Coastal Plain of Southeast Texas (Figure 6) and represented a wide range in land cover types. The main land cover types included forested, agricultural, and minimally, moderately and highly urbanized. Southeastern Texas has experienced large population and industry growth in some areas while limited growth has occurred in others sections. The stream sites were located in the counties of Harris, Brazoria, Galveston, and Montgomery. GIS analysis delineated watershed area, percent impervious area (PIA) and total impervious area (TIA), which all varied greatly for each stream site. The watershed area above the lowest transect of the stream reach ranged from 44.51 to 1,329.97 km^2 (Figure 7). The percent impervious area of the watersheds ranged from 0.80 to 37.75% (Figure 8). The total impervious area of the watersheds ranged from 1.35 to 52.5 km^2 (Figure 9). Some of the sites were located in watersheds that had lower amounts of available area for increased urbanization in the future, like Greens Bayou, while others, like Peach Creek and Lake Creek will most likely experience increased urbanization in the future. Lastly the total number of municipal and industrial wastewater outfalls in all watersheds ranged from 3 at Dickinson Bayou to 54 at the West Fork of the San Jacinto (Figure 10).

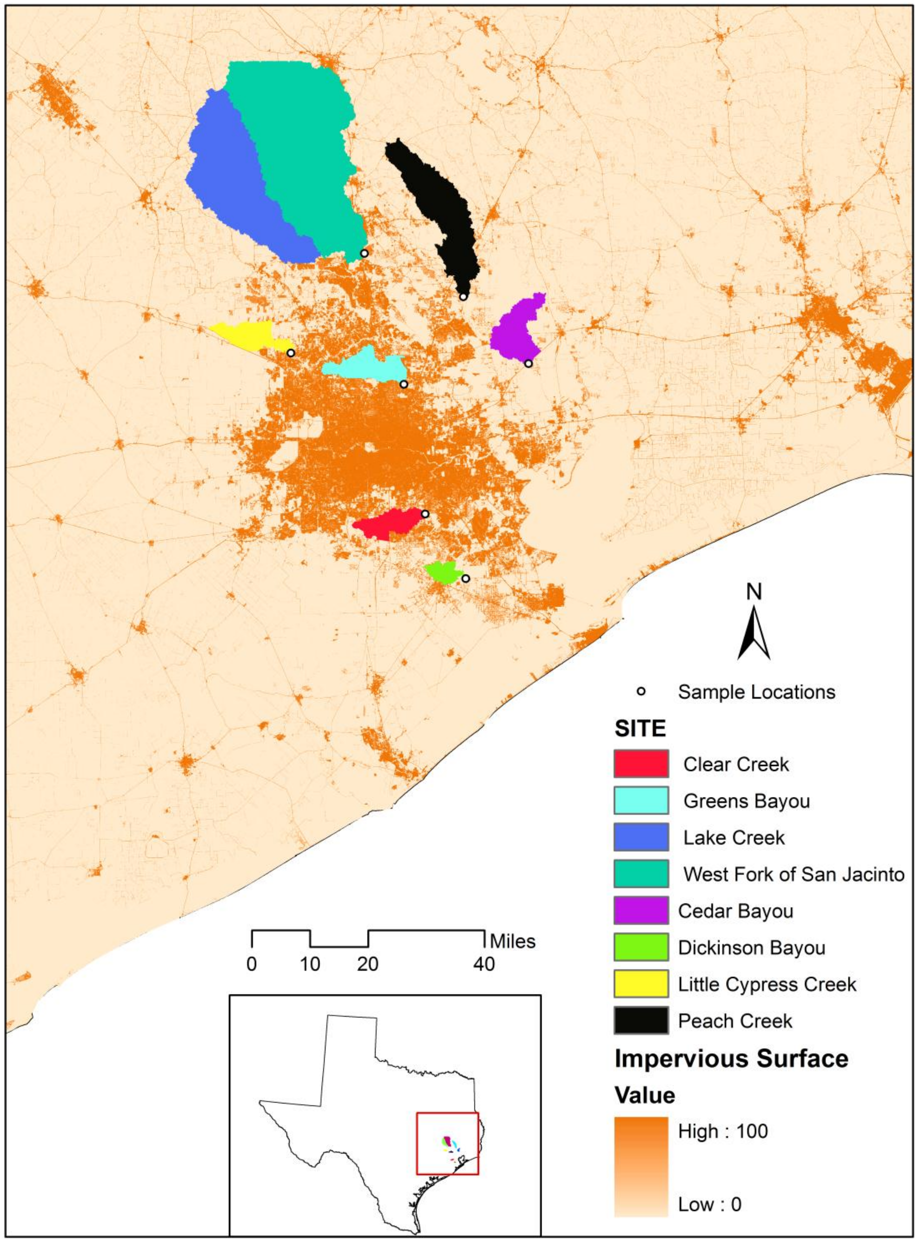

Figure 6. Map depicting all eight study sites, watersheds and impervious area. Also displyed is the 2006 impervious surface layer showing the range of urbanization across sites.

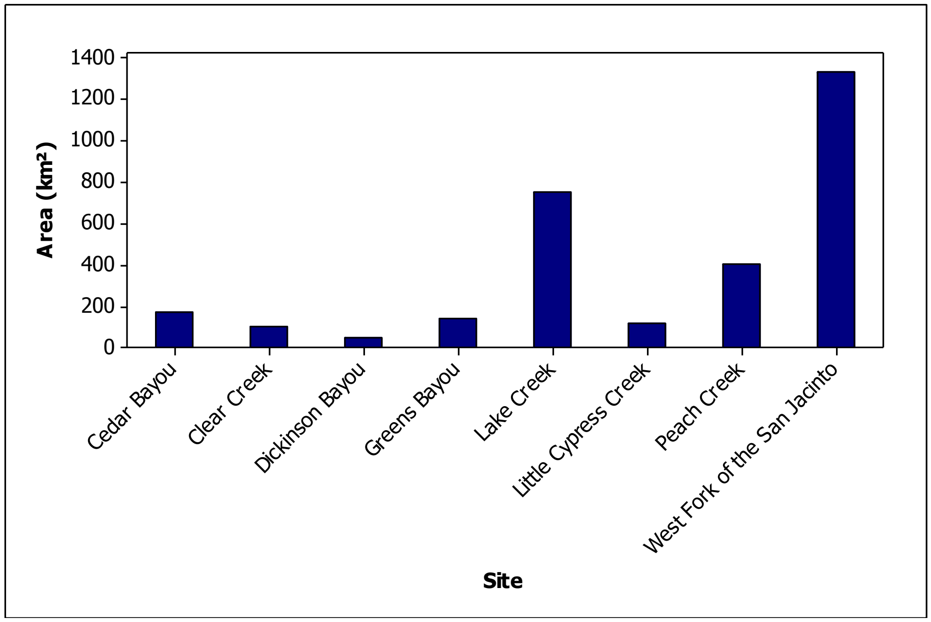

Figure 7. Size of contributing watershed above study sites.

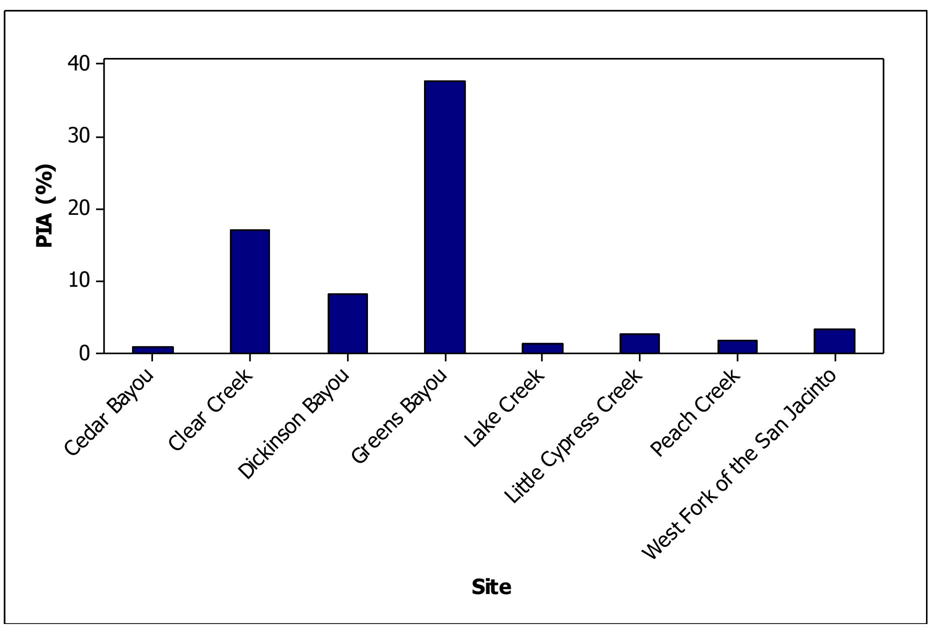

Figure 8. PIA of each study site's watershed.

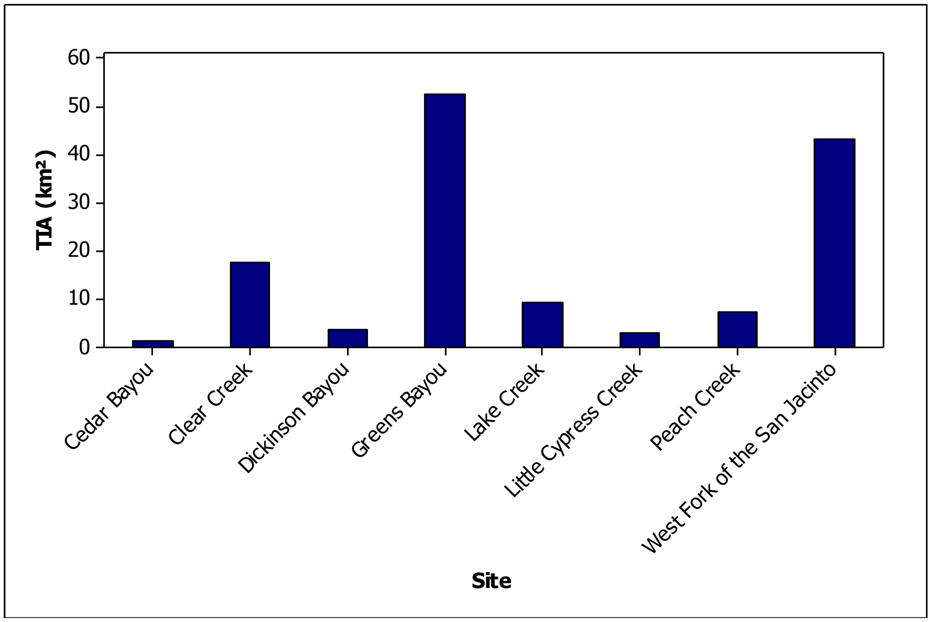

Figure 9. TIA of each study site's watershed.

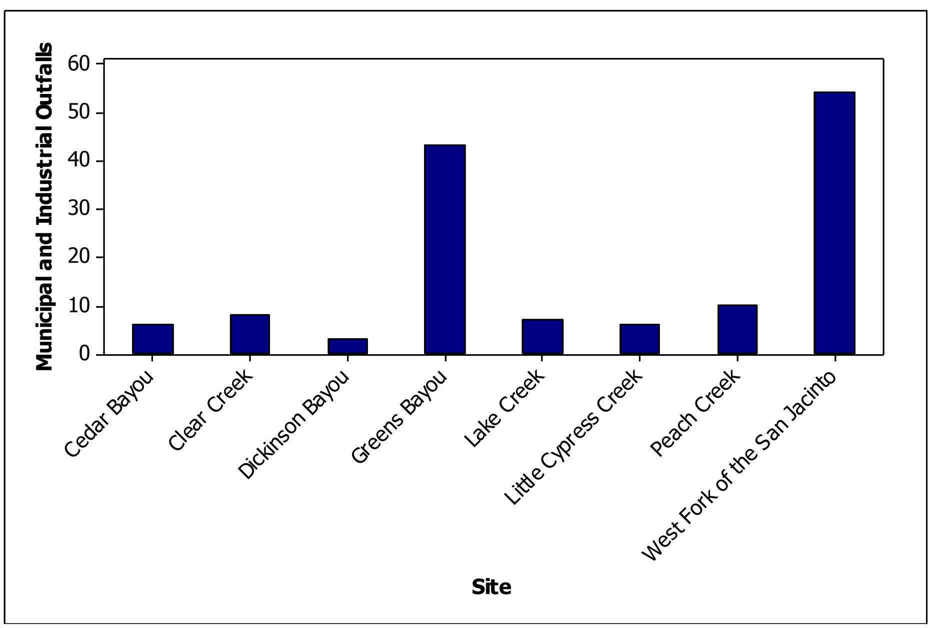

Figure 10. Total number of industrial and municipal outfalls in each study site's watershed.

Status of impairments

Currently, five of the eight study sites stream segments are on the 303d list of impaired waters for bacterial reasons in the 2010 draft: including Little Cypress Creek, Peach Creek, Greens Bayou, West Fork of the San Jacinto and Dickinson Bayou (TCEQ 2011a). Clear Creek is on the 303d list for PCB's in edible tissues. Lake Creek and Cedar Bayou were not listed in the most recent draft. These impairments may be related to the degree of urbanization, industry or agriculture in each of their watersheds. However, currently only Clear Creek stream segment 1102_2 is listed for concerned of non-attainment of fish communities (TCEQ 2011b). Many of the sites were listed as concerned (CS) based on state screening levels for nitrate (1.95 mg/L), orthophosphrus (0.37 mg/L) and dissolved oxygen (minima 3.0 mg/L for all sites except Greens Bayou 2.0 mg/L). Screening levels for each segment are based on long-term monitoring data or published levels of concern (TCEQ 2010b).

Physical habitats

Overall the study sites can be characterized as low gradient streams, with moderately steep banks and low diameter substrate. The mean bank slope angles were generally high at our sites ranging from 17.0 to 68.3 degrees. Two way ANOVA determined that the stream bank slope angles were significantly different across sites (P=0.000), but not sampling events (P=0.969) (Appendix C1 and Figure 11). Mean stream slopes were found to be highest at Peach Creek 1 (1 represents the first sampling event and 2 represents the second sampling event), while the lowest at the West Fork of the San Jacinto River 1. Mean bank slopes were significantly

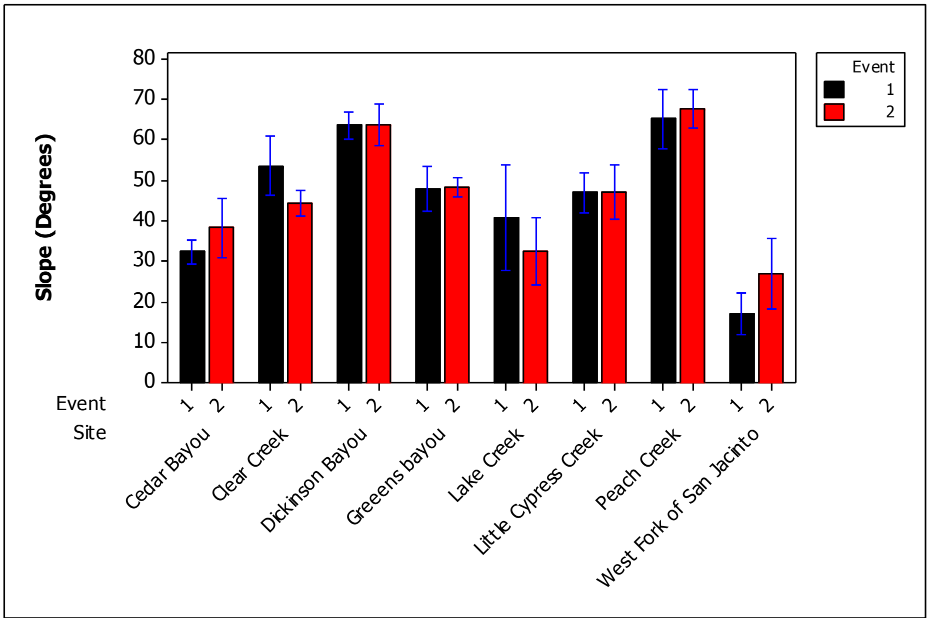

Figure 11. Steam bank slope angles for all sites and sampling events (± 1 standard error).

higher at Peach Creek 1 than Cedar Bayou 1 and the West Fork of the San Jacinto 1 and 2. In contrast the mean bank slope was significantly lower at the West Fork of the San Jacinto River 1 than Clear Creek 1, Dickinson Bayou 1 and 2 and Peach Creek 1 and 2.

The mean percent bank erosion ranged from 9.5 to 64.5%. We determined through two way ANOVA that the mean percent bank erosion was significantly different across sites and sampling events, respectively (P=0.000, P=0.000) Appendix C2 and Figure 12). The highest mean percent bank erosion was found at Clear Creek 1 and the lowest was Greens Bayou 2. The mean slope value at Clear Creek 1 was significantly higher than Greens Bayou 1 and 2, Lake Creek 2, Little Cypress Creek 1 and 2, Peach Creek 1 and 2 and the West Fork of the San Jacinto

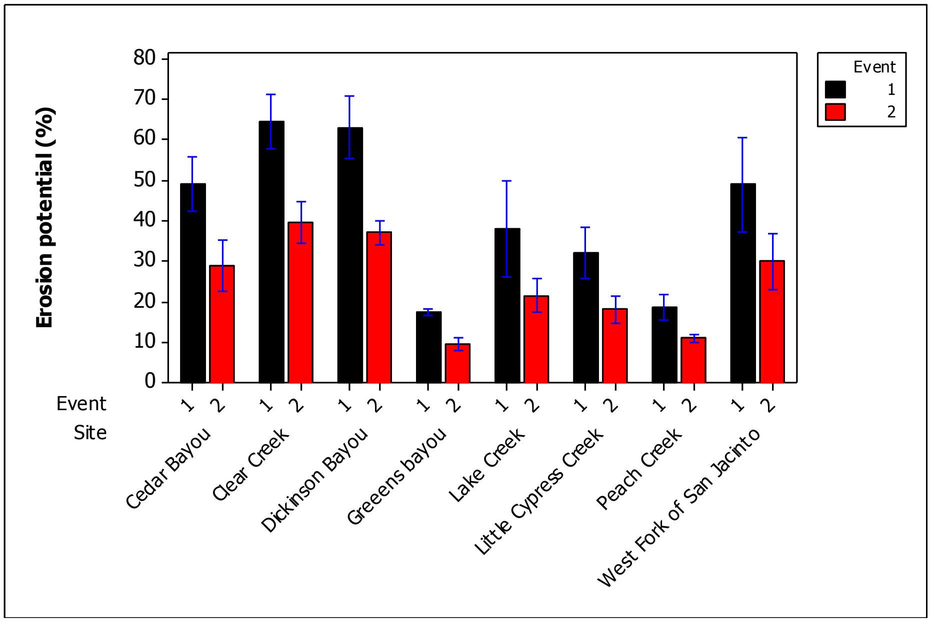

Figure 12. Stream bank erosion potential for all sites and sampling events (± 1 standard error).

River 2). In contrast Greens Bayou 2 was significantly lower than Cedar Bayou 2, Clear Creek 1, Dickinson Bayou 1 and West Fork of the San Jacinto 1.

The mean values of canopy cover ranged from zero to 94.6%. Two way ANOVA showed a significant difference in canopy cover across sites (P=0.000), but not sampling events (P=0.235) (Appendix C3 and Figure 13). The highest mean canopy cover was found at Dickinson Bayou 2, while the lowest was found at Greens Bayou 2. Dickinson Bayou 2 had significantly higher mean canopy cover than Greens Bayou 1 and 2 and the West Fork of the San Jacinto River 1 and 2. Greens Bayou 2 was significantly lower than all sites except Greens Bayou 1, and the West Fork of the San Jacinto River 1 and 2.

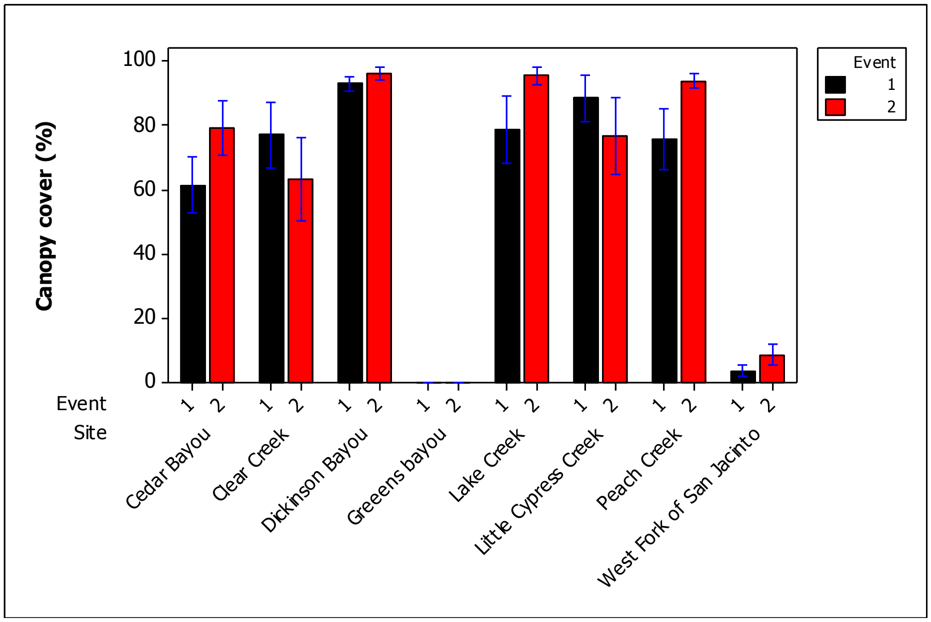

Figure 13. Percent canopy cover for all sites and sampling events (± 1 standard error).

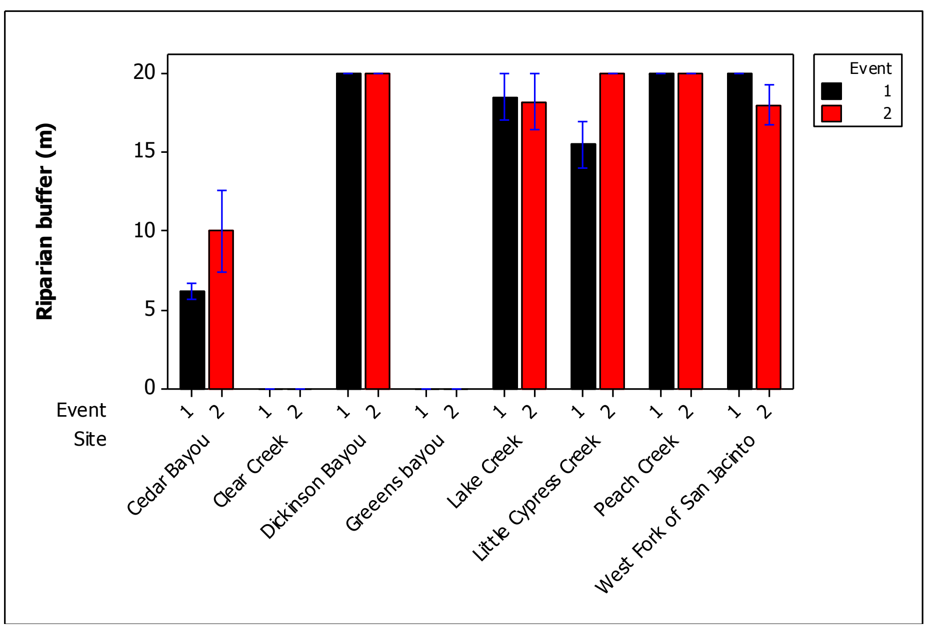

Figure 14. Riparian buffer width for all sites and sampling events (± 1 standard error).

The mean values of riparian buffer ranged from zero to greater than 20 meters. Two way ANOVA determined that riparian buffers were significantly different across sites (P=0.000), but not sampling events (P=0.142) (Appendix C4 and figure 14). The highest sites were Dickinson Bayou 1 and 2, Little Cypress Creek 2, Peach Creek 1 and 2, and the West Fork of the San Jacinto River 1, while the lowest sites were at Clear Creek 1 and 2 and Greens Bayou 1 and 2. Dickinson Bayou 1 and 2, Little Cypress Creek 2, Peach Creek 1 and 2, and the West Fork of the San Jacinto River 1 had significantly higher mean riparian widths than all sites except Little Cypress Creek 1 and the West Fork of the San Jacinto River 2. Clear Creek 1 and 2 and Greens Bayou 1 and 2 had significantly lower mean riparian widths than all other sites, but not each other.

The dominant substrate types found included clay, silt, sand and gravel. Generally sites located in northern portions of the study area, including Peach Creek, Lake Creek and the West Fork of the San Jacinto, had substrates primarily composed of sand, while southern sites were composed of silt and clay. This indicated that geographical location, which is related to underlying geology, may be more important in determining substrate type versus land use influences (USDA 2008). The mean percent gravel or larger ranged from zero to 34%. Two way ANOVA determined that the percent gravel or larger was significantly different across sites (P=0.001), but not events (P=0.212). The highest mean percent gravel or larger was found at the West Fork of the San Jacinto River 1, while several sites had zero percent including Dickinson Bayou 1, Lake Creek 1 and 2, and Little Cypress Creek 1 and 2 (Appendix C5 and Figure 15).

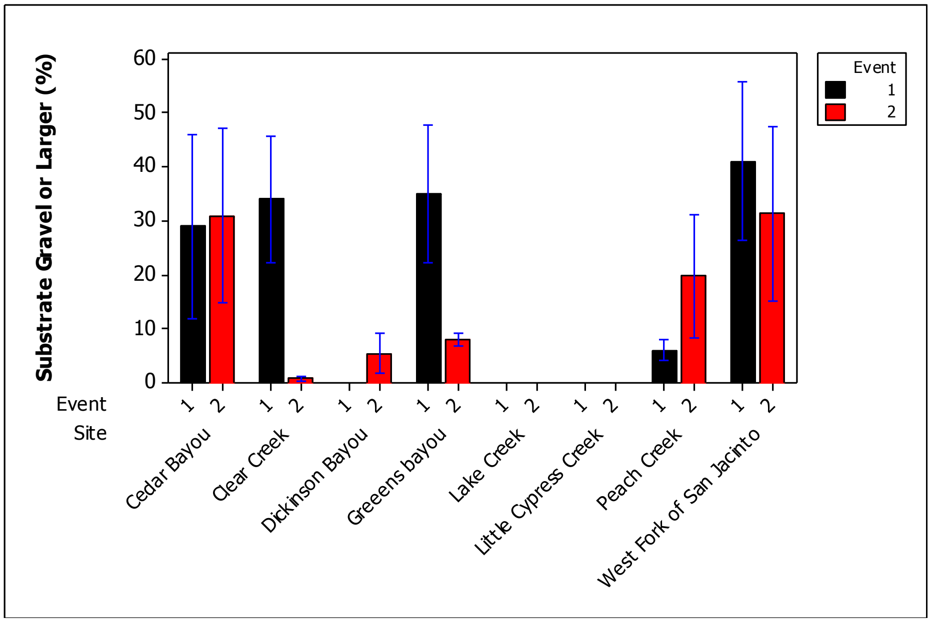

Figure 15. Percent substrate gravel or larger for all sites and sampling events (± 1 standard error).

The instream cover ranged from 6.7 to 46% across sites and sampling events. Instream cover types included undercut banks, submerged vegetation and large woody debris. However, two way ANOVA determined that instream cover did not significantly differ across sites or sampling events, respectively (P=0.190, P=0.090) (Appendix C6 and Figure 16).

Streamflow measurements varied greatly between sites ranging from as low as -0.05 cfs at Little Cypress Creek to as high as 31.83 cfs at Greens Bayou (Figure 17). The negative value was most likely attained due to very low flows and very small back eddies. A full physical habitat description of each site follows this section and raw data is presented in appendix J.

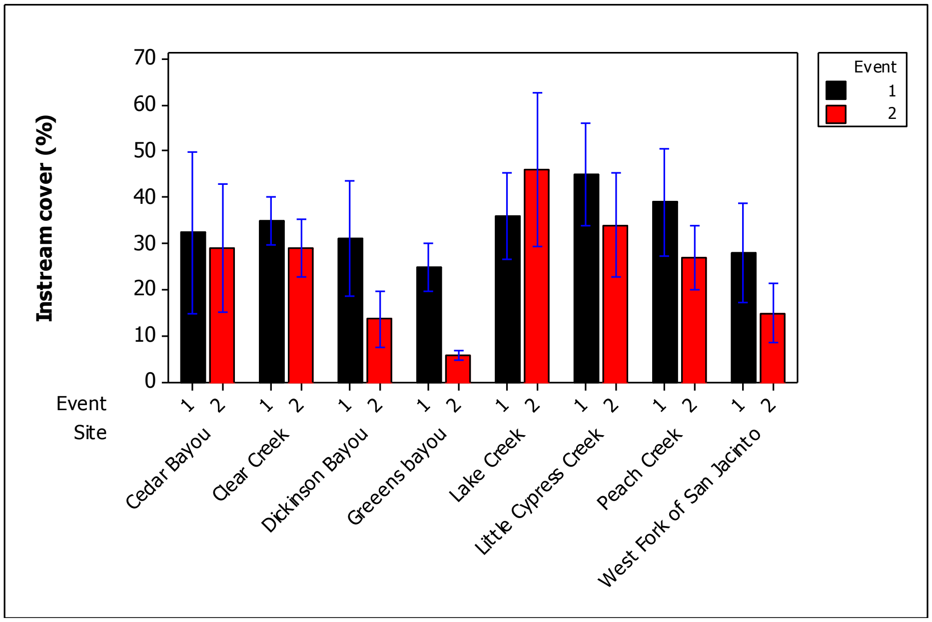

Figure 16. Percent instream cover for all sites and sampling events (± 1 standard error).

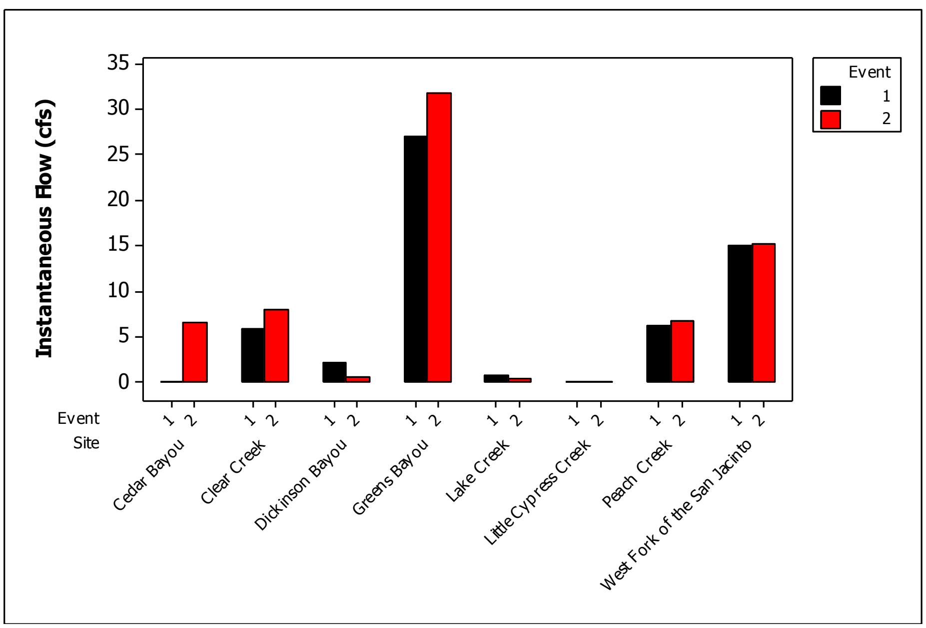

Figure 17. Streamflow for all sites and sampling events.

Site descriptions: GIS land use, physical habitat and status of impairment

Peach Creek

The Peach Creek watershed above the sampling reach was relatively large and was delineated at 403.47 km^2. The Peach Creek site was heavily forested and was located within the Lake Houston State Park. As a result the stream reach evaluated contained very minimal anthropogenic impacts. The Peach Creek watershed could be categorized as low density residential. The watershed was composed of 1.85 PIA with a resulting TIA of 7.56 km^2. A map of the Peach Creek watershed and impervious area can be found in Figure 18. The substrate was primarily sand and to a lesser extent gravel. The stream contained beneficial velocity dependent habitats including riffles, pools and runs as well as physical instream cover like large woody debris, undercut banks, root wads and aquatic vegetation. The banks were moderately steep (averages of two sampling events were 57 and 68 degrees, respectively) and contained an intact riparian zone. Instantaneous flow measurements at the two sampling events were 6.157 and 6.773 cfs, respectively. Peach Creek was listed on the 303 d list of impaired waters for bacterial impairments (TCEQ 2011a). This may be due to wastewater effluent or agricultural runoff in the upper reaches of the creek. The Peach Creek watershed had a total of ten industrial or municipal wastewater outfalls.

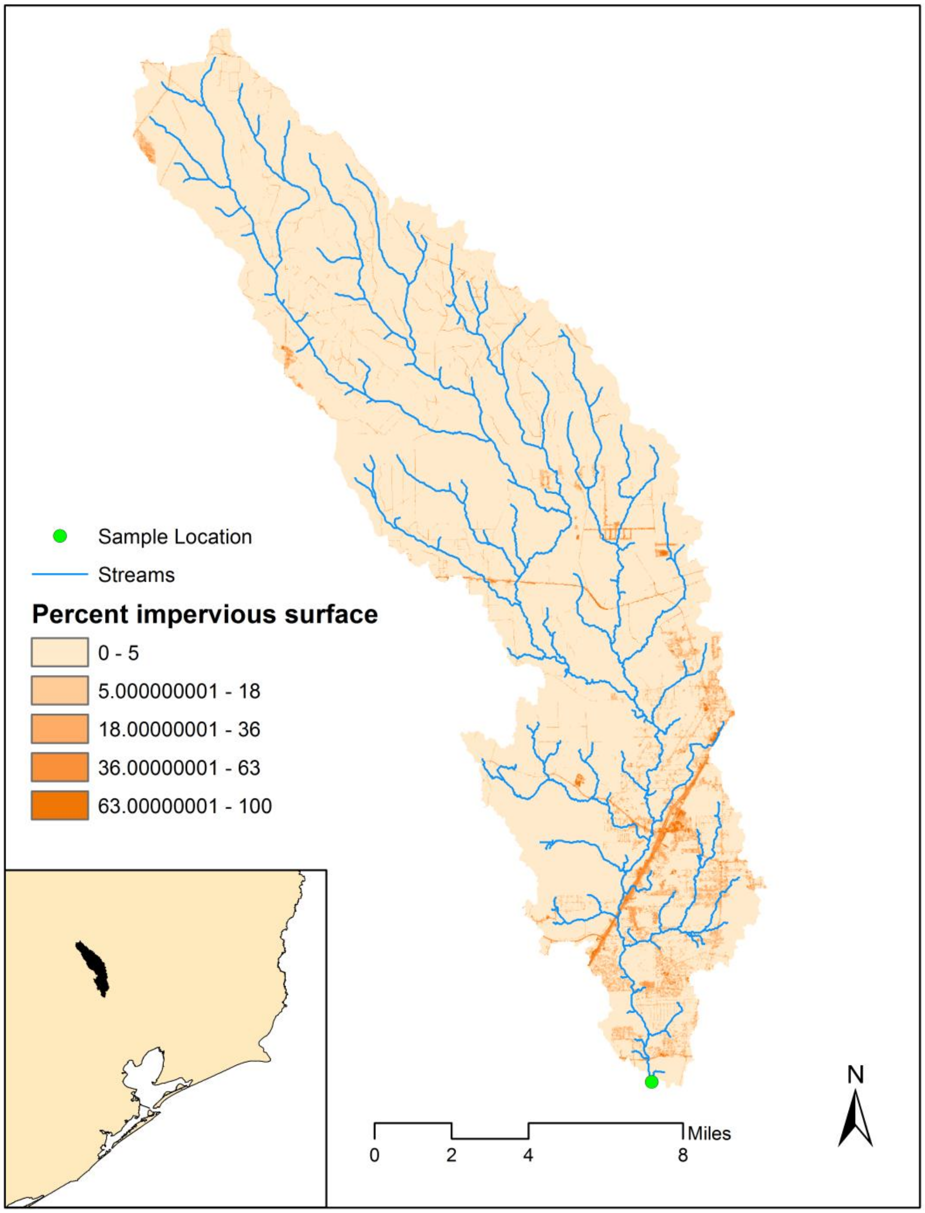

Figure 18. Map depicting the impervious area in the Peach Creek watershed above the sampling location (2006 impervious surface layer).

A detailed description for all sites GIS analysis and physical data including watershed size, PIA, TIA, number of municipal and industrial outfalls, average bank slope, bank erosion potential, canopy cover, percent instream cover, percent gravel or larger, dominant substrate types, number of stream cover types and natural buffer vegetation are listed in table 3.

West Fork of the San Jacinto River

The upstream watershed of the West Fork of the San Jacinto site was the largest catchment area (1329.97 km^2) of the sites evaluated. The watershed was composed of 3.25 PIA with a resulting TIA of 43.23 km^2. A map of the West fork of the San Jacinto River watershed and impervious area can be found in Figure 19. The site had an intact riparian zone, but due to the large stream width it had low amount of canopy cover. The site can be characterized by having a low bank slope and a large floodplain. The dominant substrate types were sand and silt. There were high amounts of instream fish habitat including large woody debris and aquatic vegetation. Stream velocity was highly variable at the site due to the diverse habitats including riffles, runs and pools. Instantaneous flow measurements at the two sampling events were 14.971 and 15.160 cfs, respectively. This site seemed to maintain baseflows throughout the summer and may be related to the high amount of municipal and industrial outfalls (fifty-four) within its watershed. The site was placed on the 303 d list 2010 for impaired bacterial concentrations which may be

Table 3. Displays physical data for both sampling events including watershed size, TIA, PIA, amount of industrial and municipal wastewater outfalls, mean bank slope, mean percent bank erosion potential, mean percent tree canopy cover, mean percent instream cover, mean percent substrate gravel or larger, instantaneous flow (cfs) and mean natural riparian buffer vegetation.

Site	Watershed Size (Km^2)	TIA (Km^2)	PIA	Industrial & Municipal Wastewater Outfalls	Mean Bank Slope	Mean % Bank Erosion	Mean % Tree Canopy	Mean % Instream Cover	Mean % Substrate Gravel or Larger	Stream-flow (cfs)	Mean Natural Buffer Vegetation
Dickinson Bayou	44.510	3.691	8.293	3	63.5	65	92.94	31	0	2.156	>20
Clear Creek	103.896	17.715	17.051	8	53.5	64.5	77.64	35	34	5.784	0
Cedar Bayou	167.998	1.351	0.804	6	32.32	49	61.5	32.5	29	0.022	6.1
West Fork of the San Jacinto	1,329.971	43.237	3.251	54	27.91	49.16	7.35	25	35	14.971	>20
Lake Creek	754.790	9.374	1.242	7	25.95	46	78.83	36	0	0.759	18.5
Greens Bayou	139.124	52.514	37.746	43	49.89	19.17	0.74	25	31.66	26.953	0
Peach Creek	403.472	7.456	1.848	10	57.12	18.67	76.08	31.17	45	6.157	>20
Little Cypress Creek	116.120	3.116	2.682	6	47	32	76.18	45	0	-0.051	14.5
Dickinson Bayou	44.510	3.691	8.293	3	38.69	29	79.12	20	31	0.577	>20
Clear Creek	103.896	17.715	17.051	8	44.2	39.5	63.22	29	0.8	7.889	0
Cedar Bayou	167.998	1.351	0.804	6	38.69	29	79.12	20	31	6.455	10
West Fork of the San Jacinto	1,329.971	43.237	3.251	54	25.75	27.5	12.44	13.33	26.5	15.160	18.33
Lake Creek	754.790	9.374	1.242	7	32.4	21.5	95.58	46	0	0.408	>20
Greens Bayou	139.123	52.514	37.746	43	48.42	20	0	6.67	14.17	31.827	0
Peach Creek	403.472	7.456	1.848	10	68.33	10.83	94.61	25.83	24.17	6.773	>20
Little Cypress Creek	116.199	3.116	2.682	6	46.25	18.75	78.92	34	0	0.003	>20

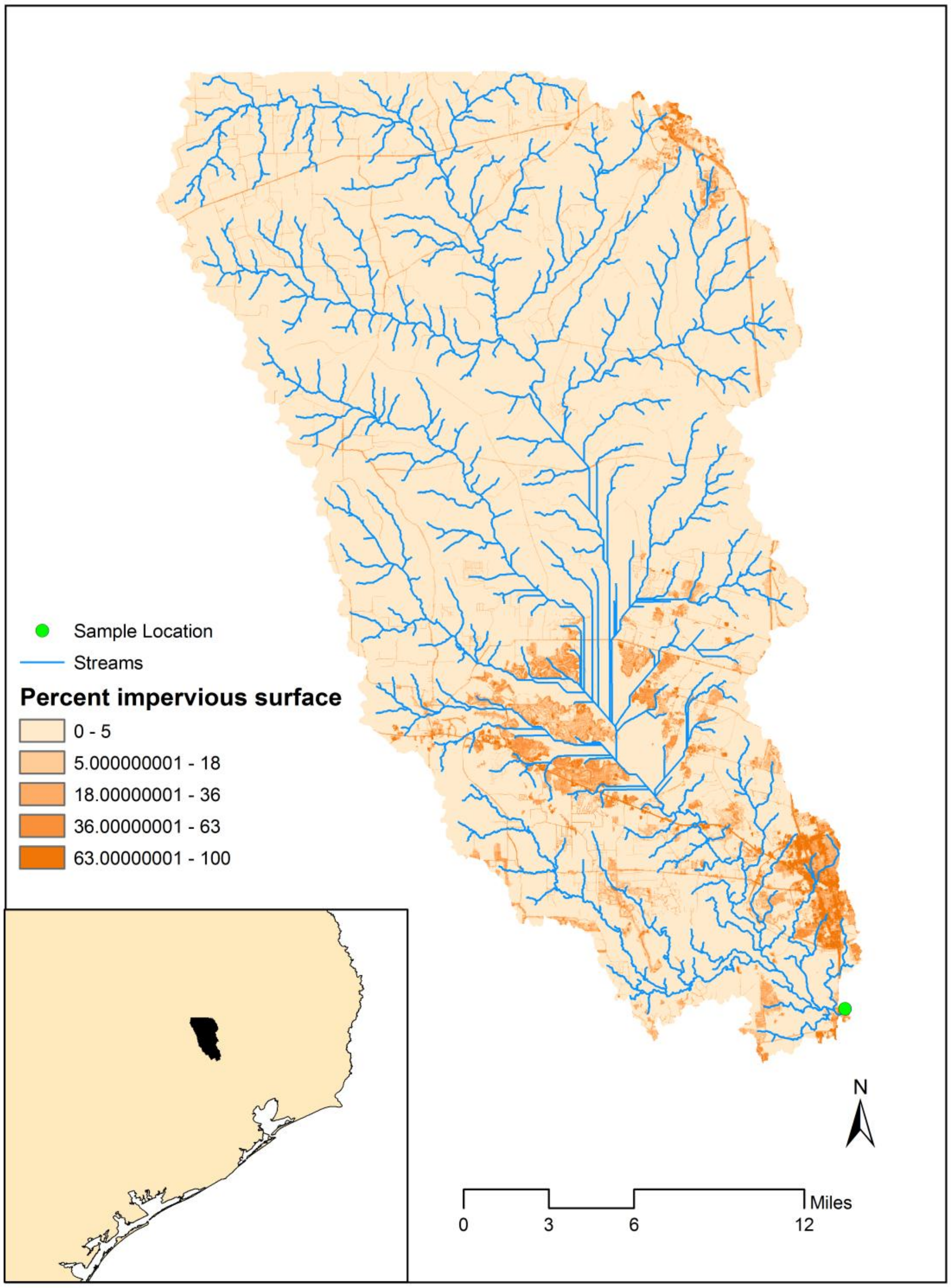

Figure 19. Map depicting the impervious area in the West Fork of the San Jacinto watershed above the sampling location (2006 impervious surface layer).

related to its large drainage area, high amount of industrial and municipal outfalls and associated human population (TCEQ, 2011).

Lake Creek

The drainage basin above the Lake Creek site was determined to be the second largest watershed in our study. The watershed was composed of 1.24 PIA with a resulting TIA of 9.37 km^2. A map of the Lake Creek watershed and impervious area can be found in Figure 20. The stream reach evaluated had steep banks and the substrate was primarily sand and silt. The stream had relatively low mean width with an intact riparian zone which resulted in high tree canopy cover. Instream fish habitat included a high degree of large woody debris, aquatic vegetation and undercut banks. Hydrological macrohabitats included riffles, runs and deep pools (greater than 1.5 meters). Instantaneous flow measurements at the two sampling events were 0.759 and 0.408 cfs, respectively. Due to impaired bacterial concentrations Lake Creek was placed on the 303 d list (TCEQ, 2011).

Little Cypress Creek

The Little Cypress Creek was located in a moderately sized watershed (116.20 km^2). The land cover adjacent to the stream could be described as moderate residential development. The watershed was composed of 2.68 PIA with a resulting TIA of 3.12 km^2. A map of the Little Cypress Creek watershed and impervious area can be found in Figure 21. There have most likely been significant increases in impervious area since the 2006 data used in this study due to the new development

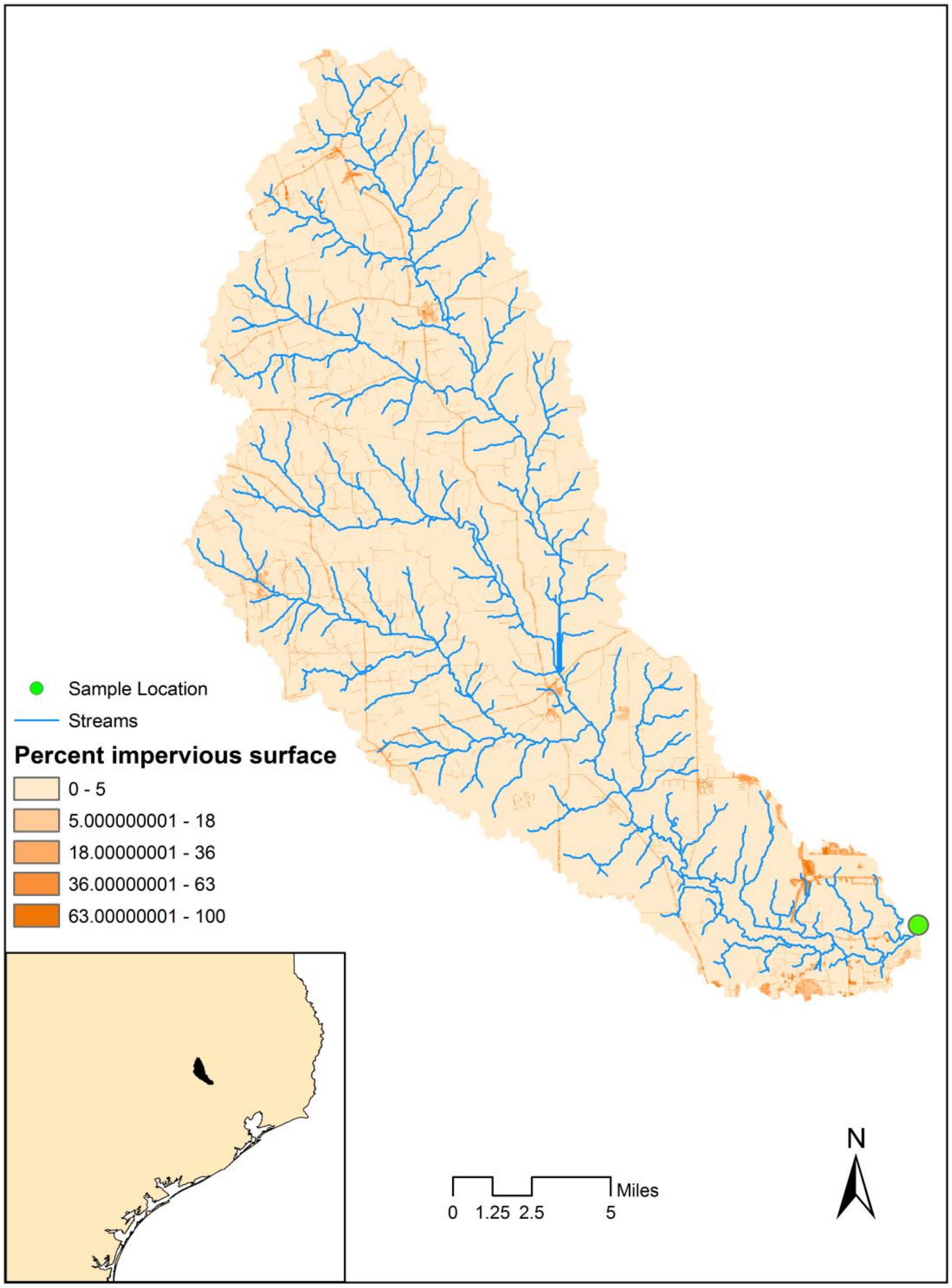

Figure 20. Map depicting the impervious area in the Lake Creek watershed above the sampling location (2006 impervious surface layer).

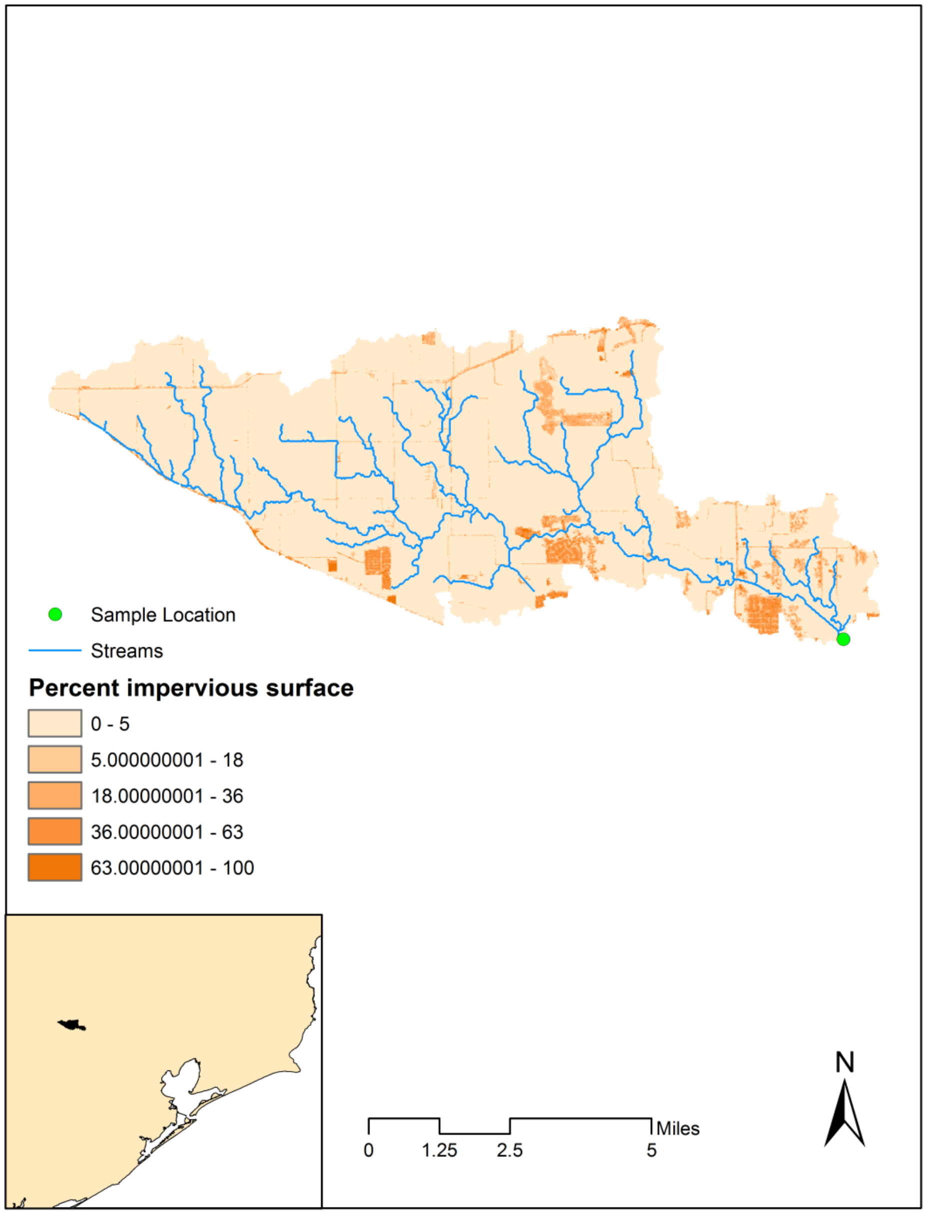

Figure 21. Map depicting the impervious area in the Little Cypress Creek watershed above the sampling location (2006 impervious surface layer).

in the watershed. The Little Cypress Creek had a primarily silt substrate, steep banks, low stream width and high canopy cover. The riparian zone was mostly intact although there was one area below the stream reach with a mowed area and a culvert. The site was limited in hydrological variable velocities, lacking riffles and was comprised of runs and small pools. Instantaneous flow measurements at the two sampling events were -0.052 and 0.003 cfs, respectively. The stream segment is on the 2010 draft of the 303 d list of impaired waters due to high bacteria concentrations (TCEQ 2011a). The segment is also listed as concerned status since it has exceeded the screening value for nitrate and orthophosphorus (TCEQ 2011b).

Dickinson Bayou

The Dickinson Bayou site was part of a small watershed (44.51 km^2) in which the land cover included urban and a low degree of agricultural area. The watershed was composed of 8.30 PIA with a resulting TIA of 3.69 km^2. A map of the Dickinson Bayou watershed and impervious area can be found in Figure 22. The site had very steep and tall banks and the substrate was primarily silt. The stream reach had minimal hydrological velocity variability and lacked riffles and pools. The stream reach had a mostly intact riparian buffer which provided high canopy cover. The instream fish cover was mainly large woody debris and undercut banks. The high degree of large woody debris made seining and movement around the site difficult. Instantaneous flow measurements at the two sampling events were 2.156 and 0.577 cfs, respectively. The stream reach in which our site was located was on the 303 d list for impaired waters due to high bacteria levels (TCEQ 2011a). It should be noted

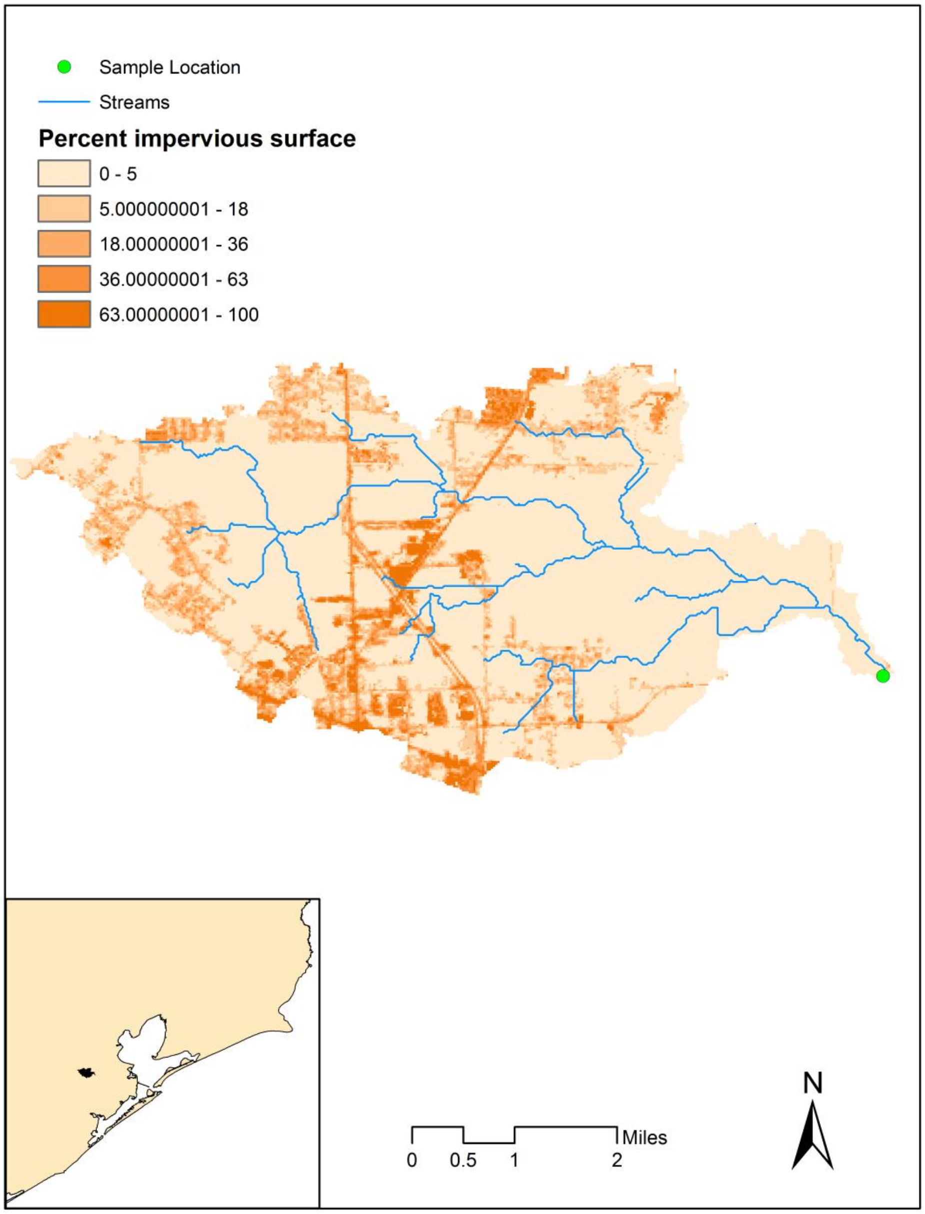

Figure 22. Map depicting the impervious area in the Dickinson Bayou watershed above the sampling location (2006 impervious surface layer).

that just below our site the stream segment was listed due to depressed dissolved oxygen levels, which may influence fish communities in upper areas the stream.

Clear Creek

The Clear Creek site was located in a moderately sized watershed (103.90 km^2) with a large amount of urban area. The watershed was composed of 17.05 PIA with a resulting TIA of 17.72 km^2. A map of the Clear Creek watershed and impervious area can be found in Figure 23. The stream reach evaluated had steep and short banks and the dominant substrate was silt. Like the Dickinson Bayou site the Clear Creek site contained only runs and lacked variable stream velocities like riffles and pools. The stream reach evaluated contained very little intact riparian area and both sides of the creek were mowed grass. The clearing of trees in riparian zone resulted in very low canopy cover. Instream cover was primarily aquatic vegetation including submerged and emergent plants. The stream also contained a small degree of woody debris and anthropogenic debris like tires. Instantaneous flow measurements at the two sampling events were 5.784 and 7.889 cfs, respectively. The site was on the TCEQ segment 1102_2 which is on the 303 d list of impaired waters due to high bacteria levels and polychlorinated biphenyl (PCBs) in edible tissues (TCEQ 2011a). The segment is also listed as concerned status based on screening levels of orthophosphorus and dissolved oxygen (TCEQ 2011b). Lastly the site's fish community is listed as near-nonattainment.

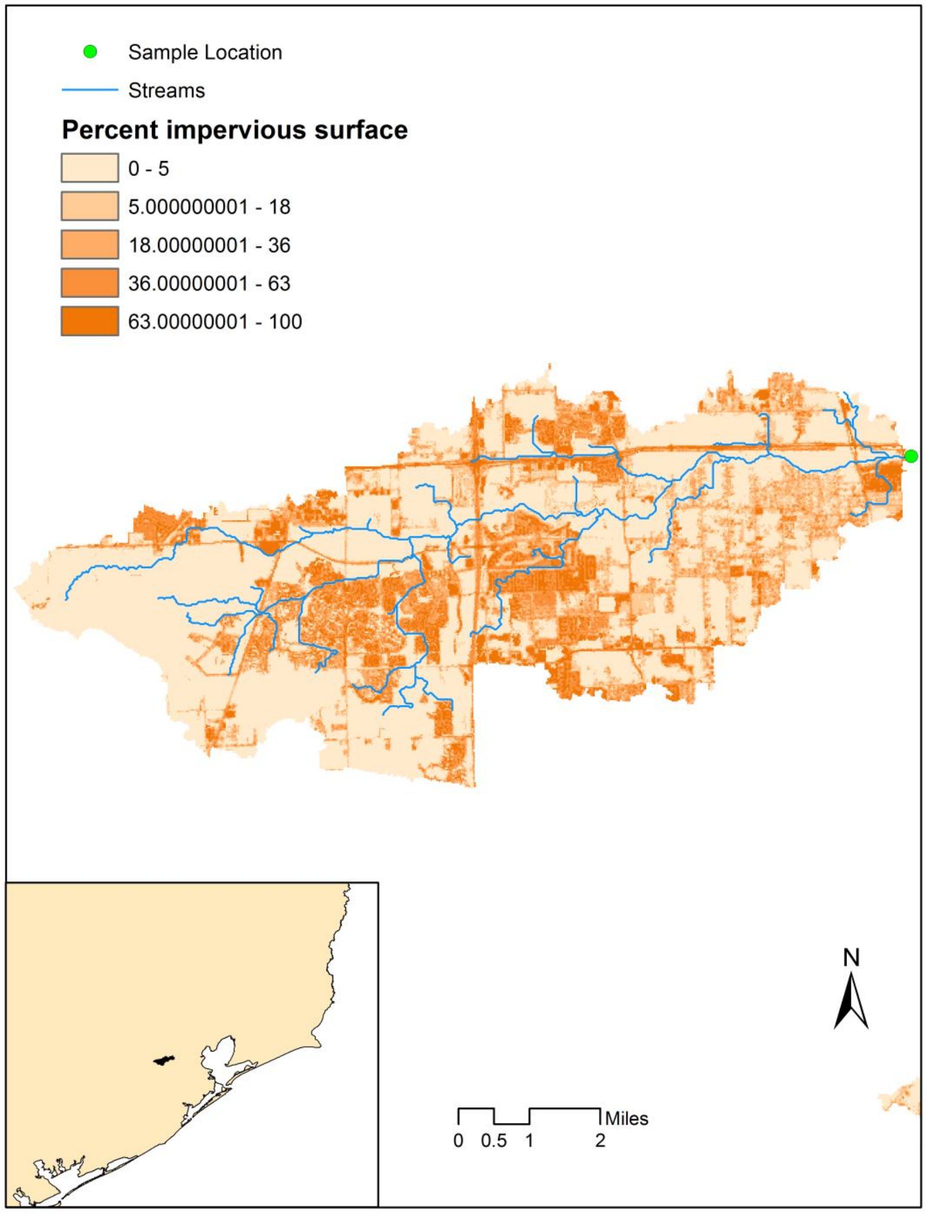

Figure 23. Map depicting the impervious area in the Clear Creek watershed above the sampling location (2006 impervious surface layer).

Cedar Bayou

The Cedar Bayou site was located on a moderately sized watershed (168.0 km^2) with little urban development. The watershed's land cover included low residential use and a larger degree of agricultural area. The watershed was composed of 0.80 PIA with a resulting TIA of 1.35 km^2. A map of the Cedar Bayou watershed and impervious area can be found in Figure 24. The stream reach contained moderate bank slope and substrate dominated by silt and clay. The sites riparian zone was mostly intact on the area we evaluated. However, the left side (facing downstream) of the stream had an agricultural field in the lower part of the stream reach. The stream contained variable hydrological velocities resulting in the creation of riffles, runs and pools. The site also contained a high degree of instream cover including vegetation, boulders and large woody debris. It should be noted that Cedar Bayou had low flows at the time of sampling due to the drought experienced in the summer of 2011, which may have influenced the physical, chemical and biological aspects in our study. Instantaneous flow measurements at the two sampling events were 0.022 and 6.455 cfs, respectively. As of the 2010 draft of the 303 d list, Cedar Bayou was not listed for impairments (TCEQ 2011a). However, the segment (902_01) was listed as concerned status based on screening levels due depressed dissolved oxygen (TCEQ 2011b).

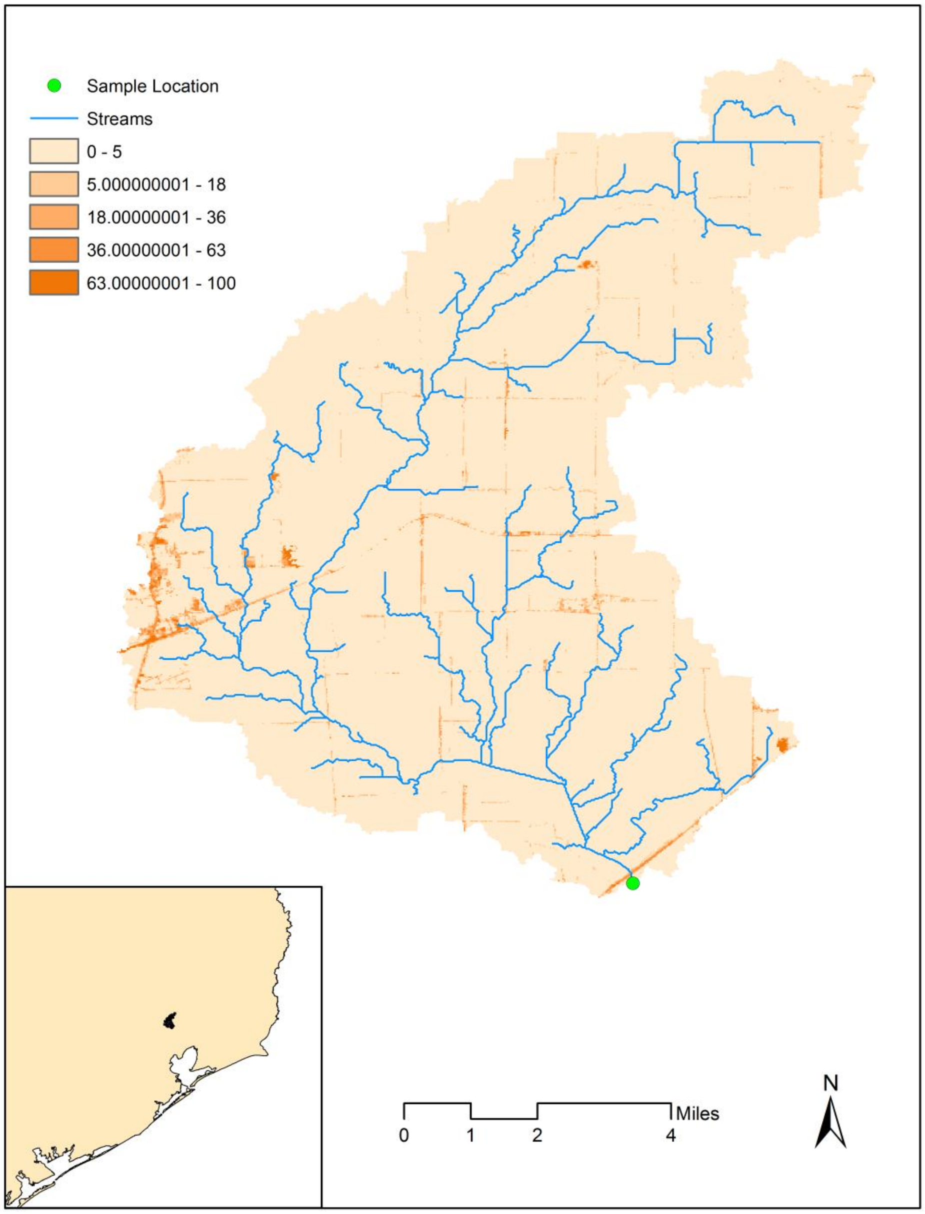

Figure 24. Map depicting the impervious area in the Cedar Bayou watershed above the sampling location (2006 impervious surface layer).

Greens Bayou

The Greens Bayou site was located on a moderately sized watershed (139.12 km^2) with high density residential and industrial areas. The watershed was composed of 37.75 PIA with a resulting TIA of 52.51 km^2. This was the highest PIA and TIA of all the sites. A map of the Greens Bayou watershed and impervious area can be found in Figure 25. The site contained moderately sloped banks and the dominant substrates were clay and silt. There was no intact riparian zone and it appeared that the sides of the stream were clear cut and planted with grass. As a result the mowed sides of the creek provided no canopy cover. The stream lacked variable stream habitats including riffles and pools. The stream reach evaluated was composed of one long channelized run. The site seemed to keep a constant flow even under drought conditions, most likely due to the fact that flows are maintained by the high number of municipal and industrial wastewater outfalls. GIS analysis determined that the watershed contained forty-three municipal and industrial wastewater outfalls. Instantaneous flow measurements at the two sampling events were 26.953 and 31.827 cfs, respectively. The stream segment (1016_03) is listed on the 2010 draft of the 303 d impaired waters due to high bacteria concentrations (TCEQ 2011a). The segment is also listed as concerned status since it has exceeded the screening value for nitrate and orthophosphorus (TCEQ 2011b).

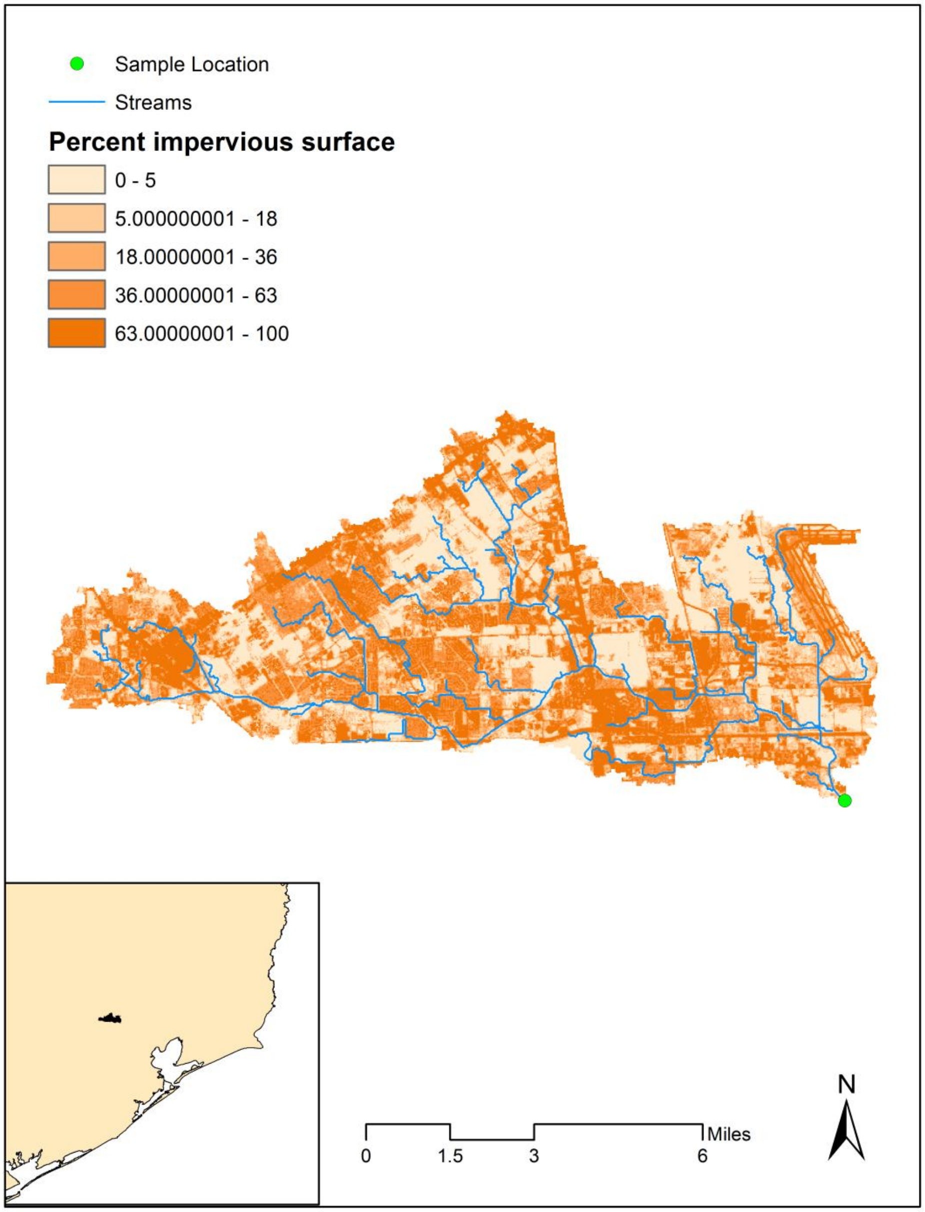

Figure 25. Map depicting the impervious area in the Greens Bayou watershed above the sampling location (2006 impervious surface layer).

Water Quality

Temperature, specific conductivity, pH, dissolved oxygen and free chlorine

Generally, with the exception of dissolved oxygen the values for temperature, specific conductance, and pH were at levels that would support freshwater stream fish communities. Overall we found higher temperatures in the second sampling event, during the critical sampling period (Figure 26). Specific conductance was lowest at both sampling events at Lake Creek and typically higher at all other sites (Figure 27). The pH values were all within acceptable levels for fish health and ranged from 7.32 to 8.03 (Figure 28). Dissolved oxygen levels ranged greatly across sites from as low as 1.29 mg/L at Little Cypress Creek to 11.54 mg/L at Clear Creek (Figure 29). Free chlorine values varied across sites from below detection limit to

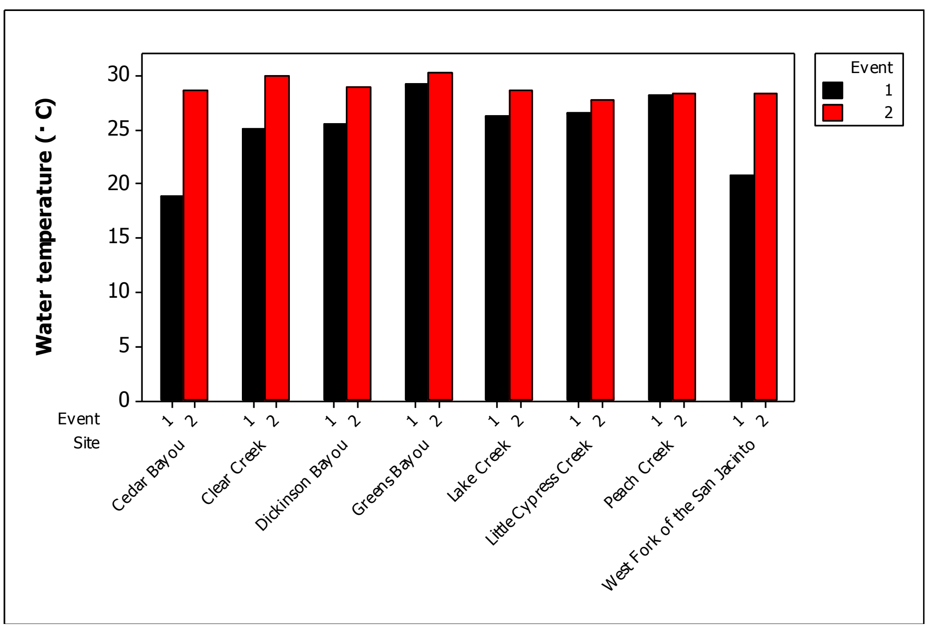

Figure 26. Water temperature for all sites and sampling events. 1=first sampling event and 2=second sampling event.

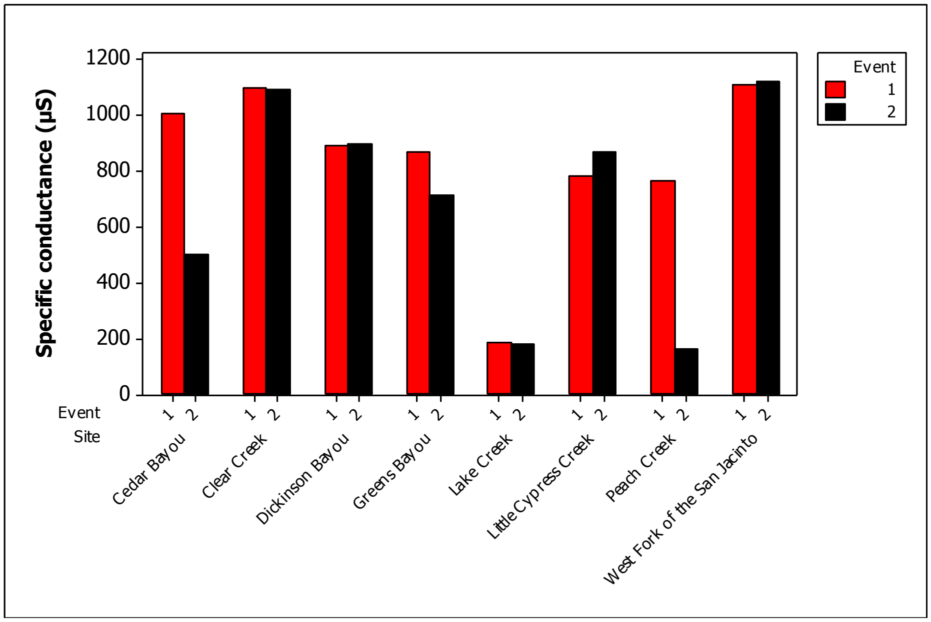

Figure 27. Specific conductance for all sites and sampling events. 1=first sampling event and 2=second sampling event.

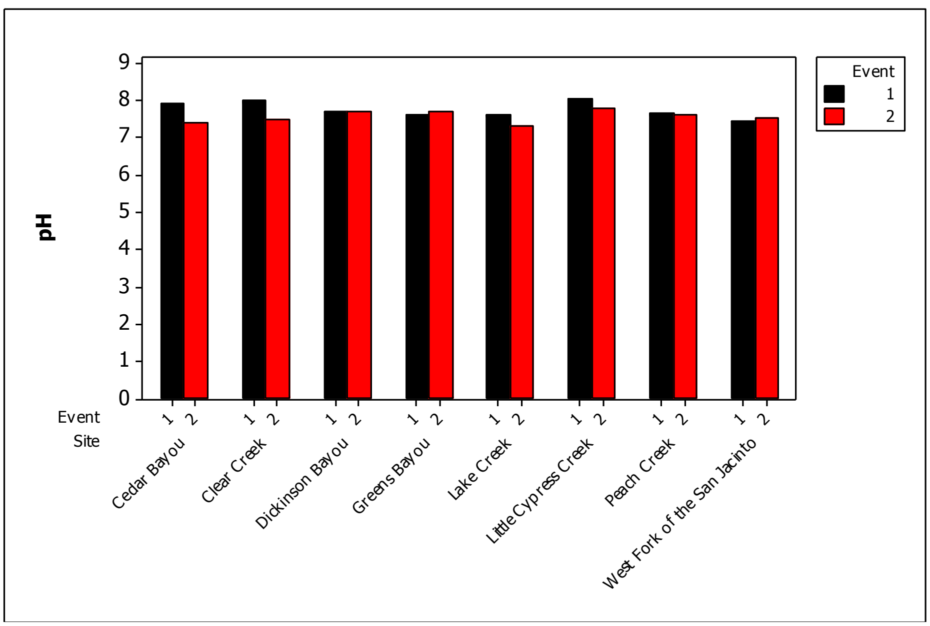

Figure 28. Recorded pH values for all sites and sampling events. 1=first sampling event and 2=second sampling event.

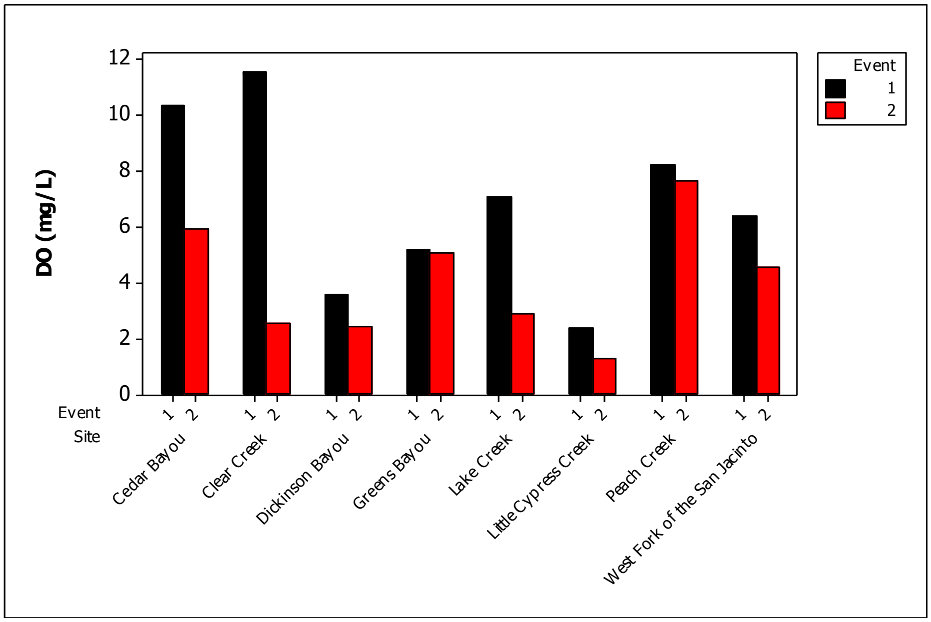

Figure 29. Dissolved oxygen (DO) levels for all sites and sampling events. 1=first sampling event and 2=second sampling event.

0.32 mg/L (Figure 30). Measurements of water temperature, specific conductance, pH, dissolved oxygen and free chlorine were not included in ANOVA analysis since they were composed of a single measurement at each sampling event. Raw data for all water quality analysis is presented in appendix K.

Nitrogen

Nitrogen measurements included combined nitrate and nitrite and ammonia. The mean combined nitrate and nitrite concentrations ranged from below the detection limit to as high as 4.15 mg/L. Two-way ANOVA results indicated that combined nitrate and nitrite concentrations were significantly different across sites and

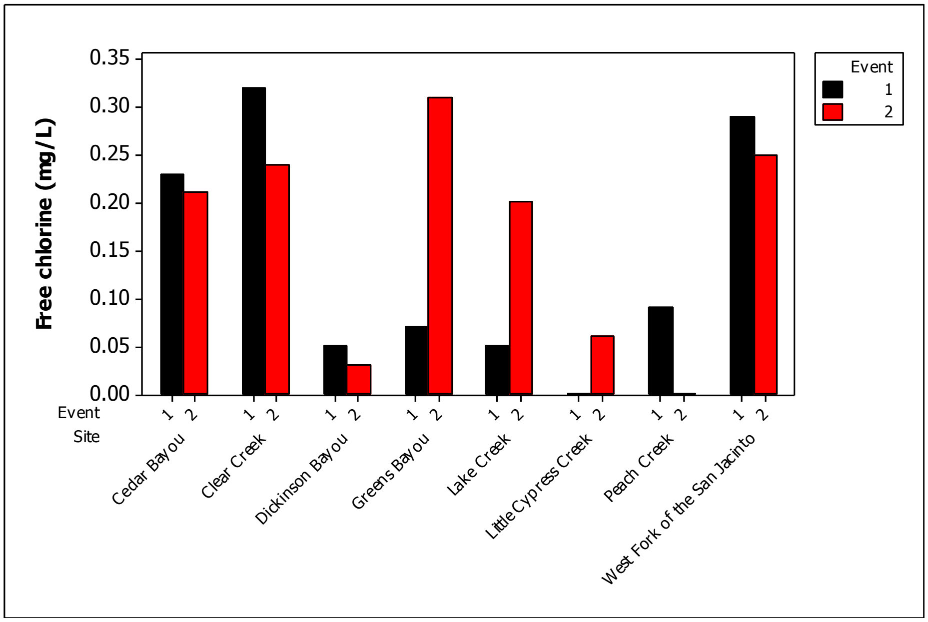

Figure 30. Free chlorine concentrations for all sites and sampling events. 1=first sampling event and 2=second sampling event.

sampling events, respectively (P=0.000, P=0.000). Mean concentration of combined nitrate and nitrite at Greens Bayou 1 was significantly higher than all other sites (Appendix C7 and Figure 31). This value is twice the screening level for nitrate of 1.95 mg/L for this particular stream segment. However, as stated earlier this site is listed as concerned status since it commonly exceeds the screening value for nitrate. Mean values of combined nitrate and nitrite concentrations were significantly lower at Cedar Bayou 1, Dickinson Bayou 1, Lake Creek 1, and Little Cypress Creek 1 and 2 than all other sites except each other, and Clear Creek 1, Peach Creek 2 and West Fork of the San Jacinto River 2.

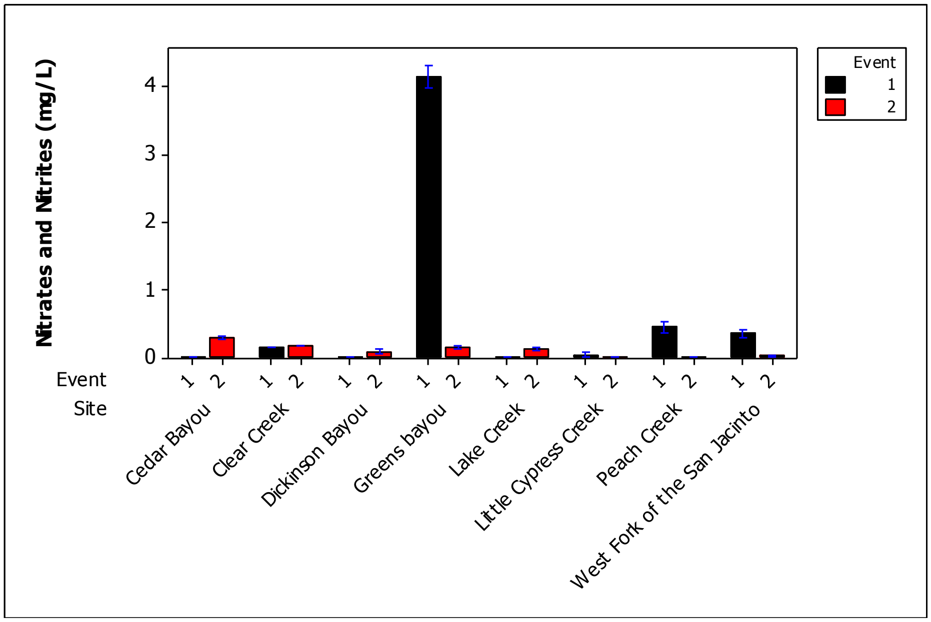

Figure 31. Nitrate and nitrite concentrations for all sites and sampling events (± 1 standard error).

Mean ammonia concentrations ranged between 0.01 to 0.33 mg/L across all sites and sampling events. Combined nitrate and nitrite concentrations were determined by two-way ANOVA to be significantly different across sites and sampling events, respectively (P=0.000, P=0.000). Mean ammonia values indicated that Lake Creek 2 and the West Fork of the San Jacinto River 2 were significantly higher than all other sites, and Lake Creek 2 was significantly higher than West Fork of the San Jacinto River 2 (Appendix C8 and Figure 32).

Orthophosphate

Orthophosphate concentrations across all sites and sampling events varied greatly, ranging between 0.20 to 5.92 mg/L. Orthophosphate concentrations were determined by two-way ANOVA to be significantly different across sites and

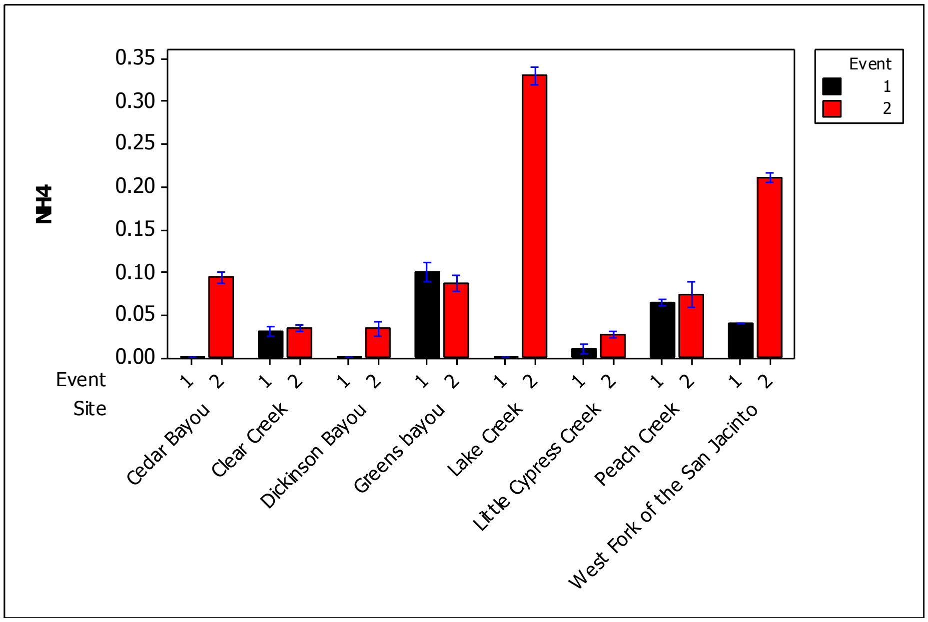

Figure 32. Ammonia concentrations for all sites and sampling events (± 1 standard error).

sampling events, respectively (P=0.000, P=0.000). Comparison or orthophosphate mean values indicated that both sites at Clear Creek, Greens Bayou and the West Fork of the San Jacinto River were significantly higher than all other sites (Appendix C9 and Figure 33).

Chlorophyll-*a* and pheophytin-*a*

Mean chlorophyll-*a* concentrations ranged from 0.70 to 17.39 mg/m^3. Chlorophyll-*a* concentrations were determined by two-way ANOVA to be significantly different across sites and sampling events (P=0.000, P=0.000). Lake Creek 2 was the highest mean value of chlorophyll-*a* at 17.39 mg/L and was significantly higher than all other sites (Appendix C10 and Figure 34). Lake Creek 1,

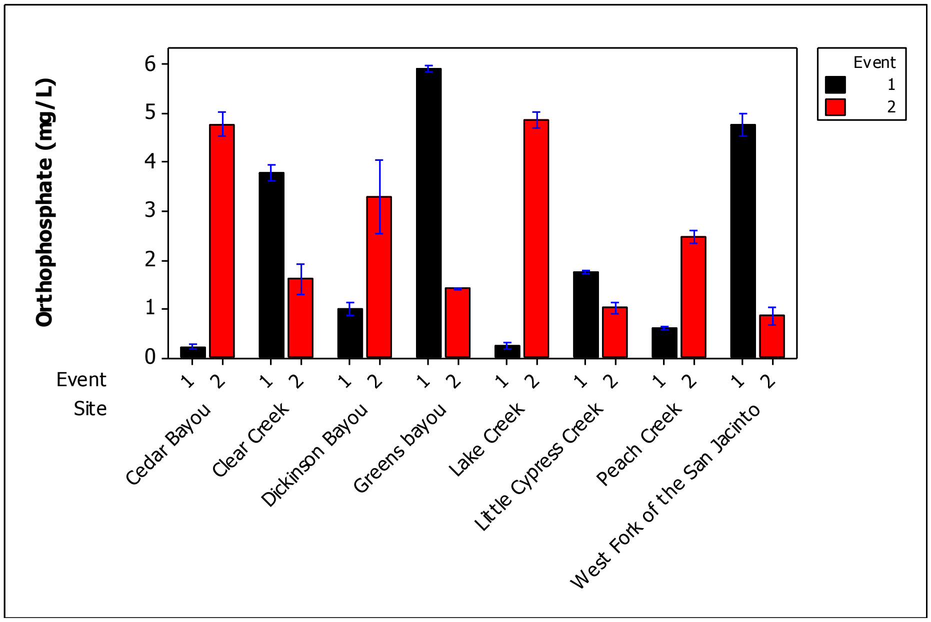

Figure 33. Orthophosphate concentrations for all sites and sampling events (± 1 standard error).

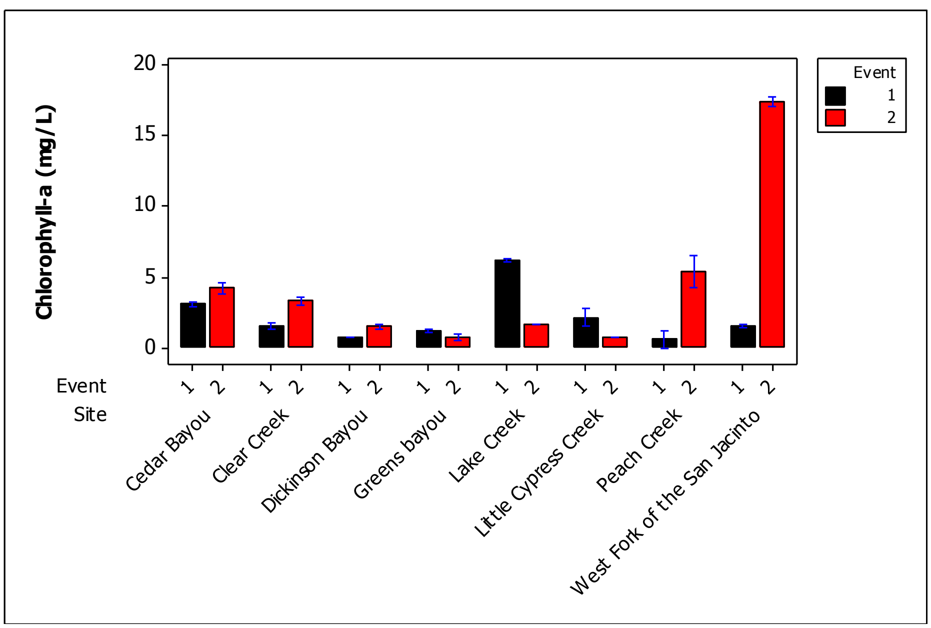

Figure 34. Chlorophyll-*a* concentrations for all sites and sampling events (± 1 standard error).

Little Cypress Creek 2 and the West Fork of the San Jacinto all had a mean chlorophyll-*a* values above 4 mg/L and were significantly higher than a majority of the sites except Lake Creek 2. Pheophytin-*a* concentrations were used to determine the degree of degradation in chlorophyll samples and therefore were not included in statistical analysis.

Turbidity

Mean turbidity levels were generally high, which is typical of streams in southeast Texas. Mean turbidity levels ranged across sites and sampling events between 1.83 and 23.83 NTU. Turbidity levels were determined by two-way ANOVA to be significantly different across sites and sampling events, respectively (P=0.000, P=0.000). The highest turbidity levels were found at Peach Creek 1 and 2, Dickinson Bayou 1 and the West Fork of the San Jacinto River 2. These sites were determined to be significantly higher than all other sites, but not each other (Appendix C11 and Figure 35).

Alkalinity

Mean alkalinity levels ranged greatly across sites and sampling events from 32.13 to 288.13 mg/L. Alkalinity were determined by two-way ANOVA to be significantly different across sites, but not sampling events, respectively (P=0.000, P=0.281). Mean alkalinity concentrations were significantly higher at both sampling events of Clear Creek, Dickinson Bayou and Little Cypress Creek than all other sites (Appendix C12 and Figure 36).

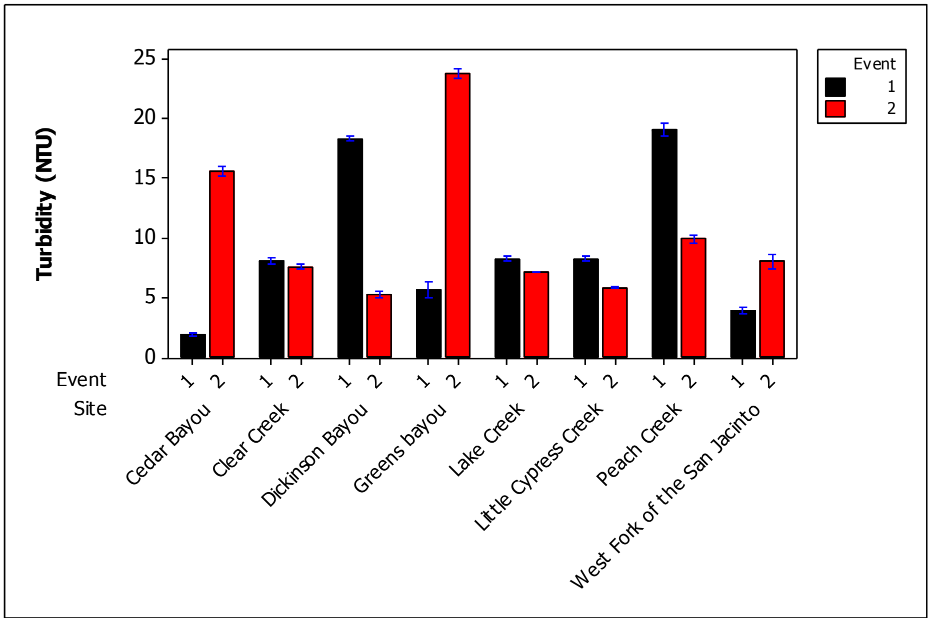

Figure 35. Turbidity levels for all sites and sampling events (± 1 standard error).

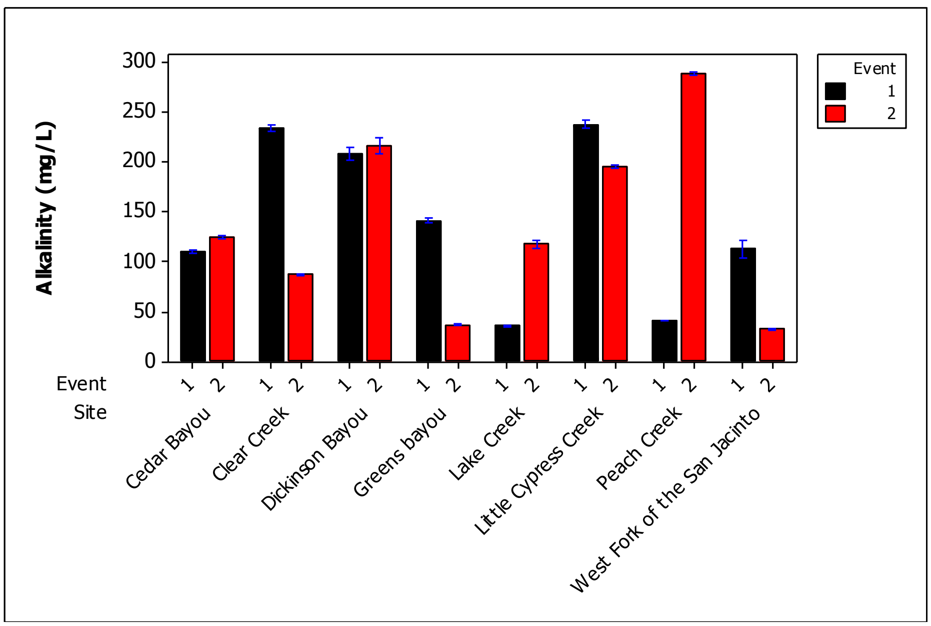

Figure 36. Alkalinity levels for all sites and sampling events (± 1 standard error).

Total suspended solids

Mean total suspended solids values varied greatly across sites and sampling events, ranging between 2.0 to 25.88 mg/L. TSS concentrations were determined by two-way ANOVA to be significantly different across sites and sampling events, respectively (P=0.000, P=0.000). Mean total suspended solids values were significantly higher at Lake Creek 2, Peach Creek 1 and 2 and the West Fork of the San Jacinto River than all other sites (Appendix C13 and Figure 37).

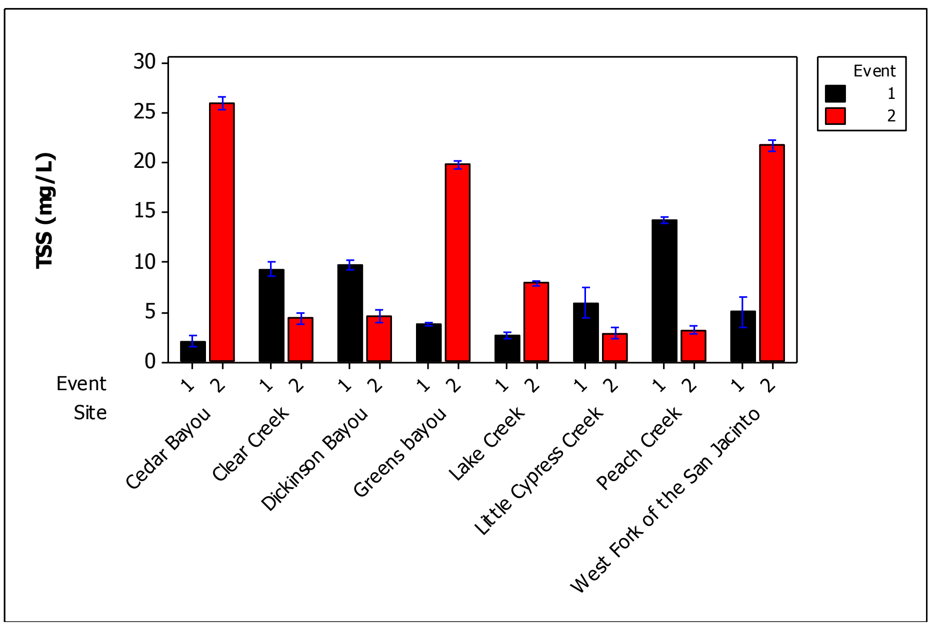

Figure 37. Total suspended solid concentrations for all sites and sampling events (± 1 standard error).

Statistical comparisons of land use, physical habitats water quality

Physical habitats

Pearson correlation analysis did not show any strong correlations between the amount of impervious area within the upstream watershed and certain physical habitat metrics including mean percent gravel or larger, mean bank erosion potential or mean bank slope. However, we did find a significant, although weak negative correlation between TIA with mean percent instream cover (r=-0.584, P=0.018) (Appendix B). This data was then analyzed using a linear regression analysis with TIA as the independent variable and mean percent instream cover as the dependent variable. TIA explained 29.3% of the variability in mean percent instream cover (R^2=29.3%, P=0.018) which suggested that as TIA increased the amount of mean percent instream cover declined (Figure 38). We also found a significant negative correlation (r=-0.749, P=0.001) (Appendix B) between PIA and the width of the natural riparian buffer. When analyzed using linear regression analysis PIA explained 52.9% of the variation in riparian width (R^2=52.9%, P=0.001) (Figure 39). As expected we also found a negative correlation (r=-0.608, P=0.012) (Appendix B) between PIA and mean canopy cover. When subjected to a linear regression analysis PIA explained 32.5 percent of the variability (R^2=32.5%, P=0.012) in mean canopy cover (Figure 40). This indicated that as PIA increased in a watershed it negatively affected the amount of riparian habitat and as a result the canopy cover.

Instantaneous streamflow was found to be significantly correlated with several water quality metrics, impervious area and instream cover. Streamflow exhibited a positive effect on nitrate and nitrite concentrations, explaining 32.3% of the variation in nitrate and nitrite concentrations (R^2=32.3%, P=0.022) (Figure 41). It should be noted that results may have been influenced by the high nitrate and nitrite values of Greens Bayou , the most urbanized site, at the first sampling event. Streamflow exhibited a stronger positive effect on orthophosphate concentrations, explaining 66.6% of the variation in orthophosphate concentrations (R^2=66.6%, P=0.022) (Figure 42). Therefore as streamflow increased the combined nitrate and nitrite and orthophosphate concentrations increased. PIA and TIA were both determined to positively affect stream flow, explaining 64.8 and 85.7% of the variation in streamflow (R^2=64.8%, P=0.000; R^2= 85.7%, P=0.000), respectively (Figures 43 and 44). Overall streamflow levels increased as the amount of PIA and TIA increased in a catchment. We hypothesized that streamflow would be a function of watershed size, however we did not find a relationship between these variables (R^2=1.9%, P=0.607). Lastly, we determined that streamflow negatively affected instream cover, with streamflow explaining 49.4% of the variation in available cover (R^2=49.4%, P=0.002) (Figure 45). As streamflow increased it caused a decrease in the available instream cover. Overall results indicate that PIA and TIA influence streamflow which may influence water quality and physical habitats either directly or indirectly.

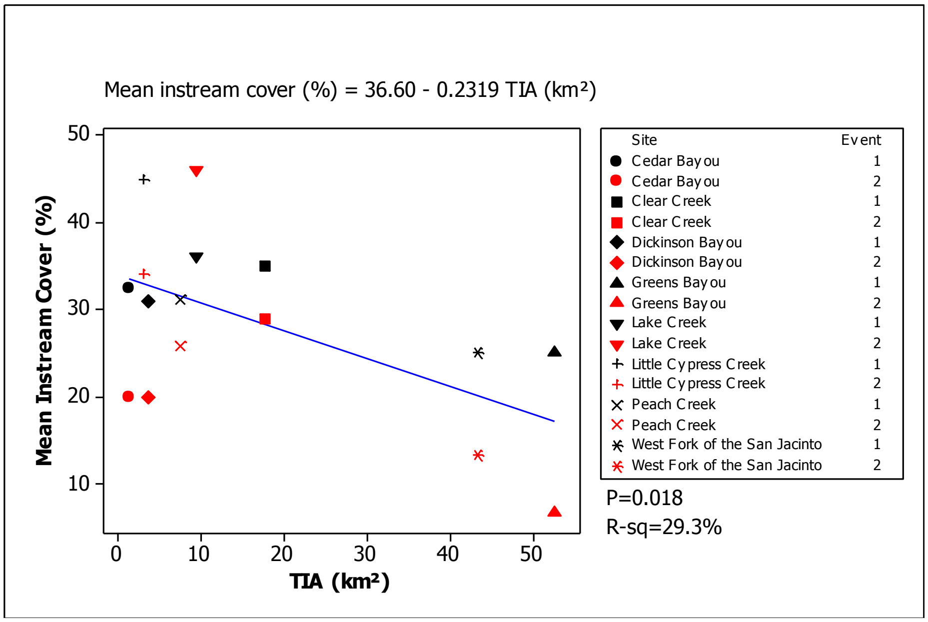

Figure 38. Linear regression of TIA and mean percent instream cover.

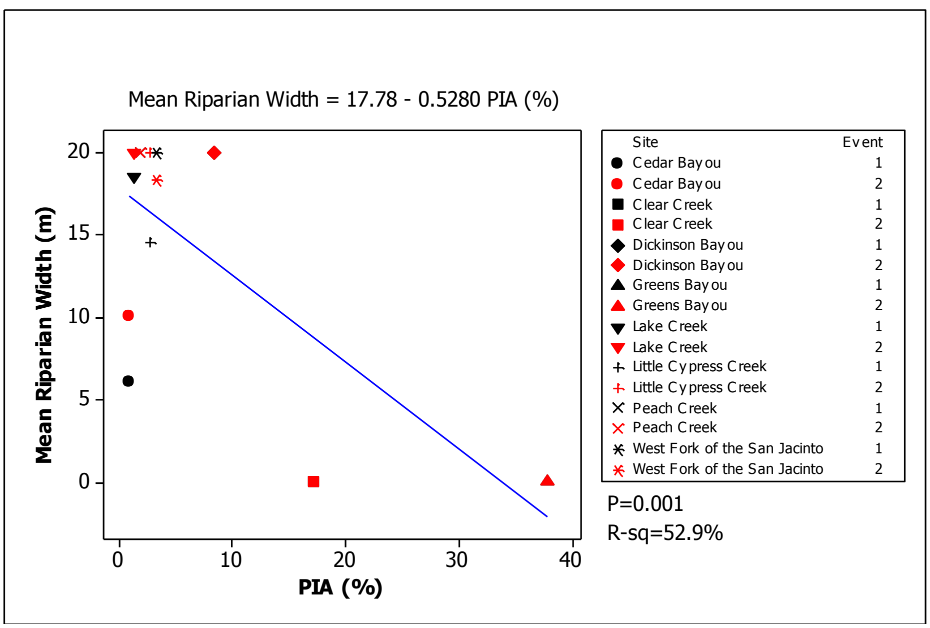

Figure 39. Linear regression of PIA and natural riparian buffer.

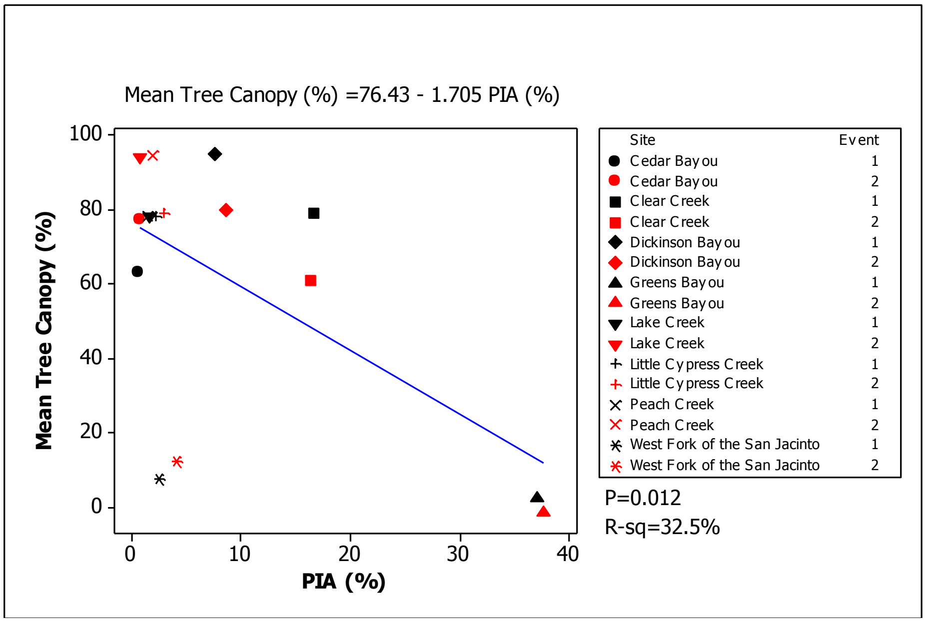

Figure 40. Linear regression of PIA and mean percent tree canopy cover.

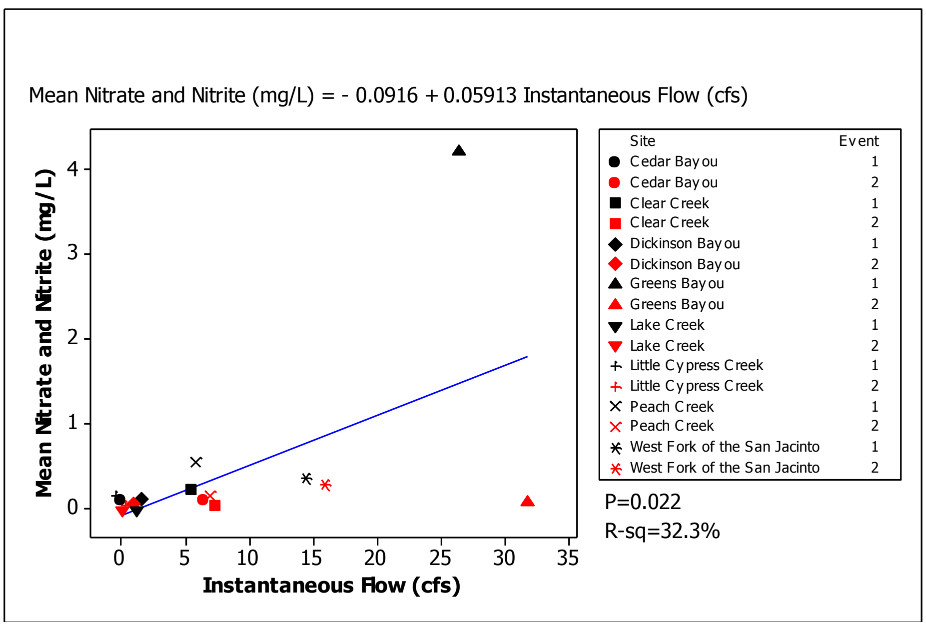

Figure 41. Linear regression of flow and the mean combined nitrate and nitrite concentrations.

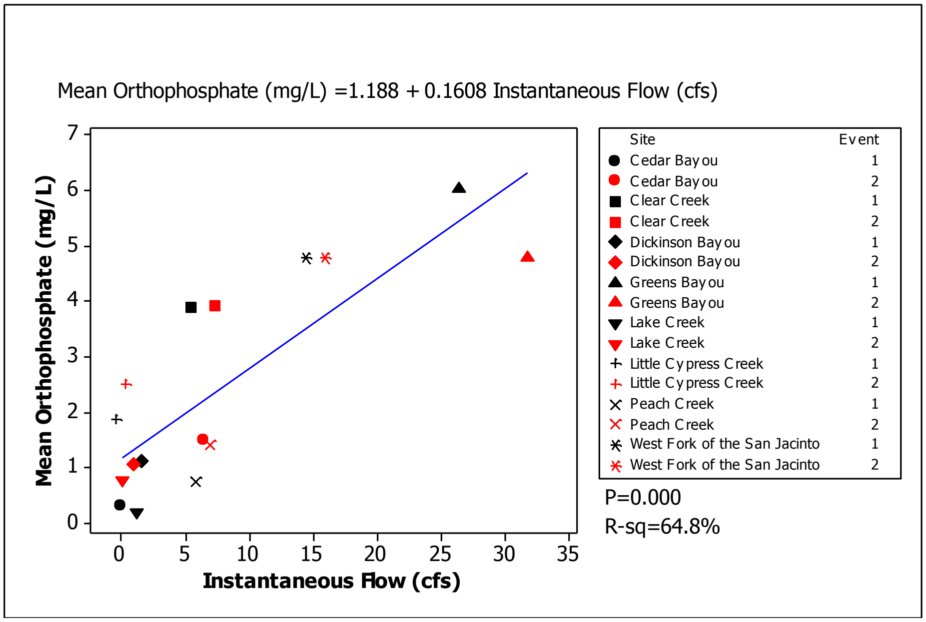

Figure 42. Linear regression of streamflow and mean orthophosphate concentrations.

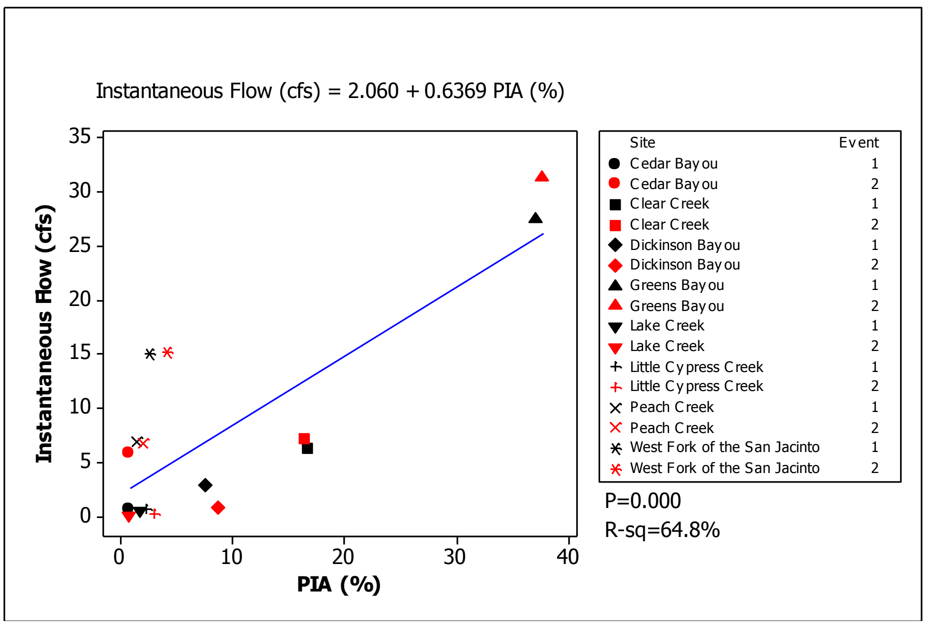

Figure 43. Linear regression of streamflow and PIA.

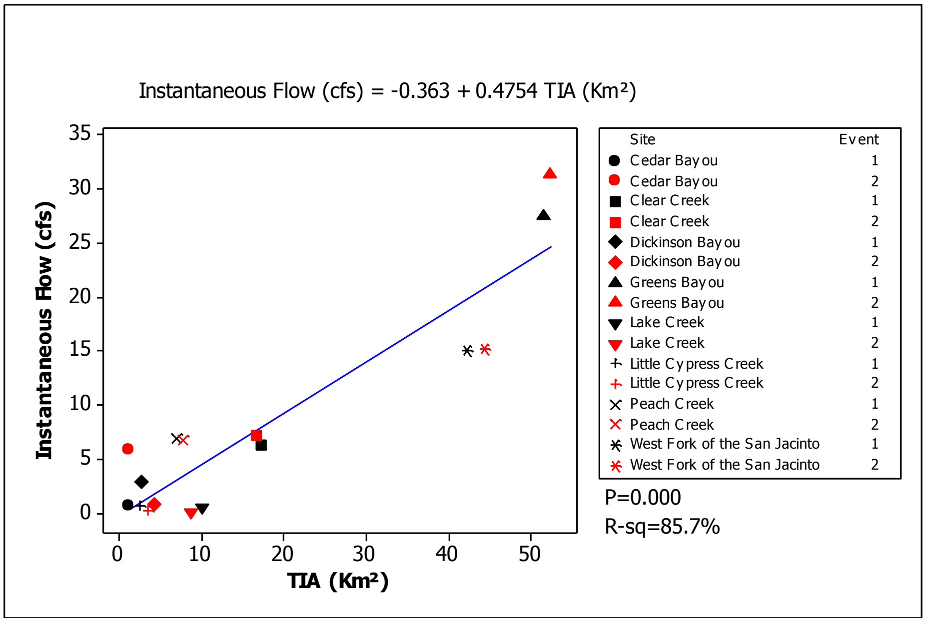

Figure 44. Linear regression of streamflow and TIA.

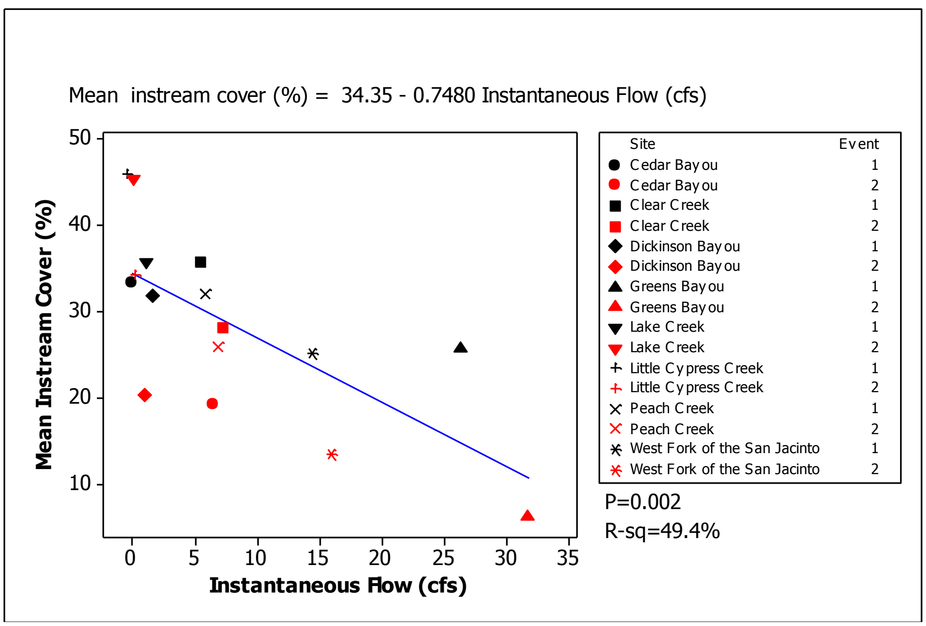

Figure 45. Linear regression of streamflow and mean percent instream cover.

Water quality

Temperature, specific conductivity, pH, dissolved oxygen and free chlorine

Pearson correlation indicated no significant relationship between water temperature, specific conductance, pH, dissolved oxygen or free chlorine with the degree of impervious surfaces within a site's watershed or physical habitat variables.

Nitrogen

Sites with higher PIA and TIA often had significantly higher mean nitrate and nitrite concentrations (Appendix D7). The mean combined nitrate and nitrite concentrations were found to be positively correlated with both PIA and TIA(r=0.609, P=0.012; r=0.542, P=0.030), respectively (Appendix B). Linear regression analysis indicated that PIA and TIA explained 37.1% and 29.4% of the variation, respectively, in combined nitrate and nitrite concentrations (R^2=37.1%, P=0.012; R^2=29.4%, P=0.030) (Figures 46 and 47). As mentioned earlier, this may have been influenced by the elevated concentrations at the highly urbanized site, Greens Bayou, during the first sampling event. Overall increased PIA and TIA caused an increase in combined nitrate and nitrite concentrations. However, we did not find any significant correlations between ammonia concentrations and the amount impervious surfaces or fish community metrics.

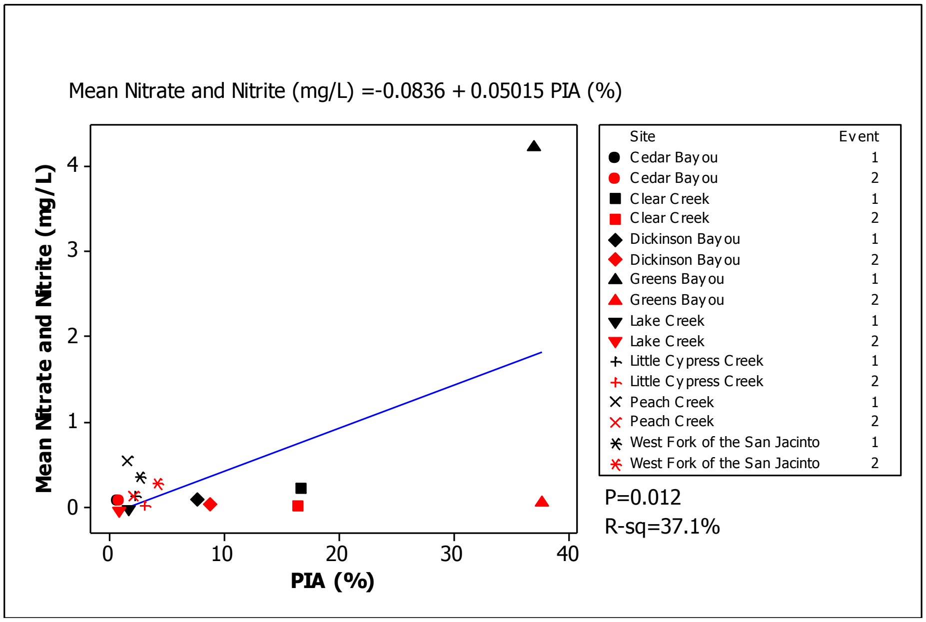

Figure 46. Linear regression of PIA and mean nitrate and nitrite concentrations.

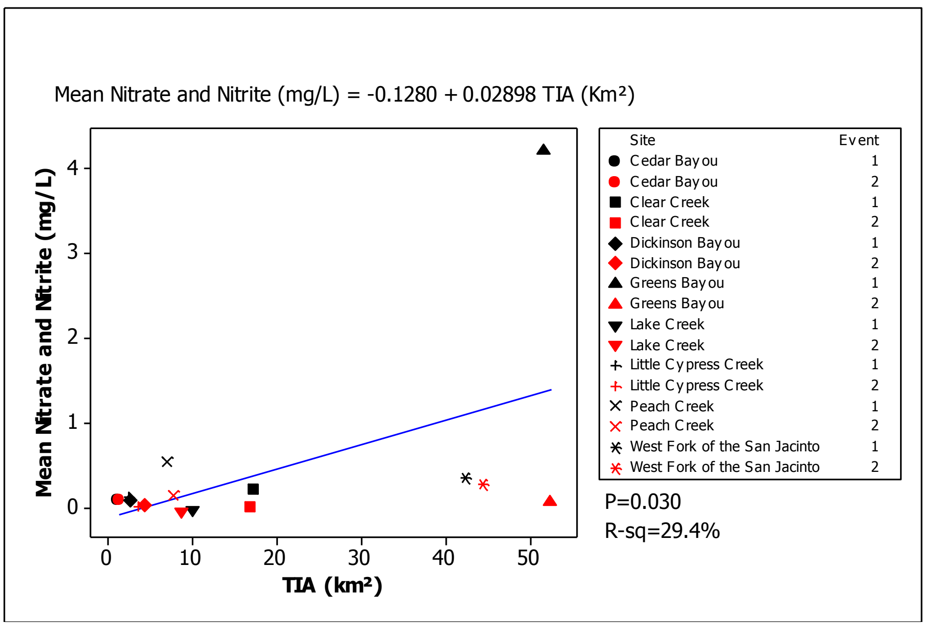

Figure 47. Linear regression of TIA and mean nitrate and nitrite concentrations.

Orthophosphate

Mean orthophosphate concentrations were consistently significantly higher in watersheds with greater TIA and PIA (Appendix D9). For instance, orthophosphates were in significantly higher concentrations at higher impervious sites (Both TIA and PIA) on both sampling events at Clear Creek, Greens Bayou and the West Fork of the San Jacinto River. Orthophosphates were determined to be strongly positively correlated with TIA (r=0.886, P=0.000) and to a lesser extent PIA (r=0.697, P=0.003) (Appendix B). Linear regression analysis indicated that PIA explained 48.5 percent of the variation (R^2=48.5%, P=0.003) in orthophosphate levels while TIA explained 78.5% of the variation (R^2=78.5%, P=0.000) (Figures 48 and 49). Therefore, results indicate that increased amounts of PIA and TIA indirectly resulted in higher concentrations of orthophosphate. We also observed a negative relationship between orthophosphate concentrations and the mean width of the natural riparian buffer. Regression analysis results indicated that mean width of the natural riparian buffer explained 28% (R^2=28.0%, P=0.035) of the variation in orthophosphate levels (Figure 50). This indicated that a higher width riparian buffer caused a decrease orthophosphate concentrations.

Chlorophyll-a, turbidity, alkalinity and total suspended solids

Pearson correlation analysis determined that chlorophyll-*a*, turbidity, alkalinity, total suspended solids concentrations were not significantly associated with land use or physical habitat variables.

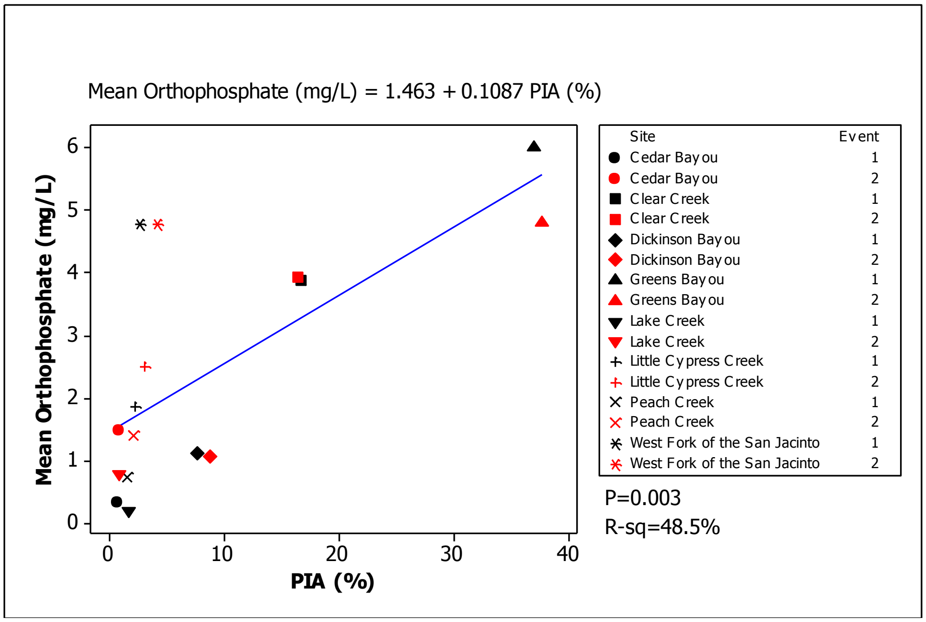

Figure 48. Linear regression of PIA and mean orthophosphate concentrations.

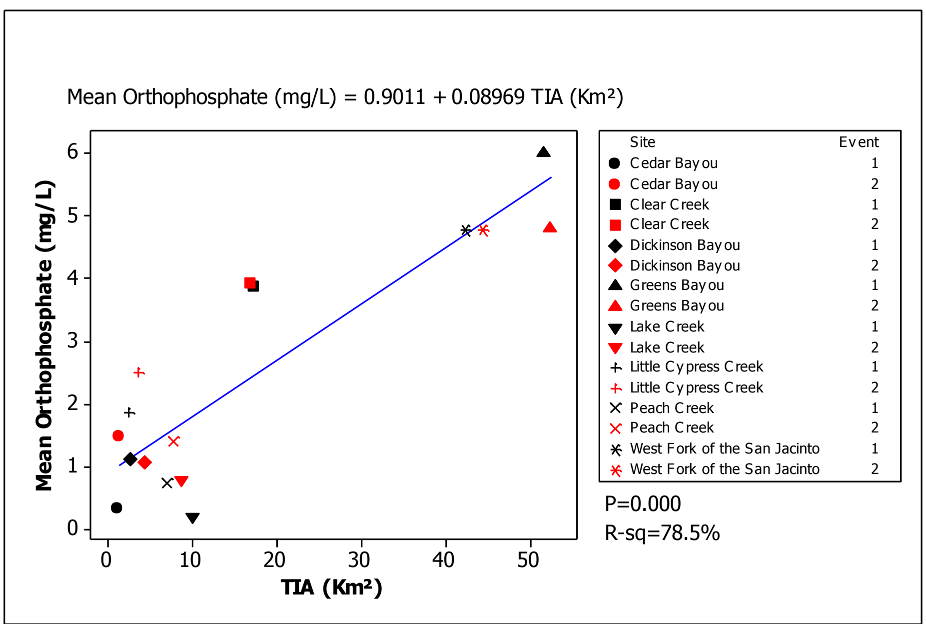

Figure 49. Linear regression of TIA and mean orthophosphate concentrations.

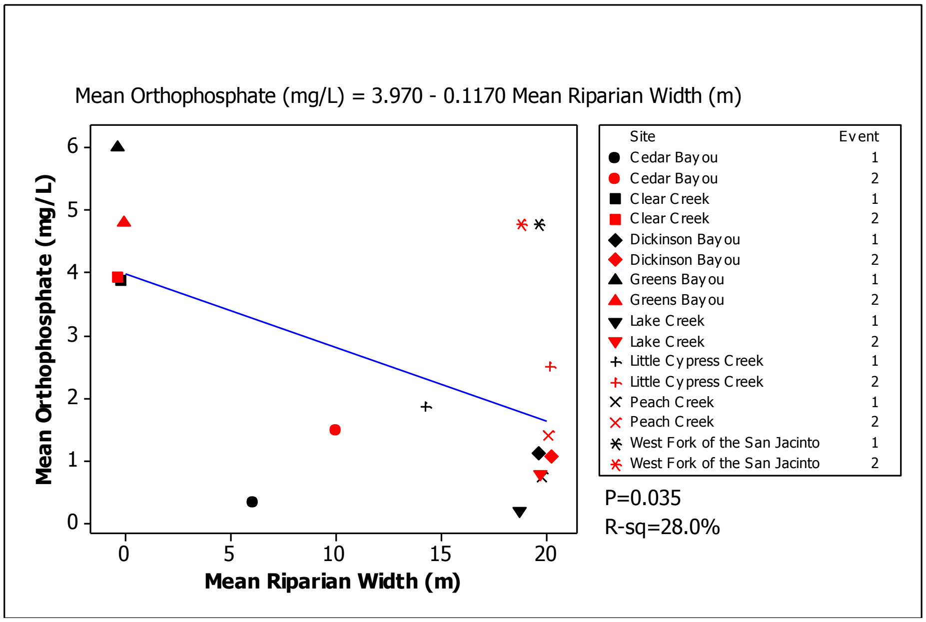

Figure 50. Linear regression of mean orthophosphate concentrations and mean riparian width.

Principle components analysis

Principle components analysis (PCA) was performed using MINITAB 15® software on physical habitat, water quality, watershed size and PIA so we could ultimately assess relationships with fish community metrics. PIA was selected instead of TIA in the PCA because it better represents the entire watershed since it is a product of the TIA divided by the watershed size. A biplot of the components scores for each site and collection and raw results are displayed in Figure 51 and Appendix E, respectively. PCA's first component explained 31.0% and the second component explained 21.8% of the variability in the data set for a total of 52.8%. Significantly positively loading variables (>0.3) in PC1 included canopy cover and riparian width. High negatively loading variables in the PC1 included PIA, orthophosphate and flow. In PC1 sites with the highest composite scores were Lake

Creek 1 and 2, while the sites with the lowest scores were Greens Bayou 1 and 2. Significant positively loading variables (>0.3) in PC2 included only alkalinity and negatively loading variables included watershed size, ammonia and TSS. In PC2 the sites with the highest scores were Dickinson Bayou 1, Cedar Bayou 2 and Little Cypress Creek 1. The sites with the lowest scores were the West Fork of the San Jacinto 2 and Lake Creek 2.

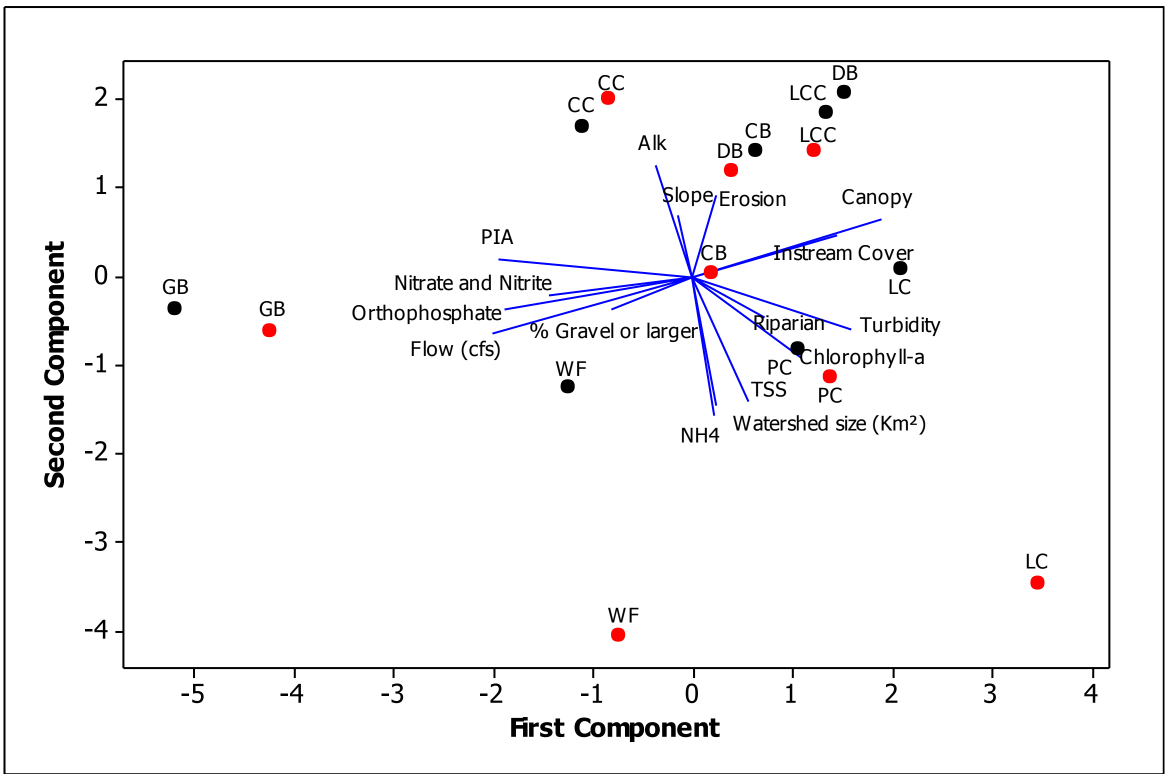

Figure 51. Biplot of principal component analysis of water quality, percent impervious area, watershed size and physical habitat variables. Black represents the first sampling event and red represents the second sampling event. CB is Cedar Bayou, CC is Clear Creek, DB is Dickinson Bayou, GB=Greens Bayou, LC is Lake Creek, LCC is Little Cypress Creek, PC is Peach Creek and WF is the West Fork of the San Jacinto River.

Fish community collections

We collected and identified a total of 8,203 fish that comprised 52 different species in 17 families (Table 4 and Appendix E). The IBI scores ranged from limited (IBI score=29) at Greens Bayou to exceptional (IBI score=54) at Lake Creek (Figure 52 and Appendix F). The percent tolerant species was relatively low across all sites and ranged from 1.1 to 24.1% (Figure 53). The highest percent tolerant species in any collection occurred during the first sampling of Dickinson Bayou and was a result of a low number of individuals being caught. The lowest percent of tolerant species occurred during the second sampling event of both Cedar Bayou and Little Cypress Creek. It should be noted that the percent tolerant species calculation excluded the species *Gambusia affinis* since during the construction of the regionalized IBI for Texas, researchers determined this better represented the integrity of the stream (Linam et al. 2002). The percent of intolerant species was low across all sites ranging from zero to 0.012% (Figure 54). Peach Creek, Lake Creek and the West Fork of the San Jacinto were the only sites to have three intolerant species collected during a single sampling event. The Shannon-Weiner diversity index ranged from 0.28 to 2.44 across all sites and sampling events. The highest Shannon-Weiner diversity indices were recorded at Peach Creek and Lake Creek and the lowest were found at Greens Bayou and Little Cypress Creek (Figure 55). Pielou's evenness index ranged from 0.12 at Little Cypress Creek 2 to 0.77 at Lake Creek 1 (Figure 56). This suggested that the fish community at Little Cypress Creek was highly uneven, which was primarily due to a high number of *Gambusia* *affinis* collected (Appendix E). Shannon-Wiener diversity index was strongly correlated with Pielou's evenness (p=0.918, p=0.000). Cumulative species richness varied considerably between sites and sampling events ranging from only six species at Greens Bayou to twenty-four species at Lake Creek (Figure 57).

Table 4. Table displays total fish abundance at all sites combined, tolerance level and trophic feeding guild. Tolerance levels and trophic guilds classified by Linam et al. (2002) as follows I=intolerant, T=tolerant, IF=invertivore, O=omnivore, P= piscivore. * Unlabeled tolerance is an intermediate level.

Scientific Name	Common Name	Total Abundance	Tolerance	Trophic Guild
Lepisosteidae				
Atractosteus spatula	Alligator gar	2	T	P
Lepisosteus oculatus	Spotted gar	3	T	P
Clupeidae				
Dorosoma cepedianum	Gizzard shad	10	T	O
Cyprinidae				
Ctenopharyngodon idella	Grass carp	1	T	H
Cyprinella lutrensis	Red shiner	141	T	IF
Cyprinella venusta	Blacktail shiner	1515		IF
Cyprinus carpio	Common carp	1	T	O
Hybopsis amnis	Pallid shiner	6		IF
Lythrurus fumeus	Ribbon shiner	6		IF
Lythurus umbratilis	Redfin shiner	4		IF
Notemigonus crysoleucas	Golden shiner	9	T	IF
Notropis atrocaudalis	Blackspot shiner	72		IF
Notropis sabinae	Sabine shiner	68		IF
Notropis texanus	Weed shiner	12		IF
Notropis volucellus	Mimic shiner	30	I	IF
Pimephales vigilax	Bullhead minnow	260		IF
Catostomidae				
Erimyzon sucetta	Lake chubsucker	1		O
Moxostoma poecilurum	Blacktail Redhorse	37		IF
Carpiodes carpio	River carpsucker	16	T	O
Ictaluridae				
Ameiurus natalis	Yellow bullhead	20		O
Ictalurus furcatus	Blue catfish	1		P
Ictalurus punctatus	Channel catfish	12	T	O
Noturus gyrinus	Tadpole madtom	6	I	IF
Noturus nocturnus	Freckled madtom	5	I	IF
Loricariidae				
Pterygoplichthys gibbiceps	Sailfin pleco	18	T	H
Escocidae				
Esox americanus	Redfin pickerel	1		P
Aphredoderidae				
Aphredoderus sayanus	Pirate perch	18		IF
Mugilidae				
Mugil cephalus	Striped mullet	1		O

Table 3. Continued

Scientific Name	Common Name	Total Abundance	Tolerance	Trophic Guild
Atherinedae				
Labidesthes sicculus	Brook silverside	38	I	IF
Menida beryllina	Inland silverside	201		IF
Poeciliidae				
Gambusia affinis	Western mosquofish	3207		IF
Poecilia latipinna	Sailfin molly	17	T	O
Fundulidae				
Fundulus chrysotus	Golden topminnow	21		IF
Fundulus notatus	Blackstripe topminnow	1582		IF
Centrachidae				
Lepomis aurus	Redbreast sunfish	11		IF
Lepomis cyanellus	Green sunfish	72	T	P
Lepomis gulosus	Warmouth	8	T	P
Lepomis humilis	Orangespotted sunfish	1		IF
Lepomis macrochirus	Bluegill sunfish	129	T	IF
Lepomis megalotis	Longear sunfish	361		IF
Lepomis microlophus	Redear sunfish	33		IF
Lepomis miniatus	Redspotted sunfish	51		IF
Micropterus punctulatus	Spotted bass	48		P
Micropterus salmoides	Largemouth bass	40		P
Percidae				
Etheostoma chlorosomum	Bluntnose darter	6		IF
Etheostoma gracile	Slough darter	2		IF
Percina sciera	Dusky darter	10	I	IF
Ammocrypta vivax	Scaly sand darter	13		IF
Sciaenidae				
Aplodinotus grunniens	Freshwater drum	1	T	IF
Elassomatidae				
Elassoma zonatum	Banded pygmy sunfish	2		IF
Cichlidae				
Cichlasomo cyanoguttatum	Rio Grande cichlid	72		IF
Oreochromis aurea	Blue tilapia	1	T	O
Esox americanus	Redfin pickerel	1		P

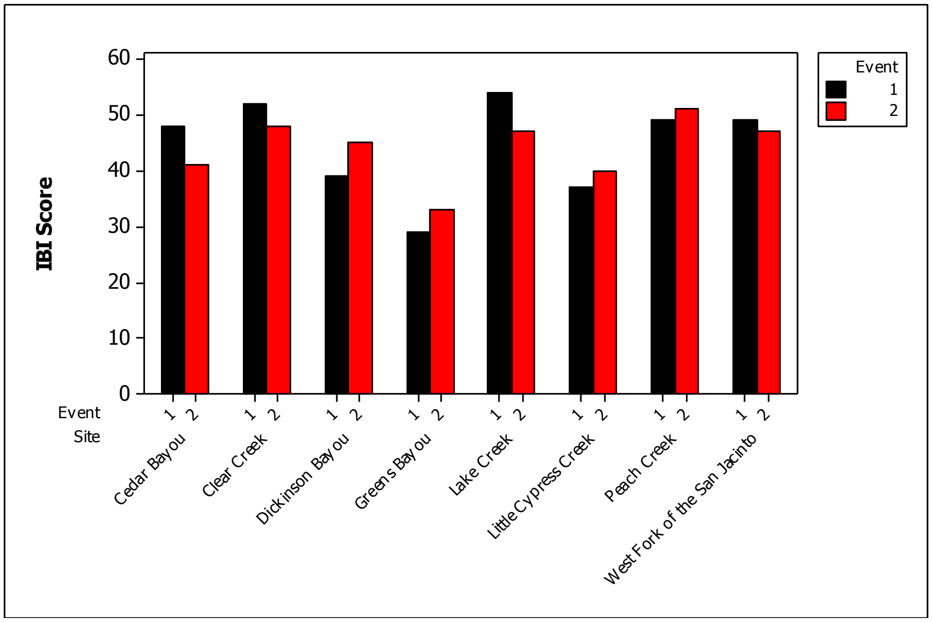

Figure 52. IBI scores by site. Data derived from combined seine and electrofishing data. 1=first sampling event and 2=second sampling event.

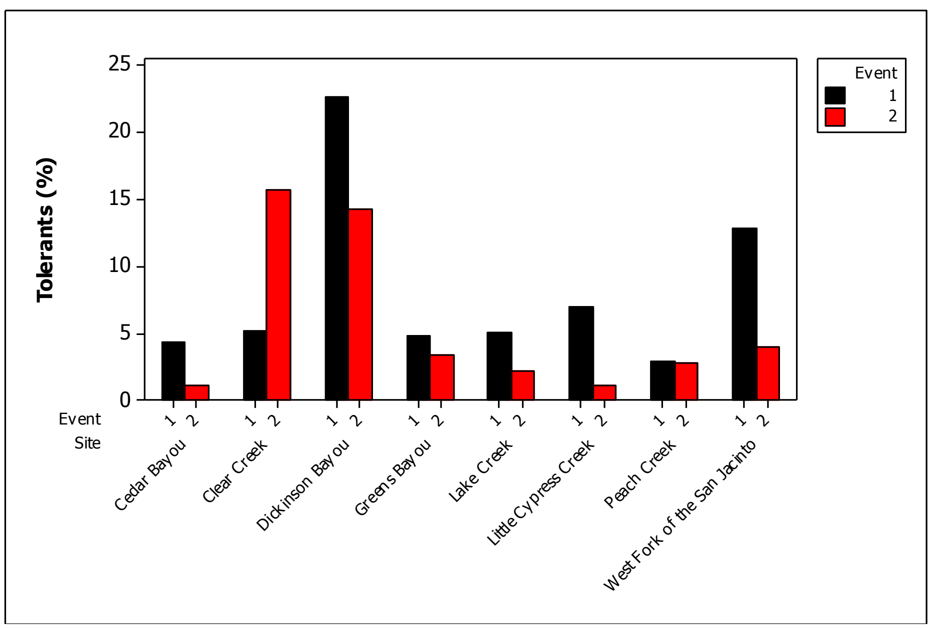

Figure 53. Percent tolerant species by site. Data derived from combined seine and electrofishing data. 1=first sampling event and 2=second sampling event.

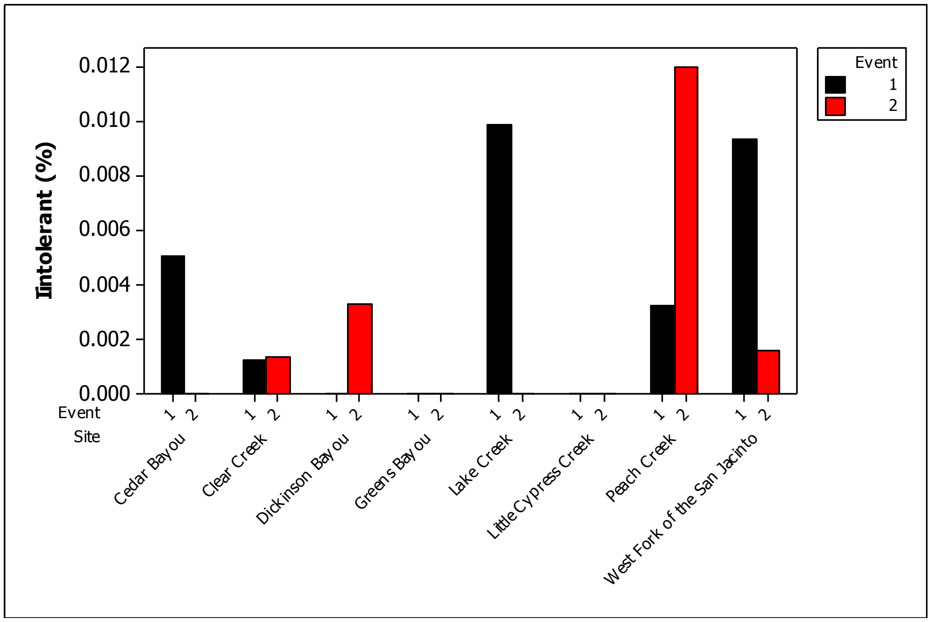

Figure 54. Percent intolerant species by site. Data derived from combined seine and electrofishing data. 1=first sampling event and 2=second sampling event.

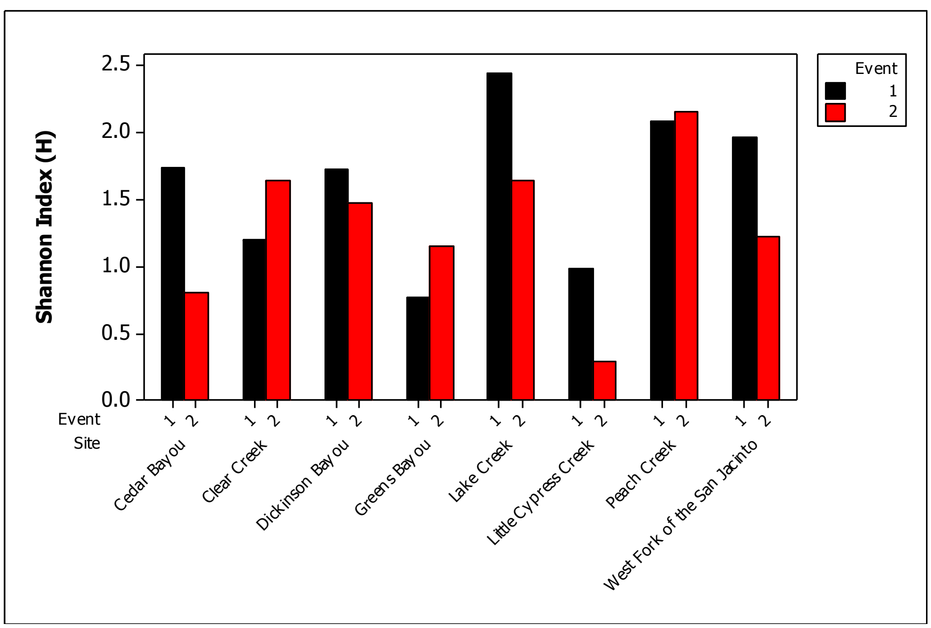

Figure 55. Shannon-Wiener diversity index (H) by site. Data derived from combined seine and electrofishing data 1=first sampling event and 2=second sampling event.

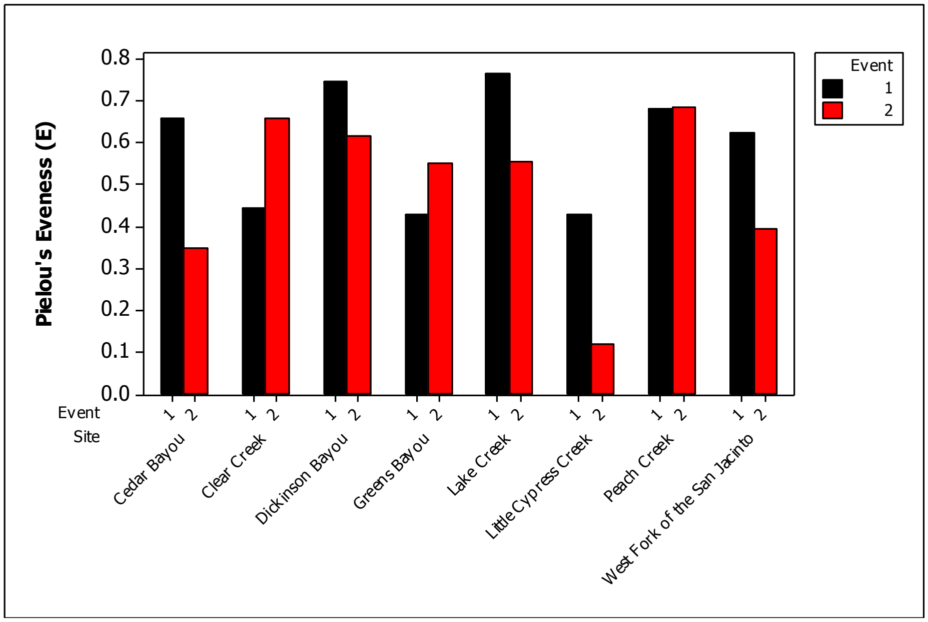

Figure 56. Pielou's evenness index (E) at site and sample period. Data derived from combined seine and electrofishing data. 1=first sampling event and 2=second sampling event.

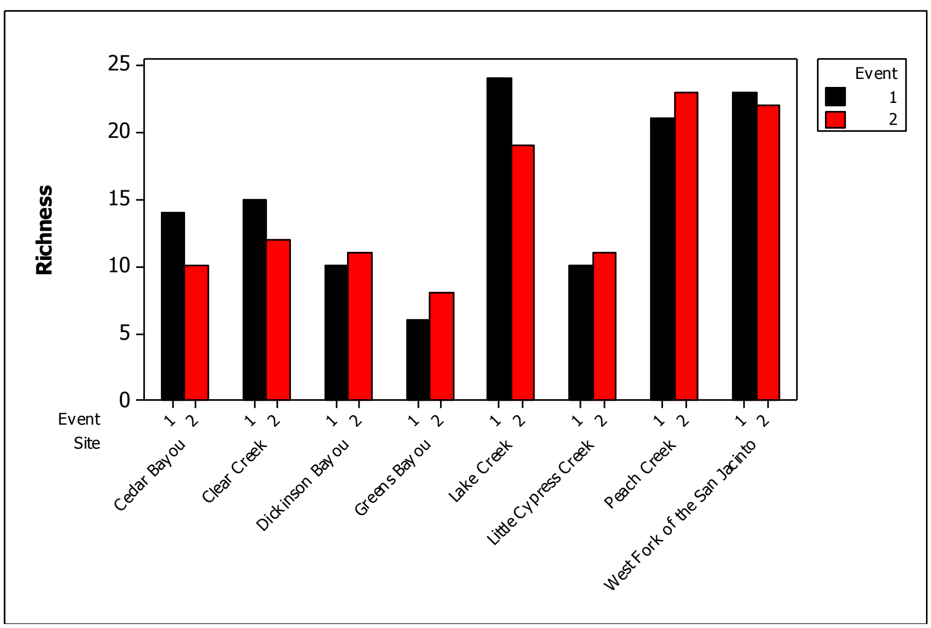

Figure 57. Species richness by site and sampling period. Data derived from combined seine and electrofishing data. 1=first sampling event and 2=second sampling event.

Cluster analysis

Cluster analysis was conducted in order to investigate similarities in fish communities across sites and sampling events. Cluster analysis was conducted separately on seining and electrofishing data. The cluster analysis of fish communities sampled by seining yielded three groups (Figure 58 and Appendix G1). The first group had the highest degree of similarity between sites at 83.07% and included ten sites. The sites in the first group included Dickinson Bayou 1 and 2 (1 = first sampling event, 2= second sampling event), Cedar Bayou 1 and 2, Peach Creek 1 and 2, Lake Creek 1 and 2, West Fork of the San Jacinto 1, Greens Bayou 1and B, Little Cypress Creek 1, The first group's sites were not dominated by a particular species; rather they had an intermediate level of many species. The first and second groups had a 16.76% similarity. The second group's sites had the highest degree of similarity across sites at 91.68%. The second group included Clear Creek 1, Cedar Bayou 2 and Little Cypress Creek 2. The second group was dominated by the species *Gambusia affinis* which played a large role in these site's similarity. The third group included only the West Fork of the San Jacinto 2. The third group was very dissimilar from the other two groups and the similarity level was -3.42%. This site was segregated due to its proportion of the species *Cyprinella venusta* and *Fundulus notatus*.

The cluster analysis for fish communities collected by electrofishing yielded four groups (Figure 59 and Appendix G2). Group one contained the majority of the sites and had the highest degree of similarity at 89.34%. The first group included

Dickinson Bayou 1 and 2, Peach Creek 1 and 2, Lake Creek 1, Clear Creek 2, Greens Bayou 1 and 2 and Little Cypress Creek 1 and 2. The first group's sites could be categorized as having a low proportion of many species and no dominant species. The first group was dissimilar to other groups, but was slightly associated to group four with 9.56 % similarity. Group two contained only Clear Creek 1 and was most similar to group three at 43.79% similarity. Group two (Clear Creek) had the highest numbers of *Cyprinella lutrensis, Lepomis cyanellus, Lepomis megalotis and Pimphales vigilax*. Group three contained Cedar Bayou 1, West Fork of the San Jacinto 1 and 2 and Lake Creek 2. Group three's sites showed 82.53% similarity. Group three's sites were dominated by *Lepomis megalotis, Cyprinella venusta* and *Fundulus notatus*. Group four contained only Cedar Bayou 2 and was separate from the other groups due to a high proportion of the species *Gambusia affinis* and low amounts of all other species.

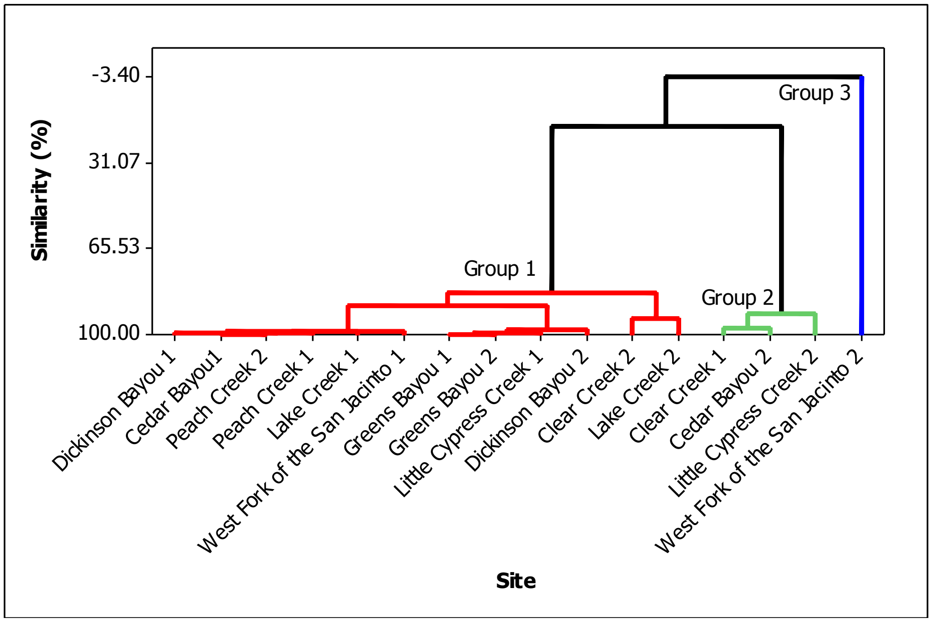

Figure 58. Cluster analysis of fish communities collected by seine showing the separation into three groups. 1 = first sampling event, 2= second sampling event.

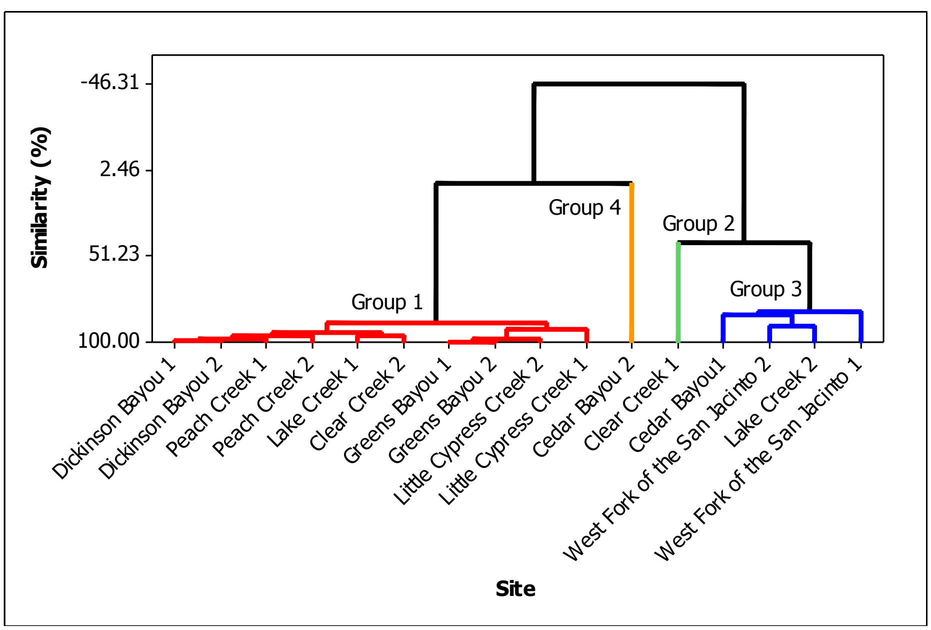

Figure 59. Cluster analysis of fish communities collected by electrofishing showing the separation into four groups. 1 = first sampling event, 2= second sampling event.

Statistical comparison of land use, physical habitat, water quality and fish communities metrics

Land use

There was a general trend of higher IBI scores in watersheds exhibiting low amounts of urbanization. However, at a few sites high impervious area was associated with high IBI scores and vice versa. We found a significant negative correlation (r=-0.623, P=0.010) between PIA and IBI scores (Appendix B). However, linear regression analysis indicated that PIA only explained 38.8% of the variation in IBI scores (R^2= 38.8%, P=0.010) (Figure 60). Therefore, as PIA increased in a watershed it caused IBI scores to decrease. However, we did not observe a significant relationship between TIA and IBI scores (Appendix B). This indicated that PIA was a better predictor of IBI scores than TIA.

We also examined other relationships between impervious area and fish community metrics including percent tolerant species, percent intolerant species, Shannon-Wiener diversity index, Pielou's evenness and species richness. We did not find a strong correlation between urbanization and these metrics, with the exception of species richness (Appendix B). There was however, a general trend of higher Shannon-Wiener diversity indices at sites with watersheds having low amounts of impervious area. In this context, Greens Bayou with the highest PIA and TIA, had the 2nd lowest Shannon-Wiener diversity index at 0.77 and 1.14 across sampling events. Species richness was found to have a significant negative correlation with PIA (r=-0.584, P=0.018) (Appendix B). Linear regression analysis indicated that PIA was accountable for 34.1% of the variation in the decline in species richness (R^2= 34.1%, P=0.018) (Figure 61). Pearson Correlation analysis also indicated that there was a positive correlation between watershed size and species richness (r=0.779, P=0.000) (Appendix B). Linear regression analysis indicated that watershed size explained 60.6% of the variation (R^2=60.6%, P=0.000) in species richness (Figure 62). This indicated that the size of the watershed affected the number of species collected.

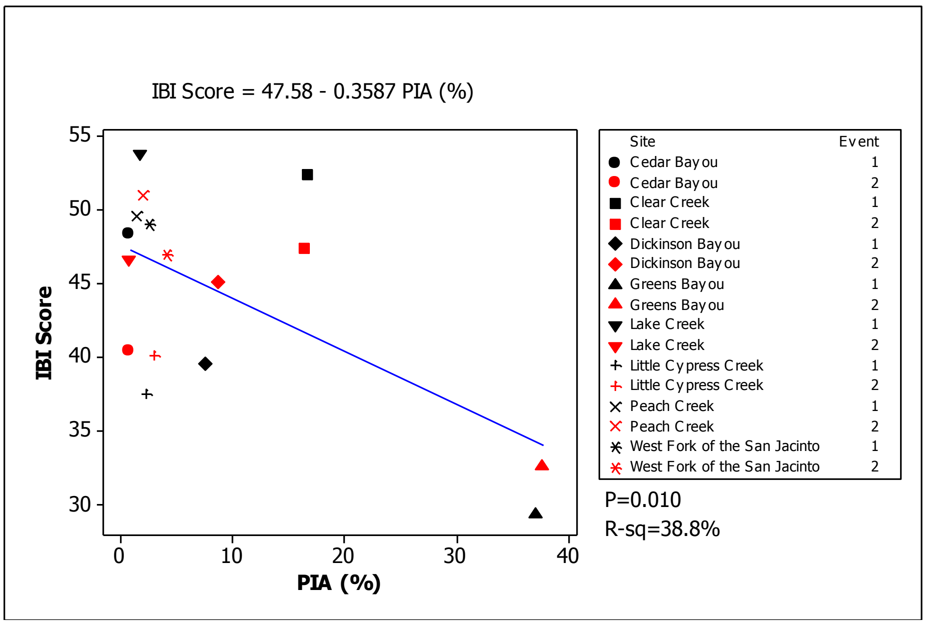

Figure 60. Linear regression of PIA and IBI scores. IBI scores based on combined seine and electrofishing data.

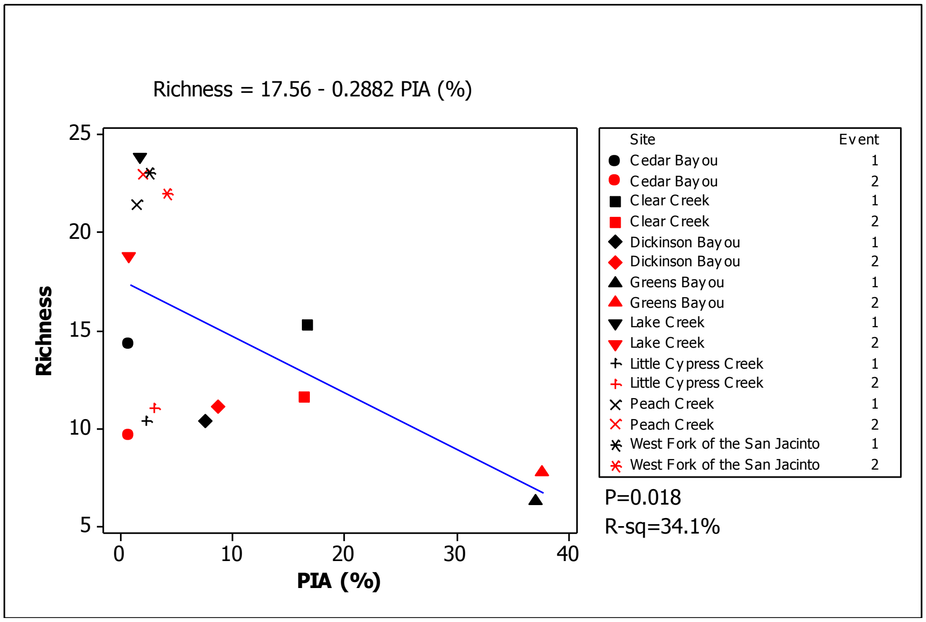

Figure 61. Linear regression of PIA and species richness. Richness based on combined seine and electrofishing data.

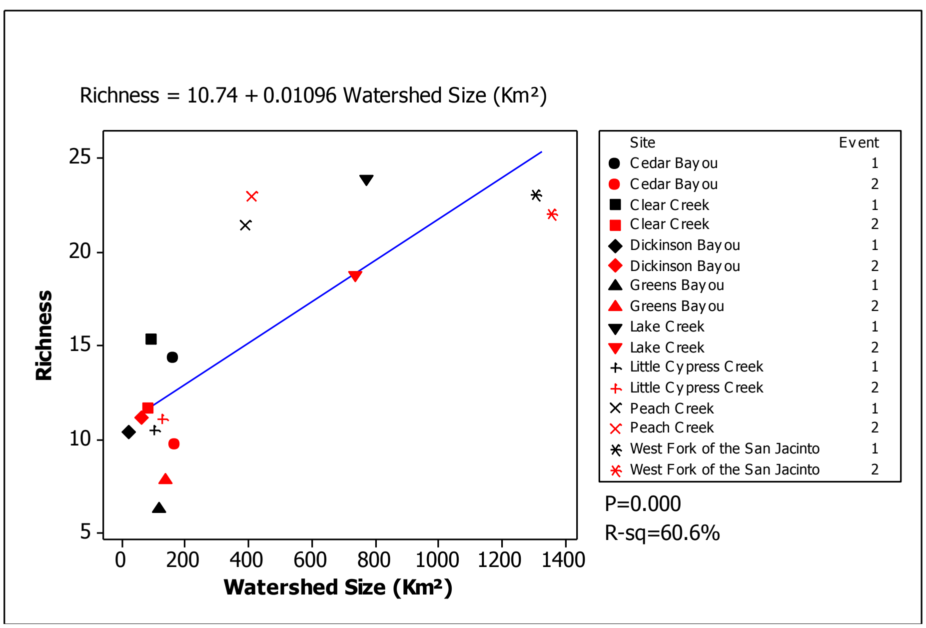

Figure 62. Linear regression of watershed size and species richness.

Water quality

Water quality parameters did not have a strong relationship with fish community metrics with the exception of a combined nitrates and nitrites and alkalinity. Nitrates and nitrites were negatively correlated with IBI scores (r=-0.543, P=0.030) (Appendix B). Nitrate and nitrate concentrations explained 29.5% of the variation in IBI scores (R^2= 29.5%, P=0.030) (Figure 63). These results indicated that as nitrate and nitrite levels increased, IBI scores decreased.

Alkalinity levels were found to be negatively correlated with the Shannon-Wiener diversity index and richness (r=-0.617, P=0.011; r=-0.602, P=0.014,) (Appendix B) respectively. Linear regression analysis indicated that alkalinity was accountable for 38.1% of the variation in the decline in Shannon-Wiener diversity index scores (R^2= 38.1%, P=0.000) and 36.2% of the variation in the decline in species richness (R^2= 36.2%, P=0.000) (Figures 64 and 65). This indicated that increased alkalinity concentrations negatively affected Shannon-Wiener diversity indices and species richness.

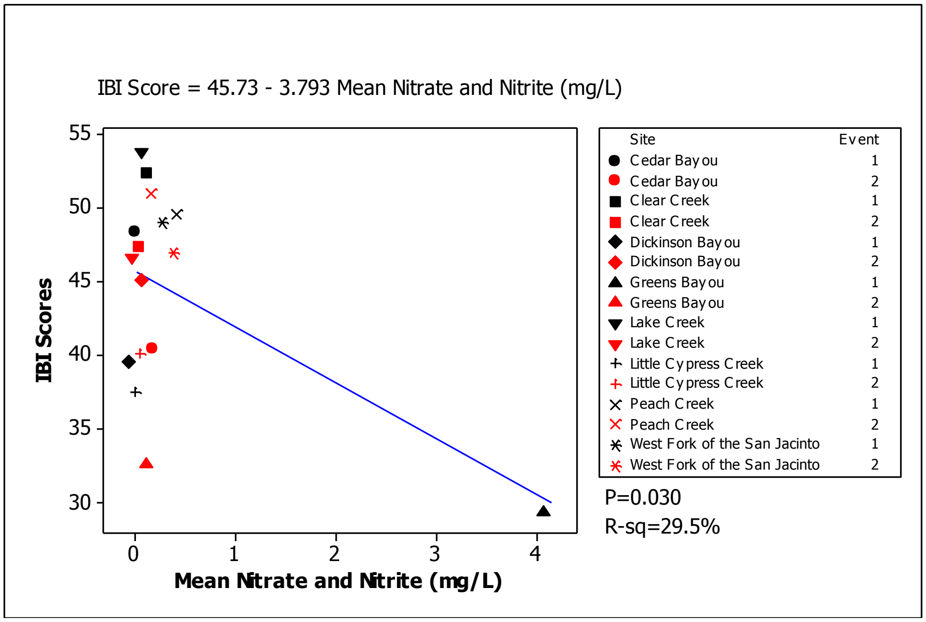

Figure 63. Linear regression of nitrate and nitrite concentrations and IBI scores.

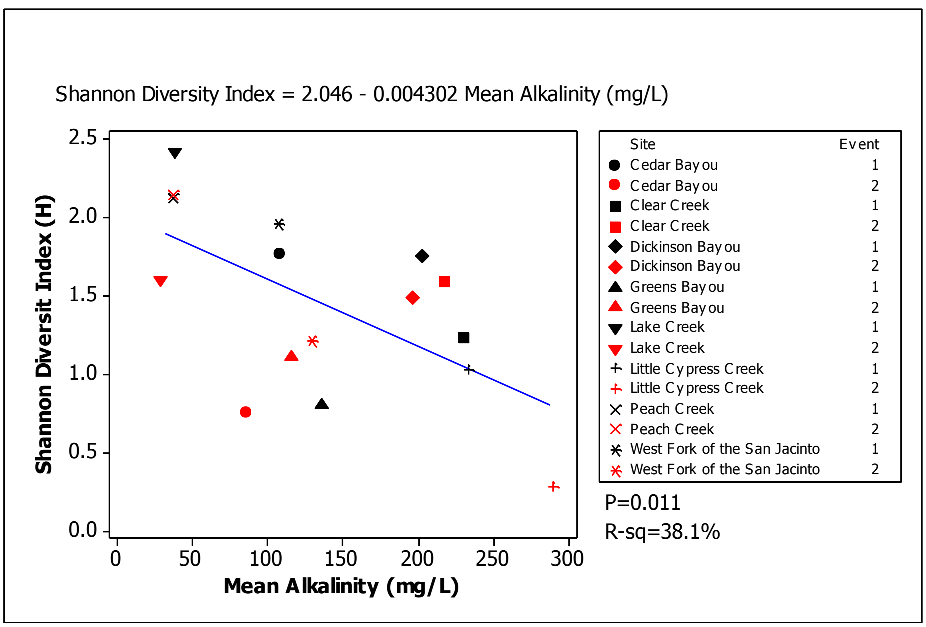

Figure 64. Linear regression of alkalinity concentrations and Shannon-Wiener diversity indices.

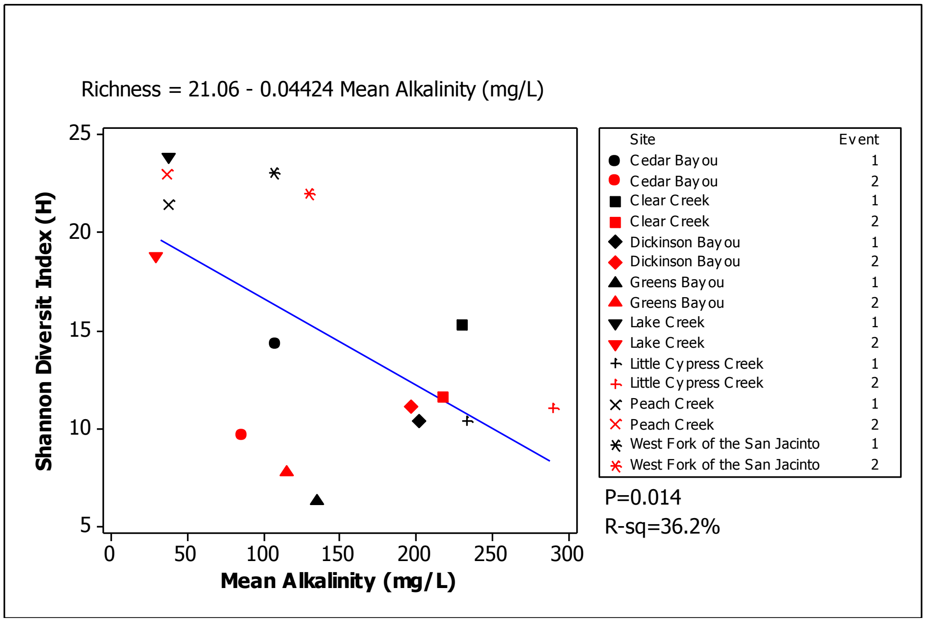

Figure 65. Linear regression of alkalinity concentrations and species richness.

Principle components analysis and fish community relationships

In order to study the relationship among principal components and fish communities we ran a regression analysis between site scores (PC1 and PC2) and IBI scores, Shannon-Wiener diversity index, Pielou's evenness and species richness. We determined a significant positive correlation (r =0.554, P=0.026) (Appendix B)between the first principal component site scores and IBI scores (Appendix B). Results of linear regression analysis indicated that PC1 explained 30.7% of the variation in IBI scores (R^2=30.7%, P=0.027) (Figure 66). These results indicated that highly loading variables in PC1 (canopy cover, riparian width, PIA, orthophosphate, and flow) affected IBI scores. We also determined a significant negative correlation between the second principal component site scores and species richness (r=-0.553, P=0.026) (Appendix B). Results of linear regression analysis indicate that PC2 explained 30.6% of the variation in species richness (R^2=30.6%, P=0.026) (Figure 67). This indicated that highly loading variables in PC2 (alkalinity, ammonia, watershed size and TSS) negatively affected species richness.

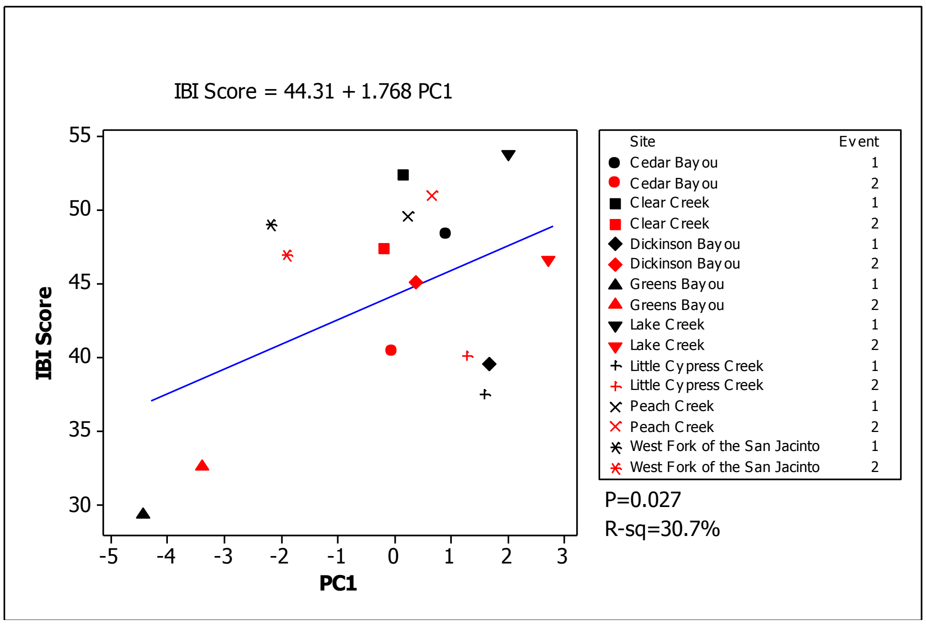

Figure 66. Regression analysis between the first principal component and IBI scores.

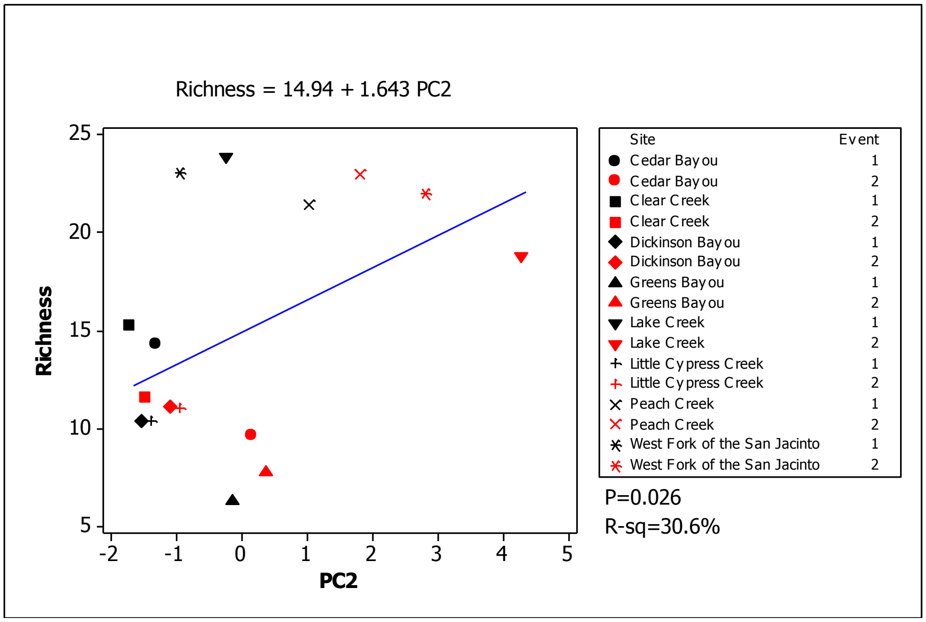

Figure 67. Regression analysis between the second principal component and richness.

Cluster analysis and impervious area

In order to determine if there was a relationship between electrofishing group membership and impervious surfaces we visualized these data in a boxplot. Group membership based on electrofishing data showed a relationship with the degree of impervious surfaces (Appendix H1 and H2). Group 3's collections were from sites with watersheds with very low PIA, but high TIA, suggesting fish communities were perhaps influenced by impervious surfaces in larger watersheds

Lastly, in order to determine if there was a trend between the seine group membership and impervious surfaces we visualized these data in a boxplot. However, based on this graphical analysis there did not seem to be any relationship between the degree of impervious surfaces and group membership for seine data (Appendix H3 and H4).

DISCUSSION

Habitat assessments

Significant relationships between physical habitat and impervious area were limited. Surprisingly, we did not find any strong indication that urbanization influenced mean percent gravel or larger, mean bank erosion potential, or mean bank slope. Contrary to our results, other studies have documented streams with a higher level of urbanization in their catchment to have increased erosion and steeper stream bank slopes (Leopold 1968; Booth and Jackson 1997). We may have missed this relationship due to our limited sample size. Intensive comprehensive sampling throughout the watershed may have been able to detect these relationships if they existed. Also our methodology was very crude and more sophisticated methods may have yielded more useful data. For example, we could have employed a total station surveying method in order to evaluate the bank slope which is more accurate than a hand held clinometer. Also, since erosion potential was a subjective visual estimation it may have resulted in biased results. In this case, we could have used different methods or perhaps used additional transects to achieve a more representative data. Other studies have investigated the role of urbanization on erosional rates. For instance, a study by Zaimes et al. (2008) used plots of erosional pins to obtain an estimate of erosional rates on streams. In general erosional pins are hammered into the stream banks in plots with a set length exposed. In their study they took length measurements four times per year to determine erosional rates. The study of erosional rates would have been a more accurate and quantitative method than our visual assessment of erosion potential, however it was beyond the scope of this project.

However, we did find some relationships between physical habitat and urbanization. For instance, we found that TIA negatively influenced mean instream cover. This may be due to urbanized sites generally having a lower fish habitat quality as a result of altered flows which can denude banks and cause bank incision (Booth and Jackson 1997). It may also be related to a decrease in large woody debris in the stream as a result of clear cutting the riparian buffer and humans actively removing trees from the stream, which has been shown to have negative effects on instream habitat (Sweeney et al. 2004).

PIA was shown to significantly negatively influenced the amount of riparian buffer and the percent tree canopy cover at the study sites. This may have been due to many of the sites with higher impervious area tended to have riparian zones with mowed grass or adjacent agricultural fields. Mean riparian buffers were not found to be significantly associated with fish community metrics. However, there may be an indirect relationship where urbanization results in loss of riparian buffer, which ultimately influences water quality. In our study we also found a significant negative relationship between mean riparian buffers with mean orthophosphate concentrations, which may have implications of fish community integrity. This may be an indication that higher amounts of riparian buffer remove overland loading of phosphorus into streams.

We found several variables influenced by streamflow, including levels of combined nitrate and nitrite and orthophosphate. We also determined that higher amounts of PIA and TIA in a watershed increased streamflow. This was an interesting finding since generally streams with a larger catchment size have higher streamflow and perhaps increased nutrients associated with a larger watershed. However, in our study we did not find an association between watershed sizes and these two water quality parameters or flow. Therefore, based on these results, higher amounts of impervious surfaces (both PIA and TIA) in the watershed were better predictors of streamflow, compared to catchment size. In contrast streamflow and impervious surfaces were better predictors of combined nitrate and nitrite and orthophosphate levels compared to catchment size. It should be noted that R-squared values from our regression analysis between combined nitrates and nitrites with flow, PIA and TIA, may have been inflated due to high mean values (4.15 mg/L) during the first sampling event at Greens Bayou. However, this data was retained for statistical analysis based on monitoring data from HGAC (2011) which displayed nitrate values often occurring higher than screening levels (1.95 mg/L). The observation of higher flows in watersheds with increased impervious surfaces supports general hydrological theory since water that comes in contact with impervious surfaces reaches the stream more quickly than water percolating slowly through the soil and recharging groundwater supplies (Leopold 1968). Also as other studies have determined (Soranno et al. 1996; Snyder et al. 2003) as water comes in contact with impervious surfaces it accumulates nitrogen and phosphorus. However, since our study was completed during a severe drought these results are most likely related to the degree of waste water run-off and discharge from water treatment plants entering the stream.

Results also indicated that streamflow negatively affected instream cover which was perplexing. General stream theory indicates that increased flows can encourage instream habitat abundance by increasing large woody debris and creating undercut banks (Wetzel 2001). Perhaps, as stated earlier, the prolonged periods of higher flows could decrease instream cover due to washing out events.

Water quality

As stated earlier, water quality variables including water temperature, specific conductivity, pH, dissolved oxygen and free chlorine were not found to be significantly correlated to land use, physical habitats or fish community metrics. However, we can make general comments about these variable's relationship to urbanization and fish communities. Water temperatures were consistently higher at the second sampling event which was most likely due to warmer air temperatures in the summer and drought conditions. We did not see any trends between water temperature and the degree of urbanization within a watershed.

Specific conductance was generally higher at sites with an increased level of urbanization, although there was not a significant relationship. Since specific conductance is a measure of all the ions present in the water it is difficult to propose why this occurred. This could be due to higher levels of nitrate and nitrite and phosphate, which we did determine through our water quality results. It should be mentioned that specific conductance may have influenced our electrofishing data since it becomes difficult to shock fish in specific conductivities higher than 1000 μS/cm, due to the voltage gradient being lower in the fish than the surrounding water (Nielsen and Johnson 1983).

Dissolved oxygen ranged from very low levels to supersaturated conditions. In all the second sampling events we found lower dissolved oxygen levels. This was most likely due to warmer water temperatures and the depressed oxygen solubility of warmer water. During the second sampling events of Clear Creek, Dickinson Bayou and Little Cypress Creek we found dissolved oxygen levels to be below 3 mg/L. These sites probably reached critically low levels of dissolved oxygen which may be a result of the drought or seasonality. We generally found that these sites contained a low to medium degree of urbanization with lower flows, slightly higher nitrogen levels and higher instream vegetation, suggesting eutrophication.

Trends in free chlorine levels indicated an increase in watersheds with a higher degree of urbanization, however no significant relationship was determined. Several of the sites with higher impervious area contained elevated free chlorine concentrations including Clear Creek, the West fork of the San Jacinto River and Greens Bayou. This may be a result of an increase in water treatment plants located within their watersheds that use chlorine to treat waste water before discharge.

We did not find a significant relationship between alkalinity levels and the degree of urbanization in a watershed. This is contrary to a study by Koteswari and Ramanibai (2005) whom found urbanized streams to have two to eight times higher total alkalinity concentrations compared to suburban streams. Our results indicated that lower alkalinity levels were associated with higher Shannon-Wiener diversity indices and species richness. This was unexpected since streams with a higher alkalinity have a higher buffering capacity and can resist pH swings and associated negative effects (Wetzel 2001).

Contrary to our hypotheses, the amount of urbanization in a watershed did not seem to influence ammonia, chlorophyll-*a*, turbidity, or TSS. However, based on our regression models, increased urbanization led to increased levels of combined nitrate and nitrite and orthophosphate. Regression analysis showed that PIA and TIA explained 32.6 and 24.3 percent of the variation, respectively, in nitrate and nitrite concentrations. This was a similar finding to that by Snyder et al. (2003) whom found a positive association between urbanization and nitrate levels in 20 catchments in West Virginia. As stated earlier, we also determined that nitrate and nitrite levels negatively affected IBI scores. Research has shown that nitrites affect the oxygen transport system in fishes (Heath 1995). As a result of high levels of nitrogen, we may see impacts on fish communities over time. It should be noted that high nitrate and nitrite values at Greens Bayou (mean of 4.15 mg/L) during the first sampling event were not unexpected given the status of the stream. For example, routine monitoring data indicated that nitrate values often exceed the stream's screening levels of 1.95 mg/L (HGAC, 2011). However, R-squared values from our regression analysis between combined nitrates and nitrites and PIA and TIA, may have been inflated due to the high value at the first sampling event.

Orthophosphates were consistently found in higher concentrations in watersheds with increased urbanization. Increased phosphorus concentrations relationship with urbanization is well documented (Soranno et al. 1996; Carle et al. 2005). Orthophosphates were determined to be highly related to the amount of TIA and to a lesser extent PIA of a watershed. PIA explained 48.5 percent of the variation (R^2=48.5%, P=0.003) of the positively associated orthophosphate levels while TIA explained 78.5% of the variation (R^2=78.5%, P=0.000) (Figures 34 and 35). Therefore our results indicate that TIA was a better predictor of orthophosphates than PIA. Phosphates are a known limiting agent in aquatic systems and even small concentrations are known to increase eutrophication and associated low oxygen levels (Heath 1995). This could have significant implications to fish community structure over long periods. Our results indicated that the width of the natural riparian buffer was also a good predictor of orthophosphate concentrations. This is supported by other studies which have determined that riparian buffers, whether forested or shrub based, are integral in attenuating nutrients and phosphorus (Zaimes et al. 2008).

Fish communities

The percent impervious area in a watershed was shown to significantly negatively affect fish IBI scores. However, total impervious area was not found to have a significant relationship with IBI scores. Therefore, in our study PIA may have been a more accurate indicator of fish community integrity than TIA. This posed an interesting question as to why IBI scores would be more closely related to PIA than TIA. Exploring this more closely we observed that certain sites, like the West Fork of the San Jacinto had a high TIA, but a low PIA. This meant that this watershed had a high degree of impervious area, but an even higher degree of un-urbanized area. Therefore, our results may be related to sites with a low PIA having a larger area in which water infiltrates the ground and is filtered by natural processes before entering streams.

Wang et al. (2001) in a study of 47 small streams in Southeastern, Wisconsin determined a threshold range of 8 to 12 PIA of a watershed where fish communities start to decline and above that range IBI scores were almost always low. They also concluded that below this threshold, IBI scores could range from low to high (Wang et al. 2001). We found similar results as their study, with sites ranging from 0.80 to 3.25 PIA having low to high IBI scores, while sites with 8.29 to 37.75 PIA generally having lower IBI scores. Interestingly, the Clear Creek watershed had a high PIA and TIA respectively (17.05% and 17.72 km^2) and we still found relatively high IBI scores (52 and 48 respectively). Reasons for why this site with a relatively high degree of urbanization could still have a relatively high IBI score are puzzling. Perhaps this may be due to intact riparian zones, which as stated earlier, has been shown to decrease the influence of nutrient pollution. Our IBI score at Clear Creek may have been slightly inflated since we collected an estuarine species (*Menida beryllina*). Otherwise this may be due to insensitivities of the IBI scoring metrics or an unstudied aspect that is influencing our results. On the other hand, the Little

Cypress Creek watershed had a low degree of urbanization (PIA=2.68, TIA=3.12) and we found low IBI scores. This may have been due to low sampling effort or drought conditions. If we would have evaluated three sites per watershed this may have produced a more complete collection that was more representative of the watershed. We also found very few intolerant fish species at these two sites which may be an indicator of the influence of urbanization or other unknown variables.

Additional metrics analyzed for relationships with impervious area included percent tolerant species, number of intolerant species, Shannon-Wiener diversity index, Pielou's evenness and species richness. Out of these metrics the only significant relationship with urbanization was species richness. PIA explained 35.1 percent of the variation linked with declined fish species (R^2=0.351, P=0.016). Therefore based on our results, increased PIA in a watershed negatively influenced species richness. It was common to see only certain fish species at the less disturbed sites including sensitive percids and cyprinids. It should be mentioned that relationships between impervious surfaces and fish community aspects represent an indirect causal relationship. Since impervious surfaces do not directly influence fish communities, the depressed fish community structure may be due to the influence of impervious surfaces on hydrology, water quality or physical habitats, which in turn influence fish community structure. As mentioned earlier, we determined that increased urbanized watersheds resulted in higher streamflow, increased concentrations of combined nitrate and nitrate and orthophosphate and lower instream habitat. We also determined that increased nitrate and nitrite concentrations negatively affected IBI scores. It should be noted that R-squared values from our regression analysis between combined nitrates and nitrites and IBI scores may have been inflated due to the high value at Greens Bayou during the first sampling event. However we retained this data for statistical analysis based on routine monitoring data which indicated that nitrate values often exceed the stream's screening levels of 1.95 mg/L (HGAC, 2011).

Statistical analysis indicated that watershed size positively influenced species richness. Our results agree with the findings of other studies (Karr et al. 1986) that found the same relationship. This is due to species richness tending to increase as streams get larger. In contrast we did not find a significant relationship between IBI scores and watershed size. Perhaps this is attributable to the computation of IBI scores relying on many metrics and not exclusively on richness.

Principal components analysis

Principal component analysis displayed a positive relationship between riparian width and canopy cover, and an inverse relationship to PIA, combined nitrates and nitrites, orthophosphate and flow. This coincided with results from our correlation and regression analysis as well as with previous studies (Snyder et al. 2003; Carle et al. 2005). It should be noted that our principal component analysis may have been influenced due to high mean values (4.15 mg/L) during the first sampling event at Greens Bayou. However, this data was retained for statistical analysis based on monitoring data from HGAC (2011) which indicated that nitrate values often occur higher than screening levels (1.95 mg/L). Principal component scores of Greens Bayou 1 and 2 were very similar despite the large difference in nitrate and nitrite values across sampling events. PC1 depicted the highest scoring sites in the previously mentioned relationship to be Lake Creek 1 and Peach Creek 1 and 2, while the lowest scoring sites were Greens Bayou 1 and 2. These results agree with our general observation which showed that Lake Creek and Peach creek contrasted greatly with Greens Bayou in regards to impervious surfaces, water quality and physical habitats. Regression analysis determined that PC1 positively influenced IBI scores. This indicated that as canopy cover and riparian width decreased, PIA, combined nitrates and nitrites, orthophosphate, and streamflow increased and ultimately influenced fish community integrity. This also supported our hypothesis that there was an indirect relationship between riparian width, PIA and streamflow with IBI scores.

PC2 was influenced by alkalinity which was the highest positive loading variable, while watershed size, ammonia and TSS were the variables with the largest negative loading coefficients. Dickinson Bayou 1, Cedar Bayou 2 and Little Cypress Creek 1 were the sites with the highest PC2 scores, while the West Fork of the San Jacinto River sites had the lowest scores. These results indicate that Dickinson Bayou 2, Cedar Bayou 2 and Little Cypress Creek 1 all had higher concentrations of alkalinity, while being located within a smaller watershed with lower ammonia and TSS concentrations. In contrast the West Fork of the San Jacinto River sites were located in a large watershed with low levels of tree canopy and alkalinity. However, correlation and linear regression analysis determined that there was no significant relationship between PC2 and IBI scores. This indicated that there was no relationship between the highly loading variables (alkalinity, ammonia, watershed size and TSS) and fish community integrity. In contrast regression analysis indicated that PC2 affected species richness. This indicated that alkalinity, ammonia, watershed size and TSS) directly or indirectly influenced species richness.

Cluster analysis

We commonly found groupings containing both sampling events at a particular site which represents that similar fish were found at each visit. However, in some cases (i.e. West Fork of the San Jacinto seining cluster analysis results) the two sites were not within the same cluster. In this case, as well as others, the cluster membership may have been largely influenced by a high proportion of *Cyprinella venusta, Gambusia affinis* and *Fundulus notatus*. This illustrates how certain high abundance schooling species can strongly influence the results of cluster analysis and affect final groupings.

Boxplots of cluster membership based on impervious area for seining data did not display any apparent trends. This was mostly due to a large amount of the sites being in cluster one. However, the boxplots of electrofishing cluster membership displayed that the cluster three was low in PIA and high in TIA. This was a significant finding, since the influence of impervious area was our main study question and supported our hypothesis that fish community structure was influenced by PIA and TIA. This also supported our regression analysis which determined that there was a stronger association between IBI scores and PIA, than with TIA.

Drought in Texas

It should be noted that our field study was completed during the one of most severe droughts in Texas history (NOAA 2012). The drought has caused baseflows in streams and rivers to drop significantly. Droughts have been shown to influence fish communities and water quality. Fish sampling may have been affected since low flow events force fish into refugia like deeper pools (Lake 2003). Deeper pools in which the fish were occupying may or may not have been evenly distributed within our sampling reach. Overall the influence of droughts on fish behavior produces unknown biases which may have affected our results. This seemed to be evident especially while sampling Cedar Bayou, in which scarcely flowing and deeper pools were present. The severe drought in Texas may have also influenced water quality. Studies have shown that water constituents are more concentrated due to less available water (Golladay and Battle 2002). Decreased flows may have masked some of the water quality parameters including nutrients and TSS since stream water was mostly a result of base flows. As a result, water flowing off of impervious surfaces may have been limited due to the drought. Also with decreased flows and high summer temperatures, stream aeration may have influenced our water quality data and fish distribution.

CONCLUSIONS

There are significant management implications that can be drawn from our study of the influence of urbanization on streams in southeast Texas. There is a valuable service often overlooked which is provided by soils and ground vegetation which filters overland flowing water as it infiltrates through the ground and slowly flows into streams. This study has shown how the movement of water over impervious surfaces into streams influences not only the water quality and some physical habitats aspects, but the attributes of fish communities including species richness and biotic integrity. One management technique that could be taken from our study is defining a threshold value or limit for impervious surfaces in watersheds which should not be exceeded to protect aquatic life. Our study and others have determined that values above 8 to 12 PIA of a watershed appears to limit the integrity of fish communities. With the projected increase in populations in the Houston metroplex area it may be very difficult to implement legislation limiting the degree of impervious area in a watershed, since many citizens might feel that this would decrease the economic values of the land. However, there may be alternatives to covering more area in impervious surfaces including efficiently using land that is already developed, but not being used and/or building upward. Another innovative way to decrease impervious surfaces is through the use of porous pavements (Ferguson 2005). Porous pavement has been implemented by other countries and could save money through lowering flood related costs and increasing water quality (Ferguson 2005). Finally, most economic models do not take into consideration the economic value of ecosystem services provided by conserving green spaces (pervious surfaces) that have been shown to reduce flood risks, improve water quality and provide an aesthetically pleasing landscape to urban dwellers (Paul and Meyer 2001). These should also be factored into future development plans.

Many stream fishes rely on the availability of clean water, sufficient stream flow and instream habitat to survive and reproduce. One beneficial method of purifying water naturally before it reaches streams, and therefore circumvent the negative effects of impervious surfaces, is the construction of wetlands and retention ponds. Constructed wetlands and retention ponds are effective methods of lowering nutrient concentrations through microbial digestion (Almendinger 1997). Another method to decrease nutrients and pollutants from entering streams, as our research suggests, is through maintaining or replanting riparian zones (Jorgensen et al. 2000). In the case of riparian habitats that are already destroyed, research has shown that the planting of new riparian plants can have significant benefits (Jorgensen et al. 2000). Overall there are a variety of methods that environmental planners can undertake to reduce the negative impacts of impervious surfaces on stream flow, physical habitats, water quality and ultimately aquatic biota.

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APPENDICES

Appendix A. Streamflow data sheet

Stream Flow (Discharge) Measurement Form

Stream:______________________________ Date:__________

Station:______________________________

Description:______________________________

Time begin:__________ Time end:__________ Meter type:________________

Observers:________________ Stream width*:________ Section width (W):__________

Observations:______________________________

Section Midpoint (ft) (m)	Section Depth (ft) (m) (cm) (D)	Observational Depth** (ft)(m)	Velocity (V)		Flow (Q) (m^3/s) (ft^3/s) Q = (W)(D)(V)
			At Point (ft/s)(m/s)	Average (ft/s)(m/s)	
m^3/s x 35.3 = ft^3/s			**Total Flow (Discharge)(∑Q)**		

* Make a minimum of 10 measurements when the total width is > 5.0 ft, 20 measurements preferred.

** When water is < 2.5 ft deep take one measurement at each cross section. When water is > 2.5 ft deep, take two measurements at each cross section; one at ½ the total depth and the other at 2 x the total depth. Average the two velocity measurements. See SWQM Procedures Manual for a detailed flow measurement method.

Appendix B. Pearson correlation analysis for all variables

Cell Contents: Pearson correlation
P-Value

	Water Temp C	Spec. Cond (uS)	pH
Spec. Cond (uS)	-0.300		
	0.258		
pH	-0.317	0.335	
	0.232	0.205	
DO mg/L	-0.516	0.018	0.257
	0.041	0.948	0.337
DO % Sat	-0.399	-0.037	0.211
	0.125	0.892	0.432
Salinity ppt	-0.327	0.916	0.307
	0.216	0.000	0.248
Instantaneous Fl	0.287	0.205	-0.231
	0.281	0.446	0.390
Turbidity mean	0.293	-0.314	-0.054
	0.270	0.236	0.842
Mean NO3+NO2	0.186	0.113	-0.108
	0.490	0.678	0.690
Mean NH4	0.360	-0.329	-0.600
	0.170	0.213	0.014
Mean Alk	0.011	0.647	0.548
	0.967	0.007	0.028
mean PO4	0.207	0.514	-0.140
	0.443	0.042	0.606
EIH Chlorine (fr	-0.217	0.403	-0.189
	0.420	0.122	0.484
EIH Chlorine (to	0.131	0.262	-0.114
	0.628	0.328	0.675
mean CHLO	0.092	-0.502	-0.408
	0.734	0.048	0.117
Mean Pheo	0.170	-0.299	-0.100
	0.529	0.261	0.714
mean TSS	0.281	-0.241	-0.331
	0.292	0.369	0.211
TIA (Km2)	0.144	0.319	-0.259
	0.595	0.229	0.333
PIA	0.375	0.246	0.078
	0.152	0.358	0.774
IBI Score	-0.340	-0.146	-0.114

	0.198	0.589	0.673
Watershed Size (	-0.226 0.399	-0.042 0.877	-0.528 0.035
Mean % Substrate	-0.209 0.437	0.293 0.271	-0.027 0.921
Mean % instream	-0.274 0.304	-0.254 0.342	0.254 0.343
Number of stream	-0.579 0.019	-0.033 0.904	0.329 0.213
Mean % Bank Eros	-0.624 0.010	0.414 0.111	0.314 0.236
Mean Bank Slope	0.283 0.289	-0.081 0.765	0.323 0.222
Mean % Tree Cano	0.021 0.938	-0.457 0.075	0.159 0.556
Shannon Index	-0.295 0.267	-0.322 0.223	-0.226 0.400
richness	-0.261 0.329	-0.301 0.258	-0.328 0.215
Pielous Eveness	-0.228 0.395	-0.216 0.421	-0.141 0.603
% tolerants	-0.150 0.579	0.411 0.114	0.002 0.995
% intolerant	-0.391 0.134	-0.327 0.217	-0.144 0.593
Riparian	-0.091 0.736	-0.336 0.203	-0.242 0.366
PC1	-0.180 0.504	-0.466 0.069	-0.006 0.983
PC2	-0.218 0.417	0.312 0.240	0.670 0.004
WWTP	-0.012 0.966	0.340 0.198	-0.314 0.236

	DO mg/L	DO % Sat	Salinity ppt
DO % Sat	0.990 0.000		
Salinity ppt	-0.074 0.785	-0.142 0.599	
Instantaneous Fl	0.056 0.836	0.109 0.687	0.197 0.464
Turbidity mean	0.050 0.855	0.122 0.652	-0.458 0.074

Mean NO3+NO2	0.024	0.056	0.092
	0.931	0.838	0.735
Mean NH4	-0.206	-0.168	-0.293
	0.445	0.535	0.271
Mean Alk	-0.392	-0.429	0.712
	0.133	0.098	0.002
mean PO4	-0.084	-0.057	0.567
	0.756	0.834	0.022
EIH Chlorine-free	0.347	0.327	0.428
	0.188	0.217	0.098
EIH Chlorine-(total)	-0.067	-0.046	0.006
	0.805	0.865	0.983
mean CHLO	-0.249	-0.260	-0.388
	0.351	0.331	0.138
Mean Pheo	-0.464	-0.474	-0.243
	0.070	0.063	0.363
mean TSS	0.017	0.069	-0.299
	0.950	0.798	0.260
TIA (Km2)	0.027	0.057	0.342
	0.922	0.834	0.194
PIA	-0.030	0.017	0.278
	0.911	0.951	0.297
IBI Score	0.466	0.449	-0.188
	0.069	0.081	0.486
Watershed Size (	0.079	0.070	-0.036
	0.771	0.797	0.894
Mean % Substrate	0.615	0.630	0.100
	0.011	0.009	0.711
Mean % instream	-0.023	-0.070	-0.253
	0.933	0.797	0.344
Number of stream	0.256	0.195	-0.142
	0.339	0.469	0.599
Mean % Bank Eros	0.341	0.274	0.485
	0.196	0.305	0.057
Mean Bank Slope	0.080	0.138	-0.196
	0.768	0.611	0.468
Mean % Tree Cano	-0.028	-0.028	-0.462
	0.918	0.917	0.072
Shannon Index	0.390	0.385	-0.398
	0.135	0.141	0.127
richness	0.368	0.371	-0.370
	0.161	0.157	0.158

Pielous Eveness	0.297	0.291	-0.274
	0.263	0.275	0.304
% tolerants	-0.293	-0.326	0.446
	0.271	0.217	0.084
% intolerant	0.430	0.416	-0.296
	0.096	0.109	0.266
Riparian	-0.278	-0.286	-0.393
	0.296	0.283	0.132
PC1	-0.090	-0.119	-0.471
	0.740	0.660	0.066
PC2	0.025	-0.017	0.334
	0.926	0.950	0.207
WWTP	0.025	0.037	0.347
	0.927	0.891	0.187

	Instantaneous Fl	Turbidity mean	Mean NO3+NO2
Turbidity mean	-0.100		
	0.714		
Mean NO3+NO2	0.568	-0.140	
	0.022	0.606	
Mean NH4	0.175	0.104	0.099
	0.517	0.700	0.714
Mean Alk	-0.133	-0.244	-0.038
	0.623	0.363	0.889
mean PO4	0.816	-0.239	0.521
	0.000	0.372	0.039
EIH Chlorine (fr	0.406	-0.427	-0.139
	0.118	0.099	0.607
EIH Chlorine (to	0.281	0.006	0.587
	0.293	0.982	0.017
mean CHLO	-0.283	-0.156	-0.172
	0.288	0.565	0.524
Mean Pheo	-0.333	0.057	-0.231
	0.207	0.833	0.390
mean TSS	0.063	0.654	-0.140
	0.818	0.006	0.604
TIA (Km2)	0.926	-0.188	0.542
	0.000	0.486	0.030
PIA	0.805	-0.264	0.609
	0.000	0.323	0.012
IBI Score	-0.517	0.168	-0.543
	0.041	0.535	0.030

Watershed Size (	0.139	0.092	-0.084
	0.607	0.736	0.756
Mean % Substrate	0.301	0.038	0.298
	0.258	0.887	0.263
Mean % instream	-0.703	-0.047	-0.133
	0.002	0.863	0.624
Number of stream	-0.429	0.329	-0.303
	0.097	0.213	0.254
Mean % Bank Eros	-0.277	-0.255	-0.251
	0.300	0.340	0.348
Mean Bank Slope	0.053	0.612	0.129
	0.844	0.012	0.635
Mean % Tree Cano	-0.875	0.335	-0.512
	0.000	0.205	0.043
Shannon Index	-0.216	0.273	-0.286
	0.422	0.305	0.282
richness	-0.225	0.375	-0.330
	0.402	0.153	0.211
Pielous Eveness	-0.096	0.173	-0.170
	0.724	0.523	0.530
% tolerants	-0.119	-0.032	-0.106
	0.660	0.908	0.697
% intolerant	-0.131	0.205	-0.168
	0.629	0.447	0.534
Riparian	-0.513	0.494	-0.384
	0.042	0.052	0.142
PC1	-0.901	0.325	-0.651
	0.000	0.220	0.006
PC2	-0.343	-0.251	-0.109
	0.194	0.348	0.687
WWTP	0.823	-0.108	0.428
	0.000	0.690	0.098

	Mean NH4	Mean Alk	mean PO4
Mean Alk	-0.443		
	0.085		
mean PO4	0.125	0.282	
	0.644	0.290	
EIH Chlorine (fr	0.257	-0.042	0.490
	0.337	0.878	0.054
EIH Chlorine (to	-0.008	-0.029	0.163
	0.975	0.914	0.546
mean CHLO	0.746	-0.315	-0.257

	0.001	0.234	0.337
Mean Pheo	0.592	0.038	-0.150
	0.016	0.890	0.580
mean TSS	0.732	-0.402	0.026
	0.001	0.123	0.924
TIA (Km2)	0.255	-0.083	0.886
	0.340	0.761	0.000
PIA	-0.028	0.207	0.697
	0.919	0.442	0.003
IBI Score	-0.016	-0.336	-0.401
	0.952	0.204	0.124
Watershed Size (	0.460	-0.477	0.200
	0.073	0.062	0.458
Mean % Substrate	-0.035	-0.291	0.188
	0.897	0.274	0.486
Mean % instream	-0.011	0.100	-0.502
	0.969	0.713	0.048
Number of stream	-0.176	-0.071	-0.353
	0.515	0.794	0.179
Mean % Bank Eros	-0.434	0.312	-0.075
	0.093	0.240	0.782
Mean Bank Slope	-0.287	0.194	-0.050
	0.281	0.471	0.854
Mean % Tree Cano	-0.105	0.025	-0.827
	0.700	0.927	0.000
Shannon Index	-0.073	-0.617	-0.426
	0.790	0.011	0.100
richness	0.230	-0.602	-0.233
	0.392	0.014	0.386
Pielous Eveness	-0.173	-0.482	-0.368
	0.522	0.059	0.161
% tolerants	-0.376	0.395	0.019
	0.151	0.130	0.943
% intolerant	-0.249	-0.513	-0.238
	0.353	0.042	0.375
Riparian	0.150	-0.242	-0.529
	0.580	0.366	0.035
PC1	0.099	-0.167	-0.850
	0.714	0.536	0.000
PC2	-0.838	0.668	-0.201
	0.000	0.005	0.456
WWTP	0.280	-0.157	0.800

	0.293	0.562	0.000

	EIH Chlorine(free)	EIH Chlorine (total)	mean CHLO
EIH Chlorine (to	-0.185 0.493		
mean CHLO	0.110 0.685	-0.161 0.551	
Mean Pheo	-0.106 0.697	-0.169 0.531	0.799 0.000
mean TSS	0.095 0.726	-0.144 0.594	0.358 0.173
TIA (Km2)	0.476 0.062	0.269 0.313	-0.150 0.579
PIA	0.252 0.346	0.288 0.279	-0.292 0.273
IBI Score	0.153 0.572	-0.289 0.278	0.161 0.550
Watershed Size	0.293 0.271	-0.029 0.914	0.326 0.217
Mean % Substrate	0.257 0.336	0.375 0.153	-0.442 0.086
Mean % instream	-0.337 0.202	-0.153 0.572	0.461 0.073
Number of stream	-0.229 0.394	-0.074 0.787	0.028 0.917
Mean % Bank Eros	0.300 0.259	-0.263 0.326	-0.177 0.512
Mean Bank Slope	-0.381 0.146	0.061 0.821	-0.460 0.073
Mean % Tree Cano	-0.471 0.065	-0.321 0.226	0.254 0.342
Shannon Index	-0.074 0.785	-0.095 0.725	0.007 0.980
richness	0.057 0.835	-0.132 0.625	0.246 0.357
Pielous Eveness	-0.090 0.741	-0.045 0.868	-0.135 0.617
% tolerants	-0.097 0.722	0.004 0.989	-0.352 0.181
% intolerant	-0.168 0.535	-0.172 0.524	-0.153 0.571
Riparian	-0.508 0.044	0.048 0.859	0.261 0.328

PC1	-0.389	-0.330	0.483
	0.137	0.211	0.058
PC2	-0.233	-0.088	-0.493
	0.386	0.745	0.052
WWTP	0.446	0.242	-0.142
	0.083	0.367	0.601

	Mean Pheo	mean TSS	TIA (Km2)
mean TSS	0.435		
	0.092		
TIA (Km2)	-0.175	0.134	
	0.517	0.622	
PIA	-0.358	-0.213	0.697
	0.173	0.429	0.003
IBI Score	0.026	0.258	-0.360
	0.925	0.334	0.171
Watershed Size	0.283	0.497	0.397
	0.289	0.050	0.128
Mean % Substrate	-0.543	0.056	0.251
	0.030	0.836	0.348
Mean % instream	0.542	-0.049	-0.584
	0.030	0.856	0.018
Number of stream	0.326	0.180	-0.326
	0.218	0.505	0.218
Mean % Bank Eros	-0.306	-0.313	-0.139
	0.248	0.238	0.609
Mean Bank Slope	-0.253	0.102	-0.176
	0.344	0.708	0.515
Mean % Tree Cano	0.251	0.055	-0.937
	0.349	0.840	0.000
Shannon Index	-0.227	0.206	-0.152
	0.399	0.443	0.575
richness	0.190	0.517	-0.041
	0.481	0.040	0.881
Pielous Eveness	-0.409	0.048	-0.100
	0.115	0.861	0.712
% tolerants	-0.354	-0.230	-0.046
	0.178	0.391	0.866
% intolerant	-0.264	0.030	-0.061
	0.323	0.912	0.824
Riparian	0.396	0.343	-0.401
	0.129	0.193	0.123

PC1	0.507	0.247	-0.831
	0.045	0.357	0.000
PC2	-0.381	-0.750	-0.446
	0.145	0.001	0.083
WWTP	-0.110	0.220	0.937
	0.685	0.413	0.000

	PIA	IBI Score	Watershed Size
IBI Score	-0.623		
	0.010		
Watershed Size	-0.351	0.428	
	0.183	0.099	
Mean % Substrate	0.067	0.146	0.147
	0.806	0.589	0.586
Mean % instream	-0.445	0.261	-0.104
	0.084	0.329	0.701
Number of stream	-0.617	0.370	0.281
	0.011	0.158	0.291
Mean % Bank Eros	-0.097	0.300	-0.020
	0.721	0.260	0.942
Mean Bank Slope	0.261	-0.243	-0.598
	0.328	0.365	0.015
Mean % Tree Cano	-0.608	0.413	-0.364
	0.012	0.112	0.166
Shannon Index	-0.336	0.687	0.373
	0.203	0.003	0.155
richness	-0.584	0.820	0.779
	0.018	0.000	0.000
Pielous Eveness	-0.079	0.426	0.108
	0.770	0.100	0.691
% tolerants	0.067	-0.016	-0.120
	0.805	0.952	0.659
% intolerant	-0.371	0.639	0.437
	0.157	0.008	0.091
Riparian	-0.749	0.332	0.448
	0.001	0.209	0.082
PC1	-0.873	0.554	0.108
	0.000	0.026	0.691
PC2	0.109	-0.136	-0.774
	0.689	0.616	0.000
WWTP	0.431	-0.265	0.606
	0.095	0.322	0.013

	Mean % Substrate	Mean %instream	Number of stream
Mean % instream	-0.423		
	0.103		
Number of stream	0.027	0.484	
	0.920	0.058	
Mean % Bank Eros	-0.076	0.231	0.037
	0.779	0.390	0.891
Mean Bank Slope	0.036	0.031	0.092
	0.896	0.908	0.736
Mean % Tree Cano	-0.321	0.628	0.252
	0.225	0.009	0.347
Shannon Index	0.078	0.142	0.257
	0.774	0.601	0.336
richness	0.171	0.143	0.513
	0.527	0.596	0.042
Pielous Eveness	0.025	0.048	0.022
	0.927	0.861	0.937
% tolerants	-0.213	-0.013	-0.192
	0.428	0.963	0.476
% intolerant	0.213	-0.006	0.427
	0.428	0.984	0.099
Riparian	-0.115	0.233	0.517
	0.672	0.386	0.040
PC1	-0.366	0.650	0.503
	0.164	0.006	0.047
PC2	-0.194	0.254	-0.021
	0.471	0.342	0.939
WWTP	0.332	-0.597	-0.115
	0.209	0.015	0.670

	Mean % Bank Eros	Mean Bank Slope	Mean% Tree Cano
Mean Bank Slope	-0.116		
	0.669		
Mean % Tree Cano	0.121	0.308	
	0.654	0.245	
Shannon Index	0.241	-0.047	0.221
	0.368	0.864	0.410
richness	0.011	-0.284	0.120
	0.967	0.286	0.657
Pielous Eveness	0.318	0.086	0.158
	0.230	0.752	0.559
% tolerants	0.582	0.138	0.057
	0.018	0.611	0.834

% intolerant	0.039	-0.097	0.067
	0.885	0.721	0.805
Riparian	-0.151	-0.101	0.402
	0.577	0.709	0.122
PC1	0.101	-0.065	0.846
	0.710	0.811	0.000
PC2	0.489	0.368	0.344
	0.054	0.161	0.192
WWTP	-0.160	-0.302	-0.936
	0.554	0.255	0.000

	Shannon Index	richness	Pielous Eveness
richness	0.713		
	0.002		
Pielous Eveness	0.918	0.388	
	0.000	0.138	
% tolerants	0.267	-0.180	0.482
	0.318	0.504	0.059
% intolerant	0.743	0.735	0.547
	0.001	0.001	0.028
Riparian	0.333	0.552	0.125
	0.207	0.027	0.644
PC1	0.369	0.453	0.187
	0.160	0.078	0.488
PC2	-0.178	-0.553	0.015
	0.511	0.026	0.955
WWTP	-0.109	0.132	-0.137
	0.687	0.627	0.612

	% tolerants	% intolerant	Riparian
% intolerant	-0.014		
	0.960		
Riparian	0.078	0.363	
	0.773	0.167	
PC1	-0.006	0.223	0.711
	0.983	0.407	0.002
PC2	0.415	-0.158	-0.318
	0.110	0.560	0.231
WWTP	-0.080	0.059	-0.157
	0.769	0.828	0.562

Appendix C. Results for two way ANOVA, one way ANOVA and Tukey's multiple comparison test. (A is the first sampling event and B is the second sampling event).

Table C1. Bank slope general linear model, one way ANOVA and Tukey's multiple comparison test

General Linear Model: slope versus Site, Event

```
Factor  Type   Levels  Values
Site    fixed       8  Cedar Bayou, Clear Creek @ SH 35, Dickinson Bayou at
                       517, Greeens bayou, Lake Creek  Near Egypt, Little
                       Cypress Creek, Peach Creek, W. Fork of San Jacinto
Event   fixed       2  A, B


Analysis of Variance for slope, using Adjusted SS for Tests

Source      DF   Seq SS   Adj SS  Adj MS      F      P
Site         7  15178.8  15178.8  2168.4  10.15  0.000
Event        1      0.3      0.3     0.3   0.00  0.969
Site*Event   7    730.3    730.3   104.3   0.49  0.840
Error       64  13677.2  13677.2   213.7
Total       79  29586.6


S = 14.6187   R-Sq = 53.77%   R-Sq(adj) = 42.94%


Unusual Observations for slope

Obs    slope      Fit  SE Fit  Residual  St Resid
 21  90.0000  40.6000  6.5377   49.4000      3.78 R
 63  62.5000  32.4000  6.5377   30.1000      2.30 R

R denotes an observation with a large standardized residual.
```

One-way ANOVA: slope versus Collection

```
Source      DF     SS    MS     F      P
Collection  15  15909  1061  4.96  0.000
Error       64  13677   214
Total       79  29587

S = 14.62   R-Sq = 53.77%   R-Sq(adj) = 42.94%


                        Individual 95% CIs For Mean Based on
                        Pooled StDev
Level  N   Mean  StDev  --------+---------+---------+---------+-
CBA    5  32.32   6.80          (-----*------)
CBB    5  38.25  16.43             (-----*------)
CCA    5  53.50  16.45                    (------*-----)
CCB    5  44.20   7.30                (-----*------)
DBA    5  63.50   7.20                         (------*-----)
DBB    5  63.55  11.58                         (------*-----)
GBA    5  47.74  12.24                 (------*-----)
GBB    5  48.10   5.39                  (-----*------)
```

```
LCA    5  40.60  29.24             (-----*------)
LCB    5  32.40  18.41         (-----*------)
LCCA   5  47.00  10.95                (------*-----)
LCCB   5  47.00  15.25                (------*-----)
PCA    5  65.22  16.34                         (------*-----)
PCB    5  67.50  10.61                          (------*-----)
WFA    5  17.00  11.10  (------*-----)
WFB    5  26.90  19.11       (-----*------)
                        --------+---------+---------+---------+-
                               20        40        60        80

Pooled StDev = 14.62


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Collection

Individual confidence level = 99.93%


Collection = CBA subtracted from:

Collection   Lower  Center  Upper  -------+---------+---------+---------+--
CBB         -27.02    5.93  38.88             (-----*------)
CCA         -11.77   21.18  54.13                (-----*------)
CCB         -21.07   11.88  44.83              (-----*------)
DBA          -1.77   31.18  64.13                  (-----*------)
DBB          -1.72   31.23  64.18                  (-----*------)
GBA         -17.53   15.42  48.37              (------*------)
GBB         -17.17   15.78  48.73               (-----*------)
LCA         -24.67    8.28  41.23             (------*-----)
LCB         -32.87    0.08  33.03           (------*------)
LCCA        -18.27   14.68  47.63              (------*------)
LCCB        -18.27   14.68  47.63              (------*------)
PCA          -0.05   32.90  65.85                  (------*-----)
PCB           2.23   35.18  68.13                  (------*------)
WFA         -48.27  -15.32  17.63        (------*------)
WFB         -38.37   -5.42  27.53          (------*------)
                                   -------+---------+---------+---------+--
                                        -50         0        50       100


Collection = CBB subtracted from:

Collection   Lower  Center  Upper  -------+---------+---------+---------+--
CCA         -17.70   15.25  48.20              (------*------)
CCB         -27.00    5.95  38.90             (-----*------)
DBA          -7.70   25.25  58.20                (------*------)
DBB          -7.65   25.30  58.25                (------*------)
GBA         -23.46    9.49  42.44             (------*-----)
GBB         -23.10    9.85  42.80             (------*------)
LCA         -30.60    2.35  35.30            (-----*------)
LCB         -38.80   -5.85  27.10          (------*-----)
LCCA        -24.20    8.75  41.70             (------*-----)
LCCB        -24.20    8.75  41.70             (------*-----)
PCA          -5.98   26.97  59.92                 (-----*------)
PCB          -3.70   29.25  62.20                 (------*-----)
WFA         -54.20  -21.25  11.70       (------*-----)
WFB         -44.30  -11.35  21.60         (------*-----)
                                   -------+---------+---------+---------+--
                                        -50         0        50       100
```

```
Collection = CCA subtracted from:

Collection   Lower  Center  Upper  -------+---------+---------+---------+--
CCB         -42.25   -9.30  23.65           (-----*------)
DBA         -22.95   10.00  42.95              (------*------)
DBB         -22.90   10.05  43.00              (------*------)
GBA         -38.71   -5.76  27.19           (------*-----)
GBB         -38.35   -5.40  27.55           (------*------)
LCA         -45.85  -12.90  20.05          (-----*------)
LCB         -54.05  -21.10  11.85        (------*-----)
LCCA        -39.45   -6.50  26.45           (------*-----)
LCCB        -39.45   -6.50  26.45           (------*-----)
PCA         -21.23   11.72  44.67               (-----*------)
PCB         -18.95   14.00  46.95               (------*-----)
WFA         -69.45  -36.50  -3.55     (------*-----)
WFB         -59.55  -26.60   6.35       (------*-----)
                                   -------+---------+---------+---------+--
                                        -50         0        50       100
```

```
Collection = CCB subtracted from:

Collection   Lower  Center  Upper  -------+---------+---------+---------+--
DBA         -13.65   19.30  52.25                (------*-----)
DBB         -13.60   19.35  52.30                (------*-----)
GBA         -29.41    3.54  36.49             (------*-----)
GBB         -29.05    3.90  36.85             (------*-----)
LCA         -36.55   -3.60  29.35            (-----*------)
LCB         -44.75  -11.80  21.15          (------*-----)
LCCA        -30.15    2.80  35.75             (------*-----)
LCCB        -30.15    2.80  35.75             (------*-----)
PCA         -11.93   21.02  53.97                 (-----*------)
PCB          -9.65   23.30  56.25                 (------*-----)
WFA         -60.15  -27.20   5.75       (------*-----)
WFB         -50.25  -17.30  15.65         (------*-----)
                                   -------+---------+---------+---------+--
                                        -50         0        50       100
```

```
Collection = DBA subtracted from:

Collection   Lower  Center   Upper  -------+---------+---------+---------+--
DBB         -32.90    0.05   33.00            (------*------)
GBA         -48.71  -15.76   17.19         (------*-----)
GBB         -48.35  -15.40   17.55         (------*------)
LCA         -55.85  -22.90   10.05        (-----*------)
LCB         -64.05  -31.10    1.85      (------*-----)
LCCA        -49.45  -16.50   16.45         (------*-----)
LCCB        -49.45  -16.50   16.45         (------*-----)
PCA         -31.23    1.72   34.67             (-----*------)
PCB         -28.95    4.00   36.95             (------*-----)
WFA         -79.45  -46.50  -13.55   (------*-----)
WFB         -69.55  -36.60   -3.65     (------*-----)
                                    -------+---------+---------+---------+--
                                         -50         0        50       100
```

```
Collection = DBB subtracted from:

Collection   Lower  Center   Upper  -------+---------+---------+---------+--
GBA         -48.76  -15.81   17.14         (------*-----)
GBB         -48.40  -15.45   17.50         (------*-----)
LCA         -55.90  -22.95   10.00        (-----*------)
```

```
LCB          -64.10  -31.15    1.80      (------*-----)
LCCA         -49.50  -16.55   16.40         (------*-----)
LCCB         -49.50  -16.55   16.40         (------*-----)
PCA          -31.28    1.67   34.62             (-----*------)
PCB          -29.00    3.95   36.90             (------*-----)
WFA          -79.50  -46.55  -13.60   (------*-----)
WFB          -69.60  -36.65   -3.70     (------*-----)
                                     -------+---------+---------+---------+--
                                          -50         0        50       100


Collection = GBA subtracted from:

Collection   Lower  Center  Upper  -------+---------+---------+---------+--
GBB          -32.59    0.36  33.31           (------*------)
LCA          -40.09   -7.14  25.81          (------*-----)
LCB          -48.29  -15.34  17.61        (------*------)
LCCA         -33.69   -0.74  32.21           (------*-----)
LCCB         -33.69   -0.74  32.21           (------*-----)
PCA          -15.47   17.48  50.43               (-----*------)
PCB          -13.19   19.76  52.71               (------*------)
WFA          -63.69  -30.74   2.21     (------*-----)
WFB          -53.79  -20.84  12.11       (------*-----)
                                   -------+---------+---------+---------+--
                                        -50         0        50       100


Collection = GBB subtracted from:

Collection   Lower  Center  Upper  -------+---------+---------+---------+--
LCA          -40.45   -7.50  25.45          (------*-----)
LCB          -48.65  -15.70  17.25        (------*-----)
LCCA         -34.05   -1.10  31.85           (------*-----)
LCCB         -34.05   -1.10  31.85           (------*-----)
PCA          -15.83   17.12  50.07               (-----*------)
PCB          -13.55   19.40  52.35               (------*-----)
WFA          -64.05  -31.10   1.85     (------*-----)
WFB          -54.15  -21.20  11.75       (------*-----)
                                   -------+---------+---------+---------+--
                                        -50         0        50       100


Collection = LCA subtracted from:

Collection   Lower  Center  Upper  -------+---------+---------+---------+--
LCB          -41.15   -8.20  24.75          (-----*------)
LCCA         -26.55    6.40  39.35             (-----*------)
LCCB         -26.55    6.40  39.35             (-----*------)
PCA           -8.33   24.62  57.57                (------*------)
PCB           -6.05   26.90  59.85                 (-----*------)
WFA          -56.55  -23.60   9.35       (-----*------)
WFB          -46.65  -13.70  19.25         (-----*------)
                                   -------+---------+---------+---------+--
                                        -50         0        50       100


Collection = LCB subtracted from:

Collection   Lower  Center  Upper  -------+---------+---------+---------+--
LCCA         -18.35   14.60  47.55              (------*------)
LCCB         -18.35   14.60  47.55              (------*------)
PCA           -0.13   32.82  65.77                  (------*-----)
PCB            2.15   35.10  68.05                  (------*------)
```

```
WFA          -48.35  -15.40  17.55         (------*------)
WFB          -38.45   -5.50  27.45           (------*-----)
                                   -------+---------+---------+---------+--
                                        -50         0        50       100


Collection = LCCA subtracted from:

Collection   Lower  Center  Upper  -------+---------+---------+---------+--
LCCB         -32.95    0.00  32.95            (------*------)
PCA          -14.73   18.22  51.17                (------*-----)
PCB          -12.45   20.50  53.45                 (-----*------)
WFA          -62.95  -30.00   2.95      (------*------)
WFB          -53.05  -20.10  12.85        (------*------)
                                   -------+---------+---------+---------+--
                                        -50         0        50       100


Collection = LCCB subtracted from:

Collection   Lower  Center  Upper  -------+---------+---------+---------+--
PCA          -14.73   18.22  51.17                (------*-----)
PCB          -12.45   20.50  53.45                 (-----*------)
WFA          -62.95  -30.00   2.95      (------*------)
WFB          -53.05  -20.10  12.85        (------*------)
                                   -------+---------+---------+---------+--
                                        -50         0        50       100


Collection = PCA subtracted from:

Collection   Lower  Center   Upper  -------+---------+---------+---------+--
PCB          -30.67    2.28   35.23             (-----*------)
WFA          -81.17  -48.22  -15.27   (-----*------)
WFB          -71.27  -38.32   -5.37     (-----*------)
                                    -------+---------+---------+---------+--
                                         -50         0        50       100


Collection = PCB subtracted from:

Collection   Lower  Center   Upper  -------+---------+---------+---------+--
WFA          -83.45  -50.50  -17.55  (------*-----)
WFB          -73.55  -40.60   -7.65    (------*-----)
                                    -------+---------+---------+---------+--
                                         -50         0        50       100


Collection = WFA subtracted from:

Collection   Lower  Center  Upper  -------+---------+---------+---------+--
WFB          -23.05    9.90  42.85             (------*------)
                                   -------+---------+---------+---------+--
                                        -50         0        50       100
```

Table C2. Percent erosion potential general linear model, one way ANOVA and Tukey's multiple comparison test

General Linear Model: % Erosion Potential versus Site, Event

```
Factor  Type   Levels  Values
Site    fixed       8  Cedar Bayou, Clear Creek @ SH 35, Dickinson Bayou at
                       517, Greeens bayou, Lake Creek  Near Egypt, Little
                       Cypress Creek, Peach Creek, W. Fork of San Jacinto
Event   fixed       2  A, B


Analysis of Variance for % Erosion Potential, using Adjusted SS for Tests

Source      DF   Seq SS   Adj SS  Adj MS      F      P
Site         7  15124.6  15124.7  2160.7  10.91  0.000
Event        1   5797.0   5797.0  5797.0  29.27  0.000
Site*Event   7    836.8    836.8   119.5   0.60  0.751
Error       64  12673.8  12673.8   198.0
Total       79  34432.3


S = 14.0722   R-Sq = 63.19%   R-Sq(adj) = 54.57%


Unusual Observations for % Erosion Potential

     % Erosion
Obs  Potential      Fit  SE Fit  Residual  St Resid
 16    90.0000  49.0000  6.2933   41.0000      3.26 R
 18    20.0000  49.0000  6.2933  -29.0000     -2.30 R
 24    10.0000  38.0000  6.2933  -28.0000     -2.22 R
 25    75.0000  38.0000  6.2933   37.0000      2.94 R

R denotes an observation with a large standardized residual.
```

One-way ANOVA: % Erosion Potential versus Collection

```
Source      DF     SS    MS     F      P
Collection  15  21759  1451  7.33  0.000
Error       64  12674   198
Total       79  34432

S = 14.07   R-Sq = 63.19%   R-Sq(adj) = 54.57%


                        Individual 95% CIs For Mean Based on
                        Pooled StDev
Level  N   Mean  StDev  -+---------+---------+---------+--------
CBA    5  49.00  15.17                  (----*----)
CBB    5  29.00  14.21          (----*----)
CCA    5  64.50  14.83                        (----*----)
CCB    5  39.50  11.65              (----*----)
DBA    5  63.00  17.54                       (----*----)
DBB    5  37.00   6.47             (----*----)
GBA    5  17.50   1.77     (----*----)
GBB    5   9.50   3.71  (----*----)
LCA    5  38.00  26.36             (----*----)
LCB    5  21.50   9.62       (----*----)
```

```
LCCA   5  32.00  13.96          (----*----)
LCCB   5  18.00   7.58     (----*----)
PCA    5  18.70   7.01     (----*-----)
PCB    5  11.00   2.24  (----*----)
WFA    5  49.00  26.08                (----*----)
WFB    5  30.00  15.51         (----*----)
                        -+---------+---------+---------+--------
                         0        25        50        75

Pooled StDev = 14.07


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Collection

Individual confidence level = 99.93%


Collection = CBA subtracted from:

Collection   Lower  Center  Upper  -------+---------+---------+---------+--
CBB         -51.72  -20.00  11.72         (-----*-----)
CCA         -16.22   15.50  47.22               (-----*-----)
CCB         -41.22   -9.50  22.22           (-----*-----)
DBA         -17.72   14.00  45.72              (------*-----)
DBB         -43.72  -12.00  19.72          (------*-----)
GBA         -63.22  -31.50   0.22      (------*-----)
GBB         -71.22  -39.50  -7.78     (-----*-----)
LCA         -42.72  -11.00  20.72          (------*-----)
LCB         -59.22  -27.50   4.22       (------*-----)
LCCA        -48.72  -17.00  14.72         (------*-----)
LCCB        -62.72  -31.00   0.72      (------*-----)
PCA         -62.02  -30.30   1.42       (-----*-----)
PCB         -69.72  -38.00  -6.28     (-----*------)
WFA         -31.72    0.00  31.72             (-----*-----)
WFB         -50.72  -19.00  12.72         (-----*------)
                                   -------+---------+---------+---------+--
                                        -50         0        50       100


Collection = CBB subtracted from:

Collection   Lower  Center  Upper  -------+---------+---------+---------+--
CCA           3.78   35.50  67.22                   (-----*-----)
CCB         -21.22   10.50  42.22              (-----*-----)
DBA           2.28   34.00  65.72                  (------*-----)
DBB         -23.72    8.00  39.72             (------*-----)
GBA         -43.22  -11.50  20.22         (------*-----)
GBB         -51.22  -19.50  12.22         (-----*-----)
LCA         -22.72    9.00  40.72             (------*-----)
LCB         -39.22   -7.50  24.22           (------*-----)
LCCA        -28.72    3.00  34.72            (------*-----)
LCCB        -42.72  -11.00  20.72          (------*-----)
PCA         -42.02  -10.30  21.42           (-----*-----)
PCB         -49.72  -18.00  13.72         (-----*------)
WFA         -11.72   20.00  51.72                (-----*-----)
WFB         -30.72    1.00  32.72            (-----*------)
                                   -------+---------+---------+---------+--
                                        -50         0        50       100


Collection = CCA subtracted from:
```

```
Collection   Lower  Center   Upper  -------+---------+---------+---------+--
CCB         -56.72  -25.00    6.72        (-----*-----)
DBA         -33.22   -1.50   30.22            (------*-----)
DBB         -59.22  -27.50    4.22       (------*-----)
GBA         -78.72  -47.00  -15.28   (------*-----)
GBB         -86.72  -55.00  -23.28  (-----*-----)
LCA         -58.22  -26.50    5.22       (------*-----)
LCB         -74.72  -43.00  -11.28    (-----*------)
LCCA        -64.22  -32.50   -0.78      (------*-----)
LCCB        -78.22  -46.50  -14.78   (------*-----)
PCA         -77.52  -45.80  -14.08   (------*-----)
PCB         -85.22  -53.50  -21.78  (-----*------)
WFA         -47.22  -15.50   16.22          (-----*-----)
WFB         -66.22  -34.50   -2.78      (-----*-----)
                                    -------+---------+---------+---------+--
                                          -50        0        50       100
```

```
Collection = CCB subtracted from:

Collection   Lower  Center  Upper  -------+---------+---------+---------+--
DBA          -8.22   23.50  55.22                 (------*-----)
DBB         -34.22   -2.50  29.22            (------*-----)
GBA         -53.72  -22.00   9.72        (------*-----)
GBB         -61.72  -30.00   1.72       (-----*-----)
LCA         -33.22   -1.50  30.22            (------*-----)
LCB         -49.72  -18.00  13.72         (-----*------)
LCCA        -39.22   -7.50  24.22           (------*-----)
LCCB        -53.22  -21.50  10.22        (------*-----)
PCA         -52.52  -20.80  10.92        (------*-----)
PCB         -60.22  -28.50   3.22       (-----*------)
WFA         -22.22    9.50  41.22               (-----*-----)
WFB         -41.22   -9.50  22.22           (-----*-----)
                                   -------+---------+---------+---------+--
                                         -50        0        50       100
```

```
Collection = DBA subtracted from:

Collection   Lower  Center   Upper  -------+---------+---------+---------+--
DBB         -57.72  -26.00    5.72       (------*-----)
GBA         -77.22  -45.50  -13.78    (-----*-----)
GBB         -85.22  -53.50  -21.78  (-----*------)
LCA         -56.72  -25.00    6.72        (-----*-----)
LCB         -73.22  -41.50   -9.78    (------*-----)
LCCA        -62.72  -31.00    0.72      (------*-----)
LCCB        -76.72  -45.00  -13.28    (-----*-----)
PCA         -76.02  -44.30  -12.58    (-----*-----)
PCB         -83.72  -52.00  -20.28  (------*-----)
WFA         -45.72  -14.00   17.72          (-----*------)
WFB         -64.72  -33.00   -1.28      (-----*------)
                                    -------+---------+---------+---------+--
                                          -50        0        50       100
```

```
Collection = DBB subtracted from:

Collection   Lower  Center  Upper  -------+---------+---------+---------+--
GBA         -51.22  -19.50  12.22         (-----*-----)
GBB         -59.22  -27.50   4.22       (------*-----)
LCA         -30.72    1.00  32.72             (-----*------)
LCB         -47.22  -15.50  16.22          (-----*-----)
LCCA        -36.72   -5.00  26.72            (-----*-----)
```

```
LCCB        -50.72  -19.00  12.72         (-----*------)
PCA         -50.02  -18.30  13.42         (-----*------)
PCB         -57.72  -26.00   5.72       (------*-----)
WFA         -19.72   12.00  43.72               (-----*------)
WFB         -38.72   -7.00  24.72           (------*-----)
                                   -------+---------+---------+---------+--
                                        -50         0        50       100


Collection = GBA subtracted from:

Collection   Lower  Center  Upper  -------+---------+---------+---------+--
GBB         -39.72   -8.00  23.72           (-----*------)
LCA         -11.22   20.50  52.22                 (-----*-----)
LCB         -27.72    4.00  35.72             (------*-----)
LCCA        -17.22   14.50  46.22                (-----*-----)
LCCB        -31.22    0.50  32.22             (-----*-----)
PCA         -30.52    1.20  32.92             (-----*------)
PCB         -38.22   -6.50  25.22           (------*-----)
WFA          -0.22   31.50  63.22                   (-----*------)
WFB         -19.22   12.50  44.22               (------*-----)
                                   -------+---------+---------+---------+--
                                        -50         0        50       100


Collection = GBB subtracted from:

Collection   Lower  Center  Upper  -------+---------+---------+---------+--
LCA          -3.22   28.50  60.22                  (------*-----)
LCB         -19.72   12.00  43.72               (-----*------)
LCCA         -9.22   22.50  54.22                 (------*-----)
LCCB        -23.22    8.50  40.22              (------*-----)
PCA         -22.52    9.20  40.92              (------*-----)
PCB         -30.22    1.50  33.22             (-----*------)
WFA           7.78   39.50  71.22                     (-----*-----)
WFB         -11.22   20.50  52.22                 (-----*-----)
                                   -------+---------+---------+---------+--
                                        -50         0        50       100


Collection = LCA subtracted from:

Collection   Lower  Center  Upper  -------+---------+---------+---------+--
LCB         -48.22  -16.50  15.22         (------*-----)
LCCA        -37.72   -6.00  25.72           (------*-----)
LCCB        -51.72  -20.00  11.72         (-----*-----)
PCA         -51.02  -19.30  12.42         (-----*-----)
PCB         -58.72  -27.00   4.72       (------*-----)
WFA         -20.72   11.00  42.72               (-----*------)
WFB         -39.72   -8.00  23.72           (-----*------)
                                   -------+---------+---------+---------+--
                                        -50         0        50       100


Collection = LCB subtracted from:

Collection   Lower  Center  Upper  -------+---------+---------+---------+--
LCCA        -21.22   10.50  42.22               (-----*-----)
LCCB        -35.22   -3.50  28.22            (-----*------)
PCA         -34.52   -2.80  28.92            (-----*------)
PCB         -42.22  -10.50  21.22           (-----*-----)
WFA          -4.22   27.50  59.22                  (------*-----)
WFB         -23.22    8.50  40.22              (------*-----)
```

```
                                   -------+---------+---------+---------+--
                                        -50         0        50       100


Collection = LCCA subtracted from:

Collection   Lower  Center  Upper  -------+---------+---------+---------+--
LCCB        -45.72  -14.00  17.72          (-----*------)
PCA         -45.02  -13.30  18.42          (-----*------)
PCB         -52.72  -21.00  10.72        (------*-----)
WFA         -14.72   17.00  48.72                (-----*------)
WFB         -33.72   -2.00  29.72            (------*-----)
                                   -------+---------+---------+---------+--
                                        -50         0        50       100


Collection = LCCB subtracted from:

Collection   Lower  Center  Upper  -------+---------+---------+---------+--
PCA         -31.02    0.70  32.42             (-----*-----)
PCB         -38.72   -7.00  24.72           (------*-----)
WFA          -0.72   31.00  62.72                   (-----*------)
WFB         -19.72   12.00  43.72               (-----*------)
                                   -------+---------+---------+---------+--
                                        -50         0        50       100


Collection = PCA subtracted from:

Collection   Lower  Center  Upper  -------+---------+---------+---------+--
PCB         -39.42   -7.70  24.02           (-----*------)
WFA          -1.42   30.30  62.02                   (-----*-----)
WFB         -20.42   11.30  43.02               (-----*------)
                                   -------+---------+---------+---------+--
                                        -50         0        50       100


Collection = PCB subtracted from:

Collection   Lower  Center  Upper  -------+---------+---------+---------+--
WFA           6.28   38.00  69.72                    (------*-----)
WFB         -12.72   19.00  50.72                (------*-----)
                                   -------+---------+---------+---------+--
                                        -50         0        50       100


Collection = WFA subtracted from:

Collection   Lower  Center  Upper  -------+---------+---------+---------+--
WFB         -50.72  -19.00  12.72         (-----*------)
                                   -------+---------+---------+---------+--
                                        -50         0        50       100
```

Table C3. Percent tree canopy cover general linear model, one way ANOVA and Tukey's multiple comparison test

General Linear Model: % Tree Cover versus Site, Event

```
Factor   Type   Levels  Values
Site     fixed       8  Cedar Bayou, Clear Creek @ SH 35, Dickinson Bayou at
                        517, Greeens bayou, Lake Creek  Near Egypt, Little
                        Cypress Creek, Peach Creek, W. Fork of San Jacinto
Event    fixed       2  A, B


Analysis of Variance for % Tree Cover, using Adjusted SS for Tests

Source       DF    Seq SS   Adj SS   Adj MS      F      P
Site          7   97448.4  97448.4  13921.2  51.86  0.000
Event         1     386.1    386.1    386.1   1.44  0.235
Site*Event    7    2819.8   2819.8    402.8   1.50  0.183
Error        64   17181.6  17181.6    268.5
Total        79  117835.8


S = 16.3848   R-Sq = 85.42%   R-Sq(adj) = 82.00%


Unusual Observations for % Tree Cover

      % Tree
Obs    Cover      Fit  SE Fit  Residual  St Resid
 11   94.200   61.500   7.328    32.700      2.23 R
 25   45.580   78.822   7.328   -33.242     -2.27 R
 33   40.000   75.800   7.328   -35.800     -2.44 R
 46   25.000   63.220   7.328   -38.220     -2.61 R
 49  100.000   63.220   7.328    36.780      2.51 R
 79   47.060   76.766   7.328   -29.706     -2.03 R

R denotes an observation with a large standardized residual.
```

One-way ANOVA: % Tree Cover versus Collection

```
Source      DF      SS    MS      F      P
Collection  15  100654  6710  25.00  0.000
Error       64   17182   268
Total       79  117836

S = 16.38   R-Sq = 85.42%   R-Sq(adj) = 82.00%


                            Individual 95% CIs For Mean Based on
                            Pooled StDev
Level  N   Mean  StDev  ----+---------+---------+---------+-----
CBA    5  61.50  19.76                   (----*---)
CBB    5  79.12  19.22                        (----*---)
CCA    5  77.05  23.22                        (---*---)
CCB    5  63.22  29.25                    (---*---)
DBA    5  92.94   5.32                            (----*---)
DBB    5  96.18   4.60                             (---*----)
GBA    5   0.04   0.08  (---*---)
GBB    5   0.00   0.00  (---*---)
LCA    5  78.82  23.73                        (----*---)
```

```
LCB    5  95.58   5.96                             (---*---)
LCCA   5  88.53  15.82                           (---*---)
LCCB   5  76.77  26.50                        (---*---)
PCA    5  75.80  21.06                       (----*---)
PCB    5  93.82   5.24                             (---*---)
WFA    5   3.52   3.83   (---*---)
WFB    5   8.66   7.42    (---*----)
                        ----+---------+---------+---------+-----
                            0        35        70       105

Pooled StDev = 16.38


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Collection

Individual confidence level = 99.93%


Collection = CBA subtracted from:

Collection   Lower  Center   Upper  ---------+---------+---------+---------+
CBB         -19.31   17.62   54.55                (-----*----)
CCA         -21.38   15.55   52.48                (----*----)
CCB         -35.21    1.72   38.65              (----*-----)
DBA          -5.49   31.44   68.37                  (----*-----)
DBB          -2.25   34.68   71.61                   (----*----)
GBA         -98.40  -61.46  -24.53     (----*----)
GBB         -98.43  -61.50  -24.57     (----*----)
LCA         -19.61   17.32   54.25                (----*-----)
LCB          -2.85   34.08   71.01                   (----*----)
LCCA         -9.90   27.03   63.96                  (----*----)
LCCB        -21.66   15.27   52.20                (----*----)
PCA         -22.63   14.30   51.23                (----*----)
PCB          -4.61   32.32   69.25                  (-----*----)
WFA         -94.91  -57.98  -21.05     (-----*----)
WFB         -89.77  -52.84  -15.91      (----*-----)
                                    ---------+---------+---------+---------+
                                           -70         0        70       140


Collection = CBB subtracted from:

Collection    Lower  Center   Upper  ---------+---------+---------+---------+
CCA          -39.00   -2.07   34.86              (-----*----)
CCB          -52.83  -15.90   21.03            (-----*----)
DBA          -23.11   13.82   50.75                 (----*----)
DBB          -19.87   17.06   53.99                 (----*-----)
GBA         -116.01  -79.08  -42.15   (-----*----)
GBB         -116.05  -79.12  -42.19   (-----*----)
LCA          -37.22   -0.29   36.64               (----*----)
LCB          -20.47   16.46   53.39                 (----*-----)
LCCA         -27.52    9.41   46.34                (----*-----)
LCCB         -39.28   -2.35   34.58              (-----*----)
PCA          -40.25   -3.32   33.61              (-----*----)
PCB          -22.22   14.71   51.64                 (----*----)
WFA         -112.53  -75.60  -38.67    (----*----)
WFB         -107.39  -70.46  -33.53     (----*----)
                                     ---------+---------+---------+---------+
                                            -70         0        70       140


Collection = CCA subtracted from:
```

```
Collection    Lower  Center   Upper  ---------+---------+---------+---------+
CCB          -50.76  -13.83   23.10              (----*----)
DBA          -21.04   15.89   52.82                  (----*-----)
DBB          -17.80   19.13   56.06                  (-----*----)
GBA         -113.94  -77.01  -40.08     (----*----)
GBB         -113.98  -77.05  -40.12     (----*----)
LCA          -35.15    1.78   38.71                (----*-----)
LCB          -18.40   18.53   55.46                  (-----*----)
LCCA         -25.45   11.48   48.41                 (-----*----)
LCCB         -37.21   -0.28   36.65                (----*----)
PCA          -38.18   -1.25   35.68                (----*----)
PCB          -20.15   16.78   53.71                  (----*-----)
WFA         -110.46  -73.53  -36.60     (----*-----)
WFB         -105.32  -68.39  -31.46      (----*-----)
                                     ---------+---------+---------+---------+
                                            -70         0        70       140
```

Collection = CCB subtracted from:

```
Collection    Lower  Center   Upper  ---------+---------+---------+---------+
DBA           -7.21   29.72   66.65                    (----*-----)
DBB           -3.97   32.96   69.89                    (-----*----)
GBA         -100.12  -63.18  -26.25       (----*----)
GBB         -100.15  -63.22  -26.29       (----*----)
LCA          -21.33   15.60   52.53                  (----*-----)
LCB           -4.57   32.36   69.29                    (-----*----)
LCCA         -11.62   25.31   62.24                   (-----*----)
LCCB         -23.38   13.55   50.48                  (----*----)
PCA          -24.35   12.58   49.51                  (----*----)
PCB           -6.33   30.60   67.53                    (----*-----)
WFA          -96.63  -59.70  -22.77       (----*-----)
WFB          -91.49  -54.56  -17.63        (----*----)
                                     ---------+---------+---------+---------+
                                            -70         0        70       140
```

Collection = DBA subtracted from:

```
Collection    Lower  Center   Upper  ---------+---------+---------+---------+
DBB          -33.69    3.24   40.17                (----*-----)
GBA         -129.84  -92.90  -55.97  (-----*----)
GBB         -129.87  -92.94  -56.01  (-----*----)
LCA          -51.05  -14.12   22.81              (----*----)
LCB          -34.29    2.64   39.57                (----*-----)
LCCA         -41.34   -4.41   32.52               (----*-----)
LCCB         -53.10  -16.17   20.76             (-----*----)
PCA          -54.07  -17.14   19.79             (-----*----)
PCB          -36.05    0.88   37.81                (----*----)
WFA         -126.35  -89.42  -52.49   (----*-----)
WFB         -121.21  -84.28  -47.35    (----*----)
                                     ---------+---------+---------+---------+
                                            -70         0        70       140
```

Collection = DBB subtracted from:

```
Collection    Lower  Center   Upper  ---------+---------+---------+---------+
GBA         -133.07  -96.14  -59.21  (----*-----)
GBB         -133.11  -96.18  -59.25  (----*-----)
LCA          -54.29  -17.36   19.57             (-----*----)
LCB          -37.53   -0.60   36.33                (----*----)
```

```
LCCA         -44.58   -7.65   29.28              (----*----)
LCCB         -56.34  -19.41   17.52            (----*-----)
PCA          -57.31  -20.38   16.55            (----*----)
PCB          -39.29   -2.36   34.57              (-----*----)
WFA         -129.59  -92.66  -55.73  (-----*----)
WFB         -124.45  -87.52  -50.59   (----*-----)
                                     ---------+---------+---------+---------+
                                            -70         0        70       140


Collection = GBA subtracted from:

Collection   Lower  Center   Upper  ---------+---------+---------+---------+
GBB         -36.97   -0.04   36.90              (----*----)
LCA          41.86   78.79  115.72                         (----*-----)
LCB          58.61   95.54  132.48                           (-----*----)
LCCA         51.56   88.49  125.42                          (-----*----)
LCCB         39.80   76.73  113.66                         (----*----)
PCA          38.83   75.76  112.70                         (----*----)
PCB          56.86   93.79  130.72                           (----*-----)
WFA         -33.45    3.48   40.42              (----*-----)
WFB         -28.31    8.62   45.55               (----*-----)
                                    ---------+---------+---------+---------+
                                           -70         0        70       140


Collection = GBB subtracted from:

Collection   Lower  Center   Upper  ---------+---------+---------+---------+
LCA          41.89   78.82  115.75                         (----*-----)
LCB          58.65   95.58  132.51                           (-----*----)
LCCA         51.60   88.53  125.46                          (-----*----)
LCCB         39.84   76.77  113.70                         (----*----)
PCA          38.87   75.80  112.73                         (----*----)
PCB          56.89   93.82  130.75                           (----*-----)
WFA         -33.41    3.52   40.45              (-----*----)
WFB         -28.27    8.66   45.59               (----*-----)
                                    ---------+---------+---------+---------+
                                           -70         0        70       140


Collection = LCA subtracted from:

Collection    Lower  Center   Upper  ---------+---------+---------+---------+
LCB          -20.17   16.76   53.69                 (----*-----)
LCCA         -27.22    9.71   46.64                (----*-----)
LCCB         -38.99   -2.06   34.87              (-----*----)
PCA          -39.95   -3.02   33.91              (-----*----)
PCB          -21.93   15.00   51.93                 (----*----)
WFA         -112.23  -75.30  -38.37     (----*-----)
WFB         -107.09  -70.16  -33.23      (----*----)
                                     ---------+---------+---------+---------+
                                            -70         0        70       140


Collection = LCB subtracted from:

Collection    Lower  Center   Upper  ---------+---------+---------+---------+
LCCA         -43.98   -7.05   29.88              (----*----)
LCCB         -55.74  -18.81   18.12            (----*-----)
PCA          -56.71  -19.78   17.15            (----*----)
PCB          -38.69   -1.76   35.17              (-----*----)
WFA         -128.99  -92.06  -55.13   (----*----)
```

```
WFB         -123.85  -86.92  -49.99   (-----*----)
                                     ---------+---------+---------+---------+
                                            -70         0        70       140


Collection = LCCA subtracted from:

Collection    Lower  Center   Upper  ---------+---------+---------+---------+
LCCB         -48.69  -11.76   25.17             (----*-----)
PCA          -49.66  -12.73   24.20             (----*----)
PCB          -31.64    5.29   42.22               (-----*----)
WFA         -121.94  -85.01  -48.08    (----*----)
WFB         -116.80  -79.87  -42.94    (-----*----)
                                     ---------+---------+---------+---------+
                                            -70         0        70       140


Collection = LCCB subtracted from:

Collection    Lower  Center   Upper  ---------+---------+---------+---------+
PCA          -37.90   -0.97   35.96               (----*----)
PCB          -19.87   17.06   53.99                 (----*-----)
WFA         -110.18  -73.25  -36.32     (-----*----)
WFB         -105.04  -68.11  -31.18      (----*-----)
                                     ---------+---------+---------+---------+
                                            -70         0        70       140


Collection = PCA subtracted from:

Collection    Lower  Center   Upper  ---------+---------+---------+---------+
PCB          -18.91   18.02   54.95                 (-----*----)
WFA         -109.21  -72.28  -35.35     (-----*----)
WFB         -104.07  -67.14  -30.21      (----*-----)
                                     ---------+---------+---------+---------+
                                            -70         0        70       140


Collection = PCB subtracted from:

Collection    Lower  Center   Upper  ---------+---------+---------+---------+
WFA         -127.23  -90.30  -53.37   (----*----)
WFB         -122.09  -85.16  -48.23    (----*----)
                                     ---------+---------+---------+---------+
                                            -70         0        70       140


Collection = WFA subtracted from:

Collection   Lower  Center  Upper  ---------+---------+---------+---------+
WFB         -31.79    5.14  42.07             (-----*----)
                                   ---------+---------+---------+---------+
                                          -70         0        70       140
```

Table C4. Riparian width general linear model, one way ANOVA and Tukey's multiple comparison test

General Linear Model: Riparian versus Site, Event

Factor	Type	Levels	Values
Site	fixed	8	Cedar Bayou, Clear Creek @ SH 35, Dickinson Bayou at 517, Greeens bayou, Lake Creek Near Egypt, Little Cypress Creek, Peach Creek, W. Fork of San Jacinto
Event	fixed	2	A, B

Analysis of Variance for Riparian, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Site	7	5471.15	5471.15	781.59	153.63	0.000
Event	1	11.25	11.25	11.25	2.21	0.142
Site*Event	7	85.70	85.70	12.24	2.41	0.030
Error	64	325.60	325.60	5.09		
Total	79	5893.70				

S = 2.25555   R-Sq = 94.48%   R-Sq(adj) = 93.18%

Unusual Observations for Riparian

Obs	Riparian	Fit	SE Fit	Residual	St Resid
25	12.5000	18.5000	1.0087	-6.0000	-2.97 R
39	20.0000	15.5000	1.0087	4.5000	2.23 R
54	17.5000	10.0000	1.0087	7.5000	3.72 R
55	1.0000	10.0000	1.0087	-9.0000	-4.46 R
65	11.0000	18.2000	1.0087	-7.2000	-3.57 R

R denotes an observation with a large standardized residual.

One-way ANOVA: Riparian versus Collection

Source	DF	SS	MS	F	P
Collection	15	5568.10	371.21	72.96	0.000
Error	64	325.60	5.09		
Total	79	5893.70			

S = 2.256   R-Sq = 94.48%   R-Sq(adj) = 93.18%

```
                         Individual 95% CIs For Mean Based on
                         Pooled StDev
Level  N    Mean  StDev  ---+---------+---------+---------+------
CBA    5   6.200  1.151           (--*--)
CBB    5  10.000  5.874                (--*--)
CCA    5   0.000  0.000  (--*--)
CCB    5   0.000  0.000  (--*--)
DBA    5  20.000  0.000                               (--*-)
DBB    5  20.000  0.000                               (--*-)
GBA    5   0.000  0.000  (--*--)
GBB    5   0.000  0.000  (--*--)
LCA    5  18.500  3.354                             (-*--)
LCB    5  18.200  4.025                            (--*--)
LCCA   5  15.500  3.260                        (--*--)
```

```
LCCB   5  20.000  0.000                              (--*-)
PCA    5  20.000  0.000                              (--*-)
PCB    5  20.000  0.000                              (--*-)
WFA    5  20.000  0.000                              (--*-)
WFB    5  18.000  2.739                           (--*--)
                        ---+---------+---------+---------+------
                          0.0       7.0      14.0      21.0

Pooled StDev = 2.256


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Collection

Individual confidence level = 99.93%


Collection = CBA subtracted from:

Collection    Lower  Center   Upper  -------+---------+---------+---------+--
CBB          -1.284   3.800   8.884                 (---*--)
CCA         -11.284  -6.200  -1.116          (---*--)
CCB         -11.284  -6.200  -1.116          (---*--)
DBA           8.716  13.800  18.884                        (--*---)
DBB           8.716  13.800  18.884                        (--*---)
GBA         -11.284  -6.200  -1.116          (---*--)
GBB         -11.284  -6.200  -1.116          (---*--)
LCA           7.216  12.300  17.384                       (--*---)
LCB           6.916  12.000  17.084                       (--*--)
LCCA          4.216   9.300  14.384                     (--*---)
LCCB          8.716  13.800  18.884                        (--*---)
PCA           8.716  13.800  18.884                        (--*---)
PCB           8.716  13.800  18.884                        (--*---)
WFA           8.716  13.800  18.884                        (--*---)
WFB           6.716  11.800  16.884                      (---*--)
                                     -------+---------+---------+---------+--
                                          -15         0        15        30


Collection = CBB subtracted from:

Collection    Lower   Center   Upper  -------+---------+---------+---------+--
CCA         -15.084  -10.000  -4.916         (--*---)
CCB         -15.084  -10.000  -4.916         (--*---)
DBA           4.916   10.000  15.084                     (---*--)
DBB           4.916   10.000  15.084                     (---*--)
GBA         -15.084  -10.000  -4.916         (--*---)
GBB         -15.084  -10.000  -4.916         (--*---)
LCA           3.416    8.500  13.584                    (---*--)
LCB           3.116    8.200  13.284                    (--*---)
LCCA          0.416    5.500  10.584                  (---*--)
LCCB          4.916   10.000  15.084                     (---*--)
PCA           4.916   10.000  15.084                     (---*--)
PCB           4.916   10.000  15.084                     (---*--)
WFA           4.916   10.000  15.084                     (---*--)
WFB           2.916    8.000  13.084                    (--*---)
                                      -------+---------+---------+---------+--
                                           -15         0        15        30


Collection = CCA subtracted from:

Collection   Lower  Center   Upper  -------+---------+---------+---------+--
```

```
CCB         -5.084   0.000   5.084                (--*--)
DBA         14.916  20.000  25.084                             (--*---)
DBB         14.916  20.000  25.084                             (--*---)
GBA         -5.084   0.000   5.084                (--*--)
GBB         -5.084   0.000   5.084                (--*--)
LCA         13.416  18.500  23.584                            (--*---)
LCB         13.116  18.200  23.284                            (--*---)
LCCA        10.416  15.500  20.584                          (--*---)
LCCB        14.916  20.000  25.084                             (--*---)
PCA         14.916  20.000  25.084                             (--*---)
PCB         14.916  20.000  25.084                             (--*---)
WFA         14.916  20.000  25.084                             (--*---)
WFB         12.916  18.000  23.084                            (--*--)
                                    -------+---------+---------+---------+--
                                         -15         0        15        30


Collection = CCB subtracted from:

Collection   Lower  Center   Upper  -------+---------+---------+---------+--
DBA         14.916  20.000  25.084                             (--*---)
DBB         14.916  20.000  25.084                             (--*---)
GBA         -5.084   0.000   5.084                (--*--)
GBB         -5.084   0.000   5.084                (--*--)
LCA         13.416  18.500  23.584                            (--*---)
LCB         13.116  18.200  23.284                            (--*---)
LCCA        10.416  15.500  20.584                          (--*---)
LCCB        14.916  20.000  25.084                             (--*---)
PCA         14.916  20.000  25.084                             (--*---)
PCB         14.916  20.000  25.084                             (--*---)
WFA         14.916  20.000  25.084                             (--*---)
WFB         12.916  18.000  23.084                            (--*--)
                                    -------+---------+---------+---------+--
                                         -15         0        15        30


Collection = DBA subtracted from:

Collection    Lower   Center    Upper  -------+---------+---------+---------+--
DBB          -5.084    0.000    5.084                (--*--)
GBA         -25.084  -20.000  -14.916  (---*--)
GBB         -25.084  -20.000  -14.916  (---*--)
LCA          -6.584   -1.500    3.584               (--*--)
LCB          -6.884   -1.800    3.284              (---*--)
LCCA         -9.584   -4.500    0.584             (--*--)
LCCB         -5.084    0.000    5.084                (--*--)
PCA          -5.084    0.000    5.084                (--*--)
PCB          -5.084    0.000    5.084                (--*--)
WFA          -5.084    0.000    5.084                (--*--)
WFB          -7.084   -2.000    3.084              (---*--)
                                       -------+---------+---------+---------+--
                                            -15         0        15        30


Collection = DBB subtracted from:

Collection    Lower   Center    Upper  -------+---------+---------+---------+--
GBA         -25.084  -20.000  -14.916  (---*--)
GBB         -25.084  -20.000  -14.916  (---*--)
LCA          -6.584   -1.500    3.584               (--*--)
LCB          -6.884   -1.800    3.284              (---*--)
LCCA         -9.584   -4.500    0.584             (--*--)
LCCB         -5.084    0.000    5.084                (--*--)
```

```
PCA          -5.084    0.000    5.084               (--*--)
PCB          -5.084    0.000    5.084               (--*--)
WFA          -5.084    0.000    5.084               (--*--)
WFB          -7.084   -2.000    3.084             (---*--)
                                      -------+---------+---------+---------+--
                                           -15         0        15        30

Collection = GBA subtracted from:

Collection   Lower  Center   Upper  -------+---------+---------+---------+--
GBB         -5.084   0.000   5.084               (--*--)
LCA         13.416  18.500  23.584                          (--*---)
LCB         13.116  18.200  23.284                          (--*---)
LCCA        10.416  15.500  20.584                        (--*---)
LCCB        14.916  20.000  25.084                           (--*---)
PCA         14.916  20.000  25.084                           (--*---)
PCB         14.916  20.000  25.084                           (--*---)
WFA         14.916  20.000  25.084                           (--*---)
WFB         12.916  18.000  23.084                          (--*--)
                                    -------+---------+---------+---------+--
                                         -15         0        15        30

Collection = GBB subtracted from:

Collection   Lower  Center   Upper  -------+---------+---------+---------+--
LCA         13.416  18.500  23.584                          (--*---)
LCB         13.116  18.200  23.284                          (--*---)
LCCA        10.416  15.500  20.584                        (--*---)
LCCB        14.916  20.000  25.084                           (--*---)
PCA         14.916  20.000  25.084                           (--*---)
PCB         14.916  20.000  25.084                           (--*---)
WFA         14.916  20.000  25.084                           (--*---)
WFB         12.916  18.000  23.084                          (--*--)
                                    -------+---------+---------+---------+--
                                         -15         0        15        30

Collection = LCA subtracted from:

Collection   Lower  Center  Upper  -------+---------+---------+---------+--
LCB         -5.384  -0.300  4.784              (---*--)
LCCA        -8.084  -3.000  2.084             (--*--)
LCCB        -3.584   1.500  6.584                (--*--)
PCA         -3.584   1.500  6.584                (--*--)
PCB         -3.584   1.500  6.584                (--*--)
WFA         -3.584   1.500  6.584                (--*--)
WFB         -5.584  -0.500  4.584              (---*--)
                                   -------+---------+---------+---------+--
                                        -15         0        15        30

Collection = LCB subtracted from:

Collection   Lower  Center  Upper  -------+---------+---------+---------+--
LCCA        -7.784  -2.700  2.384             (--*---)
LCCB        -3.284   1.800  6.884                (--*---)
PCA         -3.284   1.800  6.884                (--*---)
PCB         -3.284   1.800  6.884                (--*---)
WFA         -3.284   1.800  6.884                (--*---)
WFB         -5.284  -0.200  4.884              (---*--)
                                   -------+---------+---------+---------+--
```

```
                                     -15         0        15        30


Collection = LCCA subtracted from:

Collection   Lower  Center  Upper  -------+---------+---------+---------+--
LCCB        -0.584   4.500  9.584                  (--*--)
PCA         -0.584   4.500  9.584                  (--*--)
PCB         -0.584   4.500  9.584                  (--*--)
WFA         -0.584   4.500  9.584                  (--*--)
WFB         -2.584   2.500  7.584                (---*--)
                                   -------+---------+---------+---------+--
                                        -15         0        15        30


Collection = LCCB subtracted from:

Collection   Lower  Center  Upper  -------+---------+---------+---------+--
PCA         -5.084   0.000  5.084               (--*--)
PCB         -5.084   0.000  5.084               (--*--)
WFA         -5.084   0.000  5.084               (--*--)
WFB         -7.084  -2.000  3.084             (---*--)
                                   -------+---------+---------+---------+--
                                        -15         0        15        30


Collection = PCA subtracted from:

Collection   Lower  Center  Upper  -------+---------+---------+---------+--
PCB         -5.084   0.000  5.084               (--*--)
WFA         -5.084   0.000  5.084               (--*--)
WFB         -7.084  -2.000  3.084             (---*--)
                                   -------+---------+---------+---------+--
                                        -15         0        15        30


Collection = PCB subtracted from:

Collection   Lower  Center  Upper  -------+---------+---------+---------+--
WFA         -5.084   0.000  5.084               (--*--)
WFB         -7.084  -2.000  3.084             (---*--)
                                   -------+---------+---------+---------+--
                                        -15         0        15        30


Collection = WFA subtracted from:

Collection   Lower  Center  Upper  -------+---------+---------+---------+--
WFB         -7.084  -2.000  3.084             (---*--)
                                   -------+---------+---------+---------+--
                                        -15         0        15        30
```

Table C5. Percent substrate gravel or larger general linear model, one way ANOVA and Tukey's multiple comparison test

General Linear Model: % Substrate Gravel or Larger versus Site, Event

Factor	Type	Levels	Values
Site	fixed	8	Cedar Bayou, Clear Creek @ SH 35, Dickinson Bayou at 517, Greeens bayou, Lake Creek Near Egypt, Little Cypress Creek, Peach Creek, W. Fork of San Jacinto
Event	fixed	2	A, B

Analysis of Variance for % Substrate Gravel or Larger, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Site	7	13280.9	13280.9	1897.3	4.09	0.001
Event	1	738.1	738.1	738.1	1.59	0.212
Site*Event	7	4629.4	4629.4	661.3	1.43	0.211
Error	64	29698.0	29698.0	464.0		
Total	79	48346.4				

S = 21.5414   R-Sq = 38.57%   R-Sq(adj) = 24.18%

Unusual Observations for % Substrate Gravel or Larger

Obs	% Substrate Gravel or Larger	Fit	SE Fit	Residual	St Resid	
11	80.0000	29.0000	9.6336	51.0000	2.65	R
16	80.0000	41.0000	9.6336	39.0000	2.02	R
29	80.0000	35.0000	9.6336	45.0000	2.34	R
55	85.0000	31.0000	9.6336	54.0000	2.80	R
56	80.0000	31.4000	9.6336	48.6000	2.52	R
74	60.0000	19.8000	9.6336	40.2000	2.09	R

R denotes an observation with a large standardized residual.

One-way ANOVA: % Substrate Gravel or Larger versus Collection

Source	DF	SS	MS	F	P
Collection	15	18648	1243	2.68	0.003
Error	64	29698	464		
Total	79	48346			

S = 21.54   R-Sq = 38.57%   R-Sq(adj) = 24.18%

```
                        Individual 95% CIs For Mean Based on Pooled StDev
Level  N   Mean  StDev    +---------+---------+---------+---------
CBA    5  29.00  38.14                   (---------*--------)
CBB    5  31.00  36.47                    (---------*--------)
CCA    5  34.00  26.32                     (---------*---------)
CCB    5   0.80   1.10     (--------*---------)
DBA    5   0.00   0.00    (---------*---------)
DBB    5   5.40   8.41       (---------*--------)
GBA    5  35.00  28.72                      (---------*--------)
GBB    5   8.00   2.74        (---------*---------)
```

```
LCA    5   0.00   0.00    (---------*---------)
LCB    5   0.00   0.00    (---------*---------)
LCCA   5   0.00   0.00    (---------*---------)
LCCB   5   0.00   0.00    (---------*---------)
PCA    5   6.00   4.18       (---------*---------)
PCB    5  19.80  25.40              (---------*---------)
WFA    5  41.00  32.86                         (---------*--------)
WFB    5  31.40  36.05                    (---------*--------)
                          +---------+---------+---------+---------
                        -20         0        20        40

Pooled StDev = 21.54


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Collection

Individual confidence level = 99.93%


Collection = CBA subtracted from:

Collection   Lower  Center  Upper  --------+---------+---------+---------+-
CBB         -46.55    2.00  50.55           (--------*---------)
CCA         -43.55    5.00  53.55           (---------*---------)
CCB         -76.75  -28.20  20.35     (--------*---------)
DBA         -77.55  -29.00  19.55    (---------*---------)
DBB         -72.15  -23.60  24.95      (--------*---------)
GBA         -42.55    6.00  54.55           (---------*---------)
GBB         -69.55  -21.00  27.55      (---------*---------)
LCA         -77.55  -29.00  19.55    (---------*---------)
LCB         -77.55  -29.00  19.55    (---------*---------)
LCCA        -77.55  -29.00  19.55    (---------*---------)
LCCB        -77.55  -29.00  19.55    (---------*---------)
PCA         -71.55  -23.00  25.55      (--------*---------)
PCB         -57.75   -9.20  39.35        (---------*---------)
WFA         -36.55   12.00  60.55             (--------*---------)
WFB         -46.15    2.40  50.95           (--------*---------)
                                   --------+---------+---------+---------+-
                                         -50         0        50       100


Collection = CBB subtracted from:

Collection   Lower  Center  Upper  --------+---------+---------+---------+-
CCA         -45.55    3.00  51.55           (---------*--------)
CCB         -78.75  -30.20  18.35    (---------*---------)
DBA         -79.55  -31.00  17.55    (---------*---------)
DBB         -74.15  -25.60  22.95     (---------*---------)
GBA         -44.55    4.00  52.55           (---------*---------)
GBB         -71.55  -23.00  25.55      (--------*---------)
LCA         -79.55  -31.00  17.55    (---------*---------)
LCB         -79.55  -31.00  17.55    (---------*---------)
LCCA        -79.55  -31.00  17.55    (---------*---------)
LCCB        -79.55  -31.00  17.55    (---------*---------)
PCA         -73.55  -25.00  23.55     (---------*---------)
PCB         -59.75  -11.20  37.35        (---------*--------)
WFA         -38.55   10.00  58.55            (---------*---------)
WFB         -48.15    0.40  48.95          (---------*---------)
                                   --------+---------+---------+---------+-
                                         -50         0        50       100
```

```
Collection = CCA subtracted from:

Collection   Lower  Center  Upper  --------+---------+---------+---------+-
CCB         -81.75  -33.20  15.35    (--------*---------)
DBA         -82.55  -34.00  14.55  (---------*---------)
DBB         -77.15  -28.60  19.95     (--------*---------)
GBA         -47.55    1.00  49.55          (---------*---------)
GBB         -74.55  -26.00  22.55     (---------*---------)
LCA         -82.55  -34.00  14.55  (---------*---------)
LCB         -82.55  -34.00  14.55  (---------*---------)
LCCA        -82.55  -34.00  14.55  (---------*---------)
LCCB        -82.55  -34.00  14.55  (---------*---------)
PCA         -76.55  -28.00  20.55     (--------*---------)
PCB         -62.75  -14.20  34.35       (---------*---------)
WFA         -41.55    7.00  55.55            (--------*---------)
WFB         -51.15   -2.60  45.95          (--------*---------)
                                   --------+---------+---------+---------+-
                                         -50         0        50       100


Collection = CCB subtracted from:

Collection   Lower  Center  Upper  --------+---------+---------+---------+-
DBA         -49.35   -0.80  47.75          (---------*---------)
DBB         -43.95    4.60  53.15           (---------*---------)
GBA         -14.35   34.20  82.75                 (---------*---------)
GBB         -41.35    7.20  55.75            (--------*---------)
LCA         -49.35   -0.80  47.75          (---------*---------)
LCB         -49.35   -0.80  47.75          (---------*---------)
LCCA        -49.35   -0.80  47.75          (---------*---------)
LCCB        -49.35   -0.80  47.75          (---------*---------)
PCA         -43.35    5.20  53.75           (---------*---------)
PCB         -29.55   19.00  67.55              (---------*---------)
WFA          -8.35   40.20  88.75                  (---------*---------)
WFB         -17.95   30.60  79.15                (---------*---------)
                                   --------+---------+---------+---------+-
                                         -50         0        50       100


Collection = DBA subtracted from:

Collection   Lower  Center  Upper  --------+---------+---------+---------+-
DBB         -43.15    5.40  53.95           (---------*---------)
GBA         -13.55   35.00  83.55                 (---------*---------)
GBB         -40.55    8.00  56.55            (---------*--------)
LCA         -48.55    0.00  48.55          (---------*---------)
LCB         -48.55    0.00  48.55          (---------*---------)
LCCA        -48.55    0.00  48.55          (---------*---------)
LCCB        -48.55    0.00  48.55          (---------*---------)
PCA         -42.55    6.00  54.55           (---------*---------)
PCB         -28.75   19.80  68.35              (---------*---------)
WFA          -7.55   41.00  89.55                  (---------*---------)
WFB         -17.15   31.40  79.95                 (--------*---------)
                                   --------+---------+---------+---------+-
                                         -50         0        50       100


Collection = DBB subtracted from:

Collection   Lower  Center  Upper  --------+---------+---------+---------+-
GBA         -18.95   29.60  78.15                (---------*---------)
GBB         -45.95    2.60  51.15           (---------*--------)
LCA         -53.95   -5.40  43.15         (---------*---------)
```

```
LCB         -53.95   -5.40  43.15         (---------*---------)
LCCA        -53.95   -5.40  43.15         (---------*---------)
LCCB        -53.95   -5.40  43.15         (---------*---------)
PCA         -47.95    0.60  49.15          (---------*---------)
PCB         -34.15   14.40  62.95             (---------*---------)
WFA         -12.95   35.60  84.15                 (---------*---------)
WFB         -22.55   26.00  74.55               (---------*---------)
                                   --------+---------+---------+---------+-
                                         -50         0        50       100


Collection = GBA subtracted from:

Collection   Lower  Center  Upper  --------+---------+---------+---------+-
GBB         -75.55  -27.00  21.55      (---------*--------)
LCA         -83.55  -35.00  13.55    (---------*---------)
LCB         -83.55  -35.00  13.55    (---------*---------)
LCCA        -83.55  -35.00  13.55    (---------*---------)
LCCB        -83.55  -35.00  13.55    (---------*---------)
PCA         -77.55  -29.00  19.55     (---------*---------)
PCB         -63.75  -15.20  33.35        (---------*---------)
WFA         -42.55    6.00  54.55            (---------*---------)
WFB         -52.15   -3.60  44.95           (--------*---------)
                                   --------+---------+---------+---------+-
                                         -50         0        50       100


Collection = GBB subtracted from:

Collection   Lower  Center  Upper  --------+---------+---------+---------+-
LCA         -56.55   -8.00  40.55         (--------*---------)
LCB         -56.55   -8.00  40.55         (--------*---------)
LCCA        -56.55   -8.00  40.55         (--------*---------)
LCCB        -56.55   -8.00  40.55         (--------*---------)
PCA         -50.55   -2.00  46.55          (---------*--------)
PCB         -36.75   11.80  60.35             (--------*---------)
WFA         -15.55   33.00  81.55                 (---------*--------)
WFB         -25.15   23.40  71.95               (---------*--------)
                                   --------+---------+---------+---------+-
                                         -50         0        50       100


Collection = LCA subtracted from:

Collection   Lower  Center  Upper  --------+---------+---------+---------+-
LCB         -48.55    0.00  48.55          (---------*---------)
LCCA        -48.55    0.00  48.55          (---------*---------)
LCCB        -48.55    0.00  48.55          (---------*---------)
PCA         -42.55    6.00  54.55           (---------*---------)
PCB         -28.75   19.80  68.35              (---------*---------)
WFA          -7.55   41.00  89.55                  (---------*---------)
WFB         -17.15   31.40  79.95                 (--------*---------)
                                   --------+---------+---------+---------+-
                                         -50         0        50       100


Collection = LCB subtracted from:

Collection   Lower  Center  Upper  --------+---------+---------+---------+-
LCCA        -48.55    0.00  48.55          (---------*---------)
LCCB        -48.55    0.00  48.55          (---------*---------)
PCA         -42.55    6.00  54.55           (---------*---------)
PCB         -28.75   19.80  68.35              (---------*---------)
```

```
WFA          -7.55   41.00  89.55                  (---------*---------)
WFB         -17.15   31.40  79.95                 (--------*---------)
                                   --------+---------+---------+---------+-
                                         -50         0        50       100


Collection = LCCA subtracted from:

Collection   Lower  Center  Upper  --------+---------+---------+---------+-
LCCB        -48.55    0.00  48.55          (---------*---------)
PCA         -42.55    6.00  54.55           (---------*---------)
PCB         -28.75   19.80  68.35              (---------*---------)
WFA          -7.55   41.00  89.55                  (---------*---------)
WFB         -17.15   31.40  79.95                 (--------*---------)
                                   --------+---------+---------+---------+-
                                         -50         0        50       100


Collection = LCCB subtracted from:

Collection   Lower  Center  Upper  --------+---------+---------+---------+-
PCA         -42.55    6.00  54.55           (---------*---------)
PCB         -28.75   19.80  68.35              (---------*---------)
WFA          -7.55   41.00  89.55                  (---------*---------)
WFB         -17.15   31.40  79.95                 (--------*---------)
                                   --------+---------+---------+---------+-
                                         -50         0        50       100


Collection = PCA subtracted from:

Collection   Lower  Center  Upper  --------+---------+---------+---------+-
PCB         -34.75   13.80  62.35             (---------*--------)
WFA         -13.55   35.00  83.55                 (---------*---------)
WFB         -23.15   25.40  73.95               (---------*---------)
                                   --------+---------+---------+---------+-
                                         -50         0        50       100


Collection = PCB subtracted from:

Collection   Lower  Center  Upper  --------+---------+---------+---------+-
WFA         -27.35   21.20  69.75               (--------*---------)
WFB         -36.95   11.60  60.15             (--------*---------)
                                   --------+---------+---------+---------+-
                                         -50         0        50       100


Collection = WFA subtracted from:

Collection   Lower  Center  Upper  --------+---------+---------+---------+-
WFB         -58.15   -9.60  38.95        (---------*---------)
                                   --------+---------+---------+---------+-
                                         -50         0        50       100
```

Table C6. Percent instream cover general linear model, one way ANOVA and Tukey's multiple comparison test

General Linear Model: % Instream Cover versus Site, Event

Factor	Type	Levels	Values
Site	fixed	8	Cedar Bayou, Clear Creek @ SH 35, Dickinson Bayou at 517, Greeens bayou, Lake Creek Near Egypt, Little Cypress Creek, Peach Creek, W. Fork of San Jacinto
Event	fixed	2	A, B

Analysis of Variance for % Instream Cover, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Site	7	5627.1	5627.1	803.9	1.48	0.190
Event	1	1606.5	1606.5	1606.5	2.96	0.090
Site*Event	7	1491.2	1491.2	213.0	0.39	0.904
Error	64	34758.8	34758.8	543.1		
Total	79	43483.6				

S = 23.3046   R-Sq = 20.06%   R-Sq(adj) = 1.33%

Unusual Observations for % Instream Cover

Obs	% Instream Cover	Fit	SE Fit	Residual	St Resid
11	80.000	32.500	10.422	47.500	2.28 R
19	70.000	28.000	10.422	42.000	2.01 R
65	100.000	46.000	10.422	54.000	2.59 R

R denotes an observation with a large standardized residual.

One-way ANOVA: % Instream Cover versus Collection

Source	DF	SS	MS	F	P
Collection	15	8725	582	1.07	0.400
Error	64	34759	543		
Total	79	43484			

S = 23.30   R-Sq = 20.06%   R-Sq(adj) = 1.33%

```
                        Individual 95% CIs For Mean Based on
                        Pooled StDev
Level  N   Mean  StDev  ------+---------+---------+---------+---
CBA    5  32.50  39.05             (-------*-------)
CBB    5  29.00  30.90           (--------*-------)
CCA    5  35.00  11.73              (-------*-------)
CCB    5  29.00  13.87           (--------*-------)
DBA    5  31.00  27.93            (-------*--------)
DBB    5  13.80  13.59     (--------*-------)
GBA    5  25.00  11.73          (-------*-------)
GBB    5   6.00   2.24  (-------*--------)
LCA    5  36.00  20.74              (-------*--------)
LCB    5  46.00  37.32                  (-------*--------)
LCCA   5  45.00  24.49                  (-------*-------)
LCCB   5  34.00  25.35             (--------*-------)
```

```
PCA    5  39.00  26.08              (--------*-------)
PCB    5  27.00  15.65         (--------*-------)
WFA    5  28.00  24.14          (-------*--------)
WFB    5  15.00  14.14     (-------*-------)
                       ------+---------+---------+---------+---
                             0        25        50        75

Pooled StDev = 23.30


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Collection

Individual confidence level = 99.93%


Collection = CBA subtracted from:

Collection   Lower  Center  Upper  ---------+---------+---------+---------+
CBB         -56.03   -3.50  49.03          (---------*----------)
CCA         -50.03    2.50  55.03           (----------*---------)
CCB         -56.03   -3.50  49.03          (---------*----------)
DBA         -54.03   -1.50  51.03          (----------*---------)
DBB         -71.23  -18.70  33.83       (---------*----------)
GBA         -60.03   -7.50  45.03         (----------*---------)
GBB         -79.03  -26.50  26.03     (----------*---------)
LCA         -49.03    3.50  56.03           (----------*---------)
LCB         -39.03   13.50  66.03             (----------*---------)
LCCA        -40.03   12.50  65.03             (----------*---------)
LCCB        -51.03    1.50  54.03           (---------*----------)
PCA         -46.03    6.50  59.03            (---------*----------)
PCB         -58.03   -5.50  47.03         (----------*---------)
WFA         -57.03   -4.50  48.03          (---------*----------)
WFB         -70.03  -17.50  35.03       (----------*---------)
                                   ---------+---------+---------+---------+
                                          -50         0        50       100


Collection = CBB subtracted from:

Collection   Lower  Center  Upper  ---------+---------+---------+---------+
CCA         -46.53    6.00  58.53            (---------*----------)
CCB         -52.53    0.00  52.53          (----------*----------)
DBA         -50.53    2.00  54.53           (---------*----------)
DBB         -67.73  -15.20  37.33       (----------*---------)
GBA         -56.53   -4.00  48.53          (---------*----------)
GBB         -75.53  -23.00  29.53      (---------*----------)
LCA         -45.53    7.00  59.53            (---------*----------)
LCB         -35.53   17.00  69.53              (---------*----------)
LCCA        -36.53   16.00  68.53              (---------*----------)
LCCB        -47.53    5.00  57.53           (----------*----------)
PCA         -42.53   10.00  62.53            (----------*----------)
PCB         -54.53   -2.00  50.53          (----------*---------)
WFA         -53.53   -1.00  51.53          (----------*---------)
WFB         -66.53  -14.00  38.53        (---------*----------)
                                   ---------+---------+---------+---------+
                                          -50         0        50       100


Collection = CCA subtracted from:

Collection   Lower  Center  Upper  ---------+---------+---------+---------+
CCB         -58.53   -6.00  46.53         (----------*---------)
```

```
DBA         -56.53   -4.00  48.53           (---------*----------)
DBB         -73.73  -21.20  31.33       (----------*---------)
GBA         -62.53  -10.00  42.53         (----------*----------)
GBB         -81.53  -29.00  23.53      (---------*----------)
LCA         -51.53    1.00  53.53            (---------*----------)
LCB         -41.53   11.00  63.53              (---------*----------)
LCCA        -42.53   10.00  62.53             (----------*----------)
LCCB        -53.53   -1.00  51.53           (----------*---------)
PCA         -48.53    4.00  56.53            (----------*---------)
PCB         -60.53   -8.00  44.53          (---------*----------)
WFA         -59.53   -7.00  45.53          (----------*---------)
WFB         -72.53  -20.00  32.53       (----------*----------)
                                   ---------+---------+---------+---------+
                                          -50         0        50       100
```

```
Collection = CCB subtracted from:

Collection   Lower  Center  Upper  ---------+---------+---------+---------+
DBA         -50.53    2.00  54.53            (---------*----------)
DBB         -67.73  -15.20  37.33        (----------*---------)
GBA         -56.53   -4.00  48.53           (---------*----------)
GBB         -75.53  -23.00  29.53       (---------*----------)
LCA         -45.53    7.00  59.53             (---------*----------)
LCB         -35.53   17.00  69.53               (---------*----------)
LCCA        -36.53   16.00  68.53               (---------*----------)
LCCB        -47.53    5.00  57.53            (----------*----------)
PCA         -42.53   10.00  62.53             (----------*----------)
PCB         -54.53   -2.00  50.53           (----------*---------)
WFA         -53.53   -1.00  51.53           (----------*---------)
WFB         -66.53  -14.00  38.53         (---------*----------)
                                   ---------+---------+---------+---------+
                                          -50         0        50       100
```

```
Collection = DBA subtracted from:

Collection   Lower  Center  Upper  ---------+---------+---------+---------+
DBB         -69.73  -17.20  35.33        (----------*---------)
GBA         -58.53   -6.00  46.53          (----------*---------)
GBB         -77.53  -25.00  27.53      (----------*----------)
LCA         -47.53    5.00  57.53            (----------*----------)
LCB         -37.53   15.00  67.53              (----------*----------)
LCCA        -38.53   14.00  66.53              (----------*---------)
LCCB        -49.53    3.00  55.53            (----------*---------)
PCA         -44.53    8.00  60.53             (----------*---------)
PCB         -56.53   -4.00  48.53           (---------*----------)
WFA         -55.53   -3.00  49.53           (---------*----------)
WFB         -68.53  -16.00  36.53        (----------*---------)
                                   ---------+---------+---------+---------+
                                          -50         0        50       100
```

```
Collection = DBB subtracted from:

Collection   Lower  Center  Upper  ---------+---------+---------+---------+
GBA         -41.33   11.20  63.73              (---------*----------)
GBB         -60.33   -7.80  44.73          (---------*----------)
LCA         -30.33   22.20  74.73                (---------*----------)
LCB         -20.33   32.20  84.73                  (---------*----------)
LCCA        -21.33   31.20  83.73                  (---------*----------)
LCCB        -32.33   20.20  72.73                (---------*----------)
PCA         -27.33   25.20  77.73                 (---------*----------)
```

```
PCB         -39.33   13.20  65.73             (----------*---------)
WFA         -38.33   14.20  66.73             (----------*---------)
WFB         -51.33    1.20  53.73           (---------*----------)
                                   ---------+---------+---------+---------+
                                          -50         0       50       100


Collection = GBA subtracted from:

Collection   Lower  Center  Upper  ---------+---------+---------+---------+
GBB         -71.53  -19.00  33.53       (---------*----------)
LCA         -41.53   11.00  63.53             (---------*----------)
LCB         -31.53   21.00  73.53               (---------*----------)
LCCA        -32.53   20.00  72.53              (----------*----------)
LCCB        -43.53    9.00  61.53            (----------*---------)
PCA         -38.53   14.00  66.53             (----------*---------)
PCB         -50.53    2.00  54.53           (---------*----------)
WFA         -49.53    3.00  55.53           (----------*---------)
WFB         -62.53  -10.00  42.53        (----------*----------)
                                   ---------+---------+---------+---------+
                                          -50         0       50       100


Collection = GBB subtracted from:

Collection   Lower  Center  Upper  ---------+---------+---------+---------+
LCA         -22.53   30.00  82.53                (----------*----------)
LCB         -12.53   40.00  92.53                  (----------*----------)
LCCA        -13.53   39.00  91.53                  (----------*---------)
LCCB        -24.53   28.00  80.53                (----------*---------)
PCA         -19.53   33.00  85.53                 (----------*---------)
PCB         -31.53   21.00  73.53               (---------*----------)
WFA         -30.53   22.00  74.53               (---------*----------)
WFB         -43.53    9.00  61.53            (----------*---------)
                                   ---------+---------+---------+---------+
                                          -50         0       50       100


Collection = LCA subtracted from:

Collection   Lower  Center  Upper  ---------+---------+---------+---------+
LCB         -42.53   10.00  62.53            (----------*----------)
LCCA        -43.53    9.00  61.53            (----------*---------)
LCCB        -54.53   -2.00  50.53          (----------*---------)
PCA         -49.53    3.00  55.53           (----------*---------)
PCB         -61.53   -9.00  43.53         (---------*----------)
WFA         -60.53   -8.00  44.53         (---------*----------)
WFB         -73.53  -21.00  31.53      (----------*---------)
                                   ---------+---------+---------+---------+
                                          -50         0       50       100


Collection = LCB subtracted from:

Collection   Lower  Center  Upper  ---------+---------+---------+---------+
LCCA        -53.53   -1.00  51.53          (----------*---------)
LCCB        -64.53  -12.00  40.53        (----------*---------)
PCA         -59.53   -7.00  45.53         (----------*---------)
PCB         -71.53  -19.00  33.53       (---------*----------)
WFA         -70.53  -18.00  34.53       (---------*----------)
WFB         -83.53  -31.00  21.53    (----------*---------)
                                   ---------+---------+---------+---------+
                                          -50         0       50       100
```

```
Collection = LCCA subtracted from:

Collection   Lower  Center  Upper  ---------+---------+---------+---------+
LCCB        -63.53  -11.00  41.53        (----------*---------)
PCA         -58.53   -6.00  46.53         (----------*---------)
PCB         -70.53  -18.00  34.53       (---------*----------)
WFA         -69.53  -17.00  35.53       (----------*---------)
WFB         -82.53  -30.00  22.53    (----------*----------)
                                   ---------+---------+---------+---------+
                                          -50         0        50       100


Collection = LCCB subtracted from:

Collection   Lower  Center  Upper  ---------+---------+---------+---------+
PCA         -47.53    5.00  57.53           (----------*----------)
PCB         -59.53   -7.00  45.53         (----------*---------)
WFA         -58.53   -6.00  46.53         (----------*---------)
WFB         -71.53  -19.00  33.53       (---------*----------)
                                   ---------+---------+---------+---------+
                                          -50         0        50       100


Collection = PCA subtracted from:

Collection   Lower  Center  Upper  ---------+---------+---------+---------+
PCB         -64.53  -12.00  40.53        (----------*---------)
WFA         -63.53  -11.00  41.53        (----------*---------)
WFB         -76.53  -24.00  28.53      (---------*----------)
                                   ---------+---------+---------+---------+
                                          -50         0        50       100


Collection = PCB subtracted from:

Collection   Lower  Center  Upper  ---------+---------+---------+---------+
WFA         -51.53    1.00  53.53           (---------*----------)
WFB         -64.53  -12.00  40.53        (----------*---------)
                                   ---------+---------+---------+---------+
                                          -50         0        50       100


Collection = WFA subtracted from:

Collection   Lower  Center  Upper  ---------+---------+---------+---------+
WFB         -65.53  -13.00  39.53        (---------*----------)
                                   ---------+---------+---------+---------+
                                          -50         0        50       10
```

Table C7. Combined nitrate and nitrite general linear model, one way ANOVA and Tukey's multiple comparison test

General Linear Model: Nitrates/Nitrites versus Site, Event

```
Factor  Type   Levels  Values
Site    fixed       8  Cedar Bayou near Crosby, Clear Creek @ State 35,
                       Dickinson Bayou @ 517, Greeens bayou, Lake Creek near
                       Egypt, Little Cypress Creek, Peach Creek, West Fork of
                       the San Jacinto
Event   fixed       2  A, B


Analysis of Variance for Nitrates/Nitrites, using Adjusted SS for Tests

Source      DF    Seq SS    Adj SS    Adj MS       F      P
Site         7  0.138841  0.138841  0.019834   49.24  0.000
Event        1  0.063220  0.063220  0.063220  156.96  0.000
Site*Event   7  0.078821  0.078821  0.011260   27.96  0.000
Error       32  0.012889  0.012889  0.000403
Total       47  0.293770


S = 0.0200692   R-Sq = 95.61%   R-Sq(adj) = 93.56%


Unusual Observations for Nitrates/Nitrites

Obs  Nitrates/Nitrites       Fit    SE Fit   Residual  St Resid
 26           0.140000  0.106667  0.011587   0.033333      2.03 R
 28           0.320000  0.273333  0.011587   0.046667      2.85 R
 31           0.180000  0.140000  0.011587   0.040000      2.44 R
 39           0.090000  0.140000  0.011587  -0.050000     -3.05 R

R denotes an observation with a large standardized residual.
```

One-way ANOVA: Nitrates and Nitrites (mg/L) versus Collection

```
Source      DF        SS       MS       F      P
Collection  15  46.57379  3.10492  400.60  0.000
Error       32   0.24802  0.00775
Total       47  46.82181

S = 0.08804   R-Sq = 99.47%   R-Sq(adj) = 99.22%


                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level  N    Mean   StDev   -+---------+---------+---------+--------
CBA    3  0.0033  0.0058   (*)
CBB    3  0.1667  0.0153     *)
CCA    3  0.1467  0.0058    (*)
CCB    3  0.1067  0.0289    (*)
DBA    3  0.0000  0.0000   (*)
DBB    3  0.0033  0.0058   (*)
GBA    3  4.1533  0.2887                                    (*
GBB    3  0.1207  0.0307    (*)
LCA    3  0.0000  0.0000   (*)
LCB    3  0.0133  0.0058   (*)
```

```
LCCA   3  0.0333  0.0577   (*)
LCCB   3  0.0000  0.0000   (*)
PCA    3  0.4433  0.1528       (*)
PCB    3  0.1400  0.0458    (*)
WFA    3  0.3467  0.0902      (*)
WFB    3  0.2733  0.0404     (*)
                           -+---------+---------+---------+--------
                          0.0       1.2       2.4       3.6
```

Pooled StDev = 0.0880

Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Collection

Individual confidence level = 99.92%

Collection = CBA subtracted from:

```
Collection    Lower   Center   Upper  --------+---------+---------+---------+-
CBB         -0.1030   0.1633  0.4297                    (*)
CCA         -0.1230   0.1433  0.4097                    (*)
CCB         -0.1630   0.1033  0.3697                   (*)
DBA         -0.2697  -0.0033  0.2630                   (*)
DBB         -0.2663   0.0000  0.2663                   (*)
GBA          3.8837   4.1500  4.4163                                    (*)
GBB         -0.1490   0.1173  0.3837                   (*-)
LCA         -0.2697  -0.0033  0.2630                   (*)
LCB         -0.2563   0.0100  0.2763                   (*)
LCCA        -0.2363   0.0300  0.2963                   (*)
LCCB        -0.2697  -0.0033  0.2630                   (*)
PCA          0.1737   0.4400  0.7063                     (*)
PCB         -0.1297   0.1367  0.4030                   (-*)
WFA          0.0770   0.3433  0.6097                    (*)
WFB          0.0037   0.2700  0.5363                    (*)
                                      --------+---------+---------+---------+-
                                           -2.5       0.0       2.5       5.0
```

Collection = CBB subtracted from:

```
Collection    Lower   Center   Upper  --------+---------+---------+---------+-
CCA         -0.2863  -0.0200  0.2463                   (*)
CCB         -0.3263  -0.0600  0.2063                   (*)
DBA         -0.4330  -0.1667  0.0997                  (*)
DBB         -0.4297  -0.1633  0.1030                  (*)
GBA          3.7203   3.9867  4.2530                                   (*)
GBB         -0.3123  -0.0460  0.2203                   (*)
LCA         -0.4330  -0.1667  0.0997                  (*)
LCB         -0.4197  -0.1533  0.1130                  (*)
LCCA        -0.3997  -0.1333  0.1330                  (*-)
LCCB        -0.4330  -0.1667  0.0997                  (*)
PCA          0.0103   0.2767  0.5430                    (*)
PCB         -0.2930  -0.0267  0.2397                   (*)
WFA         -0.0863   0.1800  0.4463                    (*)
WFB         -0.1597   0.1067  0.3730                   (*)
                                      --------+---------+---------+---------+-
                                           -2.5       0.0       2.5       5.0
```

Collection = CCA subtracted from:

```
Collection    Lower   Center   Upper  --------+---------+---------+---------+-
CCB         -0.3063  -0.0400  0.2263                   (*)
DBA         -0.4130  -0.1467  0.1197                  (*)
DBB         -0.4097  -0.1433  0.1230                  (*)
GBA          3.7403   4.0067  4.2730                                    (*)
GBB         -0.2923  -0.0260  0.2403                   (*)
LCA         -0.4130  -0.1467  0.1197                  (*)
LCB         -0.3997  -0.1333  0.1330                  (*-)
LCCA        -0.3797  -0.1133  0.1530                  (-*)
LCCB        -0.4130  -0.1467  0.1197                  (*)
PCA          0.0303   0.2967  0.5630                    (*)
PCB         -0.2730  -0.0067  0.2597                   (*)
WFA         -0.0663   0.2000  0.4663                    (*)
WFB         -0.1397   0.1267  0.3930                   (-*)
                                      --------+---------+---------+---------+-
                                           -2.5       0.0       2.5       5.0
```

Collection = CCB subtracted from:

```
Collection    Lower   Center   Upper  --------+---------+---------+---------+-
DBA         -0.3730  -0.1067  0.1597                   (*)
DBB         -0.3697  -0.1033  0.1630                   (*)
GBA          3.7803   4.0467  4.3130                                    (*)
GBB         -0.2523   0.0140  0.2803                   (*)
LCA         -0.3730  -0.1067  0.1597                   (*)
LCB         -0.3597  -0.0933  0.1730                   (*)
LCCA        -0.3397  -0.0733  0.1930                   (*)
LCCB        -0.3730  -0.1067  0.1597                   (*)
PCA          0.0703   0.3367  0.6030                    (*)
PCB         -0.2330   0.0333  0.2997                   (*)
WFA         -0.0263   0.2400  0.5063                    (*)
WFB         -0.0997   0.1667  0.4330                    (*)
                                      --------+---------+---------+---------+-
                                           -2.5       0.0       2.5       5.0
```

Collection = DBA subtracted from:

```
Collection    Lower  Center   Upper  --------+---------+---------+---------+-
DBB         -0.2630  0.0033  0.2697                   (*)
GBA          3.8870  4.1533  4.4197                                    (*)
GBB         -0.1457  0.1207  0.3870                   (*-)
LCA         -0.2663  0.0000  0.2663                   (*)
LCB         -0.2530  0.0133  0.2797                   (*)
LCCA        -0.2330  0.0333  0.2997                   (*)
LCCB        -0.2663  0.0000  0.2663                   (*)
PCA          0.1770  0.4433  0.7097                     (*)
PCB         -0.1263  0.1400  0.4063                   (-*)
WFA          0.0803  0.3467  0.6130                    (*)
WFB          0.0070  0.2733  0.5397                    (*)
                                     --------+---------+---------+---------+-
                                          -2.5       0.0       2.5       5.0
```

Collection = DBB subtracted from:

```
Collection    Lower   Center   Upper  --------+---------+---------+---------+-
GBA          3.8837   4.1500  4.4163                                     (*)
GBB         -0.1490   0.1173  0.3837                   (*-)
LCA         -0.2697  -0.0033  0.2630                   (*)
LCB         -0.2563   0.0100  0.2763                   (*)
LCCA        -0.2363   0.0300  0.2963                   (*)
```

```
LCCB        -0.2697  -0.0033  0.2630                  (*)
PCA          0.1737   0.4400  0.7063                    (*)
PCB         -0.1297   0.1367  0.4030                  (-*)
WFA          0.0770   0.3433  0.6097                   (*)
WFB          0.0037   0.2700  0.5363                   (*)
                                      --------+---------+---------+---------+-
                                           -2.5       0.0       2.5       5.0


Collection = GBA subtracted from:

Collection    Lower   Center    Upper  --------+---------+---------+---------+-
GBB         -4.2990  -4.0327  -3.7663   (*)
LCA         -4.4197  -4.1533  -3.8870  (*)
LCB         -4.4063  -4.1400  -3.8737  (*-)
LCCA        -4.3863  -4.1200  -3.8537  (-*)
LCCB        -4.4197  -4.1533  -3.8870  (*)
PCA         -3.9763  -3.7100  -3.4437    (*)
PCB         -4.2797  -4.0133  -3.7470   (*)
WFA         -4.0730  -3.8067  -3.5403    (*)
WFB         -4.1463  -3.8800  -3.6137   (*-)
                                       --------+---------+---------+---------+-
                                            -2.5       0.0       2.5       5.0


Collection = GBB subtracted from:

Collection    Lower   Center   Upper  --------+---------+---------+---------+-
LCA         -0.3870  -0.1207  0.1457                 (-*)
LCB         -0.3737  -0.1073  0.1590                  (*)
LCCA        -0.3537  -0.0873  0.1790                  (*)
LCCB        -0.3870  -0.1207  0.1457                 (-*)
PCA          0.0563   0.3227  0.5890                   (*)
PCB         -0.2470   0.0193  0.2857                  (*)
WFA         -0.0403   0.2260  0.4923                   (*)
WFB         -0.1137   0.1527  0.4190                   (*)
                                      --------+---------+---------+---------+-
                                           -2.5       0.0       2.5       5.0


Collection = LCA subtracted from:

Collection    Lower  Center   Upper  --------+---------+---------+---------+-
LCB         -0.2530  0.0133  0.2797                 (*)
LCCA        -0.2330  0.0333  0.2997                 (*)
LCCB        -0.2663  0.0000  0.2663                 (*)
PCA          0.1770  0.4433  0.7097                   (*)
PCB         -0.1263  0.1400  0.4063                 (-*)
WFA          0.0803  0.3467  0.6130                  (*)
WFB          0.0070  0.2733  0.5397                  (*)
                                     --------+---------+---------+---------+-
                                          -2.5       0.0       2.5       5.0


Collection = LCB subtracted from:

Collection    Lower   Center   Upper  --------+---------+---------+---------+-
LCCA        -0.2463   0.0200  0.2863                  (*)
LCCB        -0.2797  -0.0133  0.2530                  (*)
PCA          0.1637   0.4300  0.6963                    (*)
PCB         -0.1397   0.1267  0.3930                  (-*)
WFA          0.0670   0.3333  0.5997                   (*)
WFB         -0.0063   0.2600  0.5263                   (*)
```

```
                                          --------+---------+---------+---------+-
                                              -2.5       0.0       2.5       5.0


Collection = LCCA subtracted from:

Collection    Lower   Center   Upper  --------+---------+---------+---------+-
LCCB        -0.2997  -0.0333  0.2330                  (*)
PCA          0.1437   0.4100  0.6763                    (*)
PCB         -0.1597   0.1067  0.3730                  (*)
WFA          0.0470   0.3133  0.5797                   (*)
WFB         -0.0263   0.2400  0.5063                   (*)
                                      --------+---------+---------+---------+-
                                          -2.5       0.0       2.5       5.0


Collection = LCCB subtracted from:

Collection    Lower  Center   Upper  --------+---------+---------+---------+-
PCA          0.1770  0.4433  0.7097                   (*)
PCB         -0.1263  0.1400  0.4063                 (-*)
WFA          0.0803  0.3467  0.6130                  (*)
WFB          0.0070  0.2733  0.5397                  (*)
                                     --------+---------+---------+---------+-
                                         -2.5       0.0       2.5       5.0


Collection = PCA subtracted from:

Collection    Lower   Center    Upper  --------+---------+---------+---------+-
PCB         -0.5697  -0.3033  -0.0370                (*)
WFA         -0.3630  -0.0967   0.1697                 (*)
WFB         -0.4363  -0.1700   0.0963                (*)
                                       --------+---------+---------+---------+-
                                           -2.5       0.0       2.5       5.0


Collection = PCB subtracted from:

Collection    Lower  Center   Upper  --------+---------+---------+---------+-
WFA         -0.0597  0.2067  0.4730                  (*)
WFB         -0.1330  0.1333  0.3997                 (-*)
                                     --------+---------+---------+---------+-
                                         -2.5       0.0       2.5       5.0


Collection = WFA subtracted from:

Collection    Lower   Center   Upper  --------+---------+---------+---------+-
WFB         -0.3397  -0.0733  0.1930                  (*)
                                      --------+---------+---------+---------+-
                                          -2.5       0.0       2.5       5.0
```

Table C8. Ammonia general linear model, one way ANOVA and Tukey's multiple comparison test

General Linear Model: NH4 versus Site, Event

```
Factor   Type   Levels  Values
Site     fixed       8  Cedar Bayou near Crosby, Clear Creek @ State 35,
                        Dickinson Bayou @ 517, Greeens bayou, Lake Creek near
                        Egypt, Little Cypress Creek, Peach Creek, West Fork of
                        the San Jacinto
Event    fixed       2  A, B


Analysis of Variance for NH4, using Adjusted SS for Tests

Source      DF    Seq SS    Adj SS    Adj MS       F      P
Site         7  0.120731  0.120731  0.017247  118.27  0.000
Event        1  0.077602  0.077602  0.077602  532.13  0.000
Site*Event   7  0.144681  0.144681  0.020669  141.73  0.000
Error       32  0.004667  0.004667  0.000146
Total       47  0.347681


S = 0.0120761   R-Sq = 98.66%   R-Sq(adj) = 98.03%


Unusual Observations for NH4

Obs       NH4       Fit    SE Fit   Residual  St Resid
 14  0.080000  0.100000  0.006972  -0.020000     -2.03 R
 22  0.120000  0.100000  0.006972   0.020000      2.03 R
 31  0.100000  0.073333  0.006972   0.026667      2.70 R
 45  0.350000  0.330000  0.006972   0.020000      2.03 R
 47  0.050000  0.073333  0.006972  -0.023333     -2.37 R

R denotes an observation with a large standardized residual.
```

One-way ANOVA: NH4 versus Collection

```
Source      DF        SS        MS       F      P
Collection  15  0.343015  0.022868  156.81  0.000
Error       32  0.004667  0.000146
Total       47  0.347681

S = 0.01208   R-Sq = 98.66%   R-Sq(adj) = 98.03%


                            Individual 95% CIs For Mean Based on
                            Pooled StDev
Level  N     Mean    StDev   -+---------+---------+---------+--------
CBA    3  0.00000  0.00000   (*)
CBB    3  0.09333  0.01155            (*-)
CCA    3  0.03000  0.01000      (*)
CCB    3  0.03333  0.00577      (*-)
DBA    3  0.00000  0.00000   (*)
DBB    3  0.03333  0.01528      (*-)
GBA    3  0.10000  0.02000             (*)
GBB    3  0.08667  0.01528           (-*)
LCA    3  0.00000  0.00000   (*)
LCB    3  0.33000  0.01732                                 (*)
```

```
LCCA   3  0.01000  0.01000    (*)
LCCB   3  0.02667  0.00577     (-*)
PCA    3  0.06333  0.00577         (*-)
PCB    3  0.07333  0.02517          (*-)
WFA    3  0.04000  0.00000       (*)
WFB    3  0.21000  0.01000                        (*)
                             -+---------+---------+---------+--------
                            0.00      0.10      0.20      0.30

Pooled StDev = 0.01208


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Collection

Individual confidence level = 99.92%


Collection = CBA subtracted from:

Collection     Lower   Center    Upper
CBB          0.05680  0.09333  0.12987
CCA         -0.00653  0.03000  0.06653
CCB         -0.00320  0.03333  0.06987
DBA         -0.03653  0.00000  0.03653
DBB         -0.00320  0.03333  0.06987
GBA          0.06347  0.10000  0.13653
GBB          0.05013  0.08667  0.12320
LCA         -0.03653  0.00000  0.03653
LCB          0.29347  0.33000  0.36653
LCCA        -0.02653  0.01000  0.04653
LCCB        -0.00987  0.02667  0.06320
PCA          0.02680  0.06333  0.09987
PCB          0.03680  0.07333  0.10987
WFA          0.00347  0.04000  0.07653
WFB          0.17347  0.21000  0.24653

Collection  --------+---------+---------+---------+-
CBB                              (-*)
CCA                           (-*)
CCB                           (-*)
DBA                         (-*-)
DBB                           (-*)
GBA                              (-*-)
GBB                              (*-)
LCA                         (-*-)
LCB                                          (-*)
LCCA                         (-*)
LCCB                          (*-)
PCA                            (-*-)
PCB                             (-*)
WFA                           (-*-)
WFB                                    (-*)
            --------+---------+---------+---------+-
                 -0.20      0.00      0.20      0.40


Collection = CBB subtracted from:

Collection     Lower    Center     Upper
CCA         -0.09987  -0.06333  -0.02680
CCB         -0.09653  -0.06000  -0.02347
DBA         -0.12987  -0.09333  -0.05680
```

DBB	-0.09653	-0.06000	-0.02347
GBA	-0.02987	0.00667	0.04320
GBB	-0.04320	-0.00667	0.02987
LCA	-0.12987	-0.09333	-0.05680
LCB	0.20013	0.23667	0.27320
LCCA	-0.11987	-0.08333	-0.04680
LCCB	-0.10320	-0.06667	-0.03013
PCA	-0.06653	-0.03000	0.00653
PCB	-0.05653	-0.02000	0.01653
WFA	-0.08987	-0.05333	-0.01680
WFB	0.08013	0.11667	0.15320

```
Collection  --------+---------+---------+---------+-
CCA                      (-*-)
CCB                      (-*-)
DBA                     (*-)
DBB                      (-*-)
GBA                          (*-)
GBB                         (-*)
LCA                     (*-)
LCB                                     (-*-)
LCCA                    (-*-)
LCCB                     (-*)
PCA                        (*-)
PCB                        (-*-)
WFA                       (*-)
WFB                               (-*-)
            --------+---------+---------+---------+-
                 -0.20      0.00      0.20      0.40
```

Collection = CCA subtracted from:

Collection	Lower	Center	Upper
CCB	-0.03320	0.00333	0.03987
DBA	-0.06653	-0.03000	0.00653
DBB	-0.03320	0.00333	0.03987
GBA	0.03347	0.07000	0.10653
GBB	0.02013	0.05667	0.09320
LCA	-0.06653	-0.03000	0.00653
LCB	0.26347	0.30000	0.33653
LCCA	-0.05653	-0.02000	0.01653
LCCB	-0.03987	-0.00333	0.03320
PCA	-0.00320	0.03333	0.06987
PCB	0.00680	0.04333	0.07987
WFA	-0.02653	0.01000	0.04653
WFB	0.14347	0.18000	0.21653

```
Collection  --------+---------+---------+---------+-
CCB                         (-*-)
DBA                        (*-)
DBB                         (-*-)
GBA                             (-*)
GBB                            (-*-)
LCA                        (*-)
LCB                                        (-*-)
LCCA                       (-*-)
LCCB                        (-*-)
PCA                           (-*)
PCB                           (-*-)
WFA                          (-*)
WFB                                  (-*-)
            --------+---------+---------+---------+-
```

```
                 -0.20      0.00      0.20      0.40


Collection = CCB subtracted from:

Collection     Lower    Center    Upper
DBA         -0.06987  -0.03333  0.00320
DBB         -0.03653   0.00000  0.03653
GBA          0.03013   0.06667  0.10320
GBB          0.01680   0.05333  0.08987
LCA         -0.06987  -0.03333  0.00320
LCB          0.26013   0.29667  0.33320
LCCA        -0.05987  -0.02333  0.01320
LCCB        -0.04320  -0.00667  0.02987
PCA         -0.00653   0.03000  0.06653
PCB          0.00347   0.04000  0.07653
WFA         -0.02987   0.00667  0.04320
WFB          0.14013   0.17667  0.21320

Collection  --------+---------+---------+---------+-
DBA                        (*-)
DBB                         (-*-)
GBA                             (*-)
GBB                            (-*)
LCA                        (*-)
LCB                                        (-*-)
LCCA                       (-*-)
LCCB                        (-*)
PCA                           (-*)
PCB                           (-*-)
WFA                          (*-)
WFB                                  (-*-)
            --------+---------+---------+---------+-
                 -0.20      0.00      0.20      0.40


Collection = DBA subtracted from:

Collection     Lower   Center    Upper
DBB         -0.00320  0.03333  0.06987
GBA          0.06347  0.10000  0.13653
GBB          0.05013  0.08667  0.12320
LCA         -0.03653  0.00000  0.03653
LCB          0.29347  0.33000  0.36653
LCCA        -0.02653  0.01000  0.04653
LCCB        -0.00987  0.02667  0.06320
PCA          0.02680  0.06333  0.09987
PCB          0.03680  0.07333  0.10987
WFA          0.00347  0.04000  0.07653
WFB          0.17347  0.21000  0.24653

Collection  --------+---------+---------+---------+-
DBB                           (-*)
GBA                              (-*-)
GBB                              (*-)
LCA                         (-*-)
LCB                                          (-*)
LCCA                         (-*)
LCCB                          (*-)
PCA                            (-*-)
PCB                             (-*)
WFA                           (-*-)
WFB                                    (-*)
```

```
            --------+---------+---------+---------+-
                 -0.20      0.00      0.20      0.40
```

Collection = DBB subtracted from:

Collection	Lower	Center	Upper
GBA	0.03013	0.06667	0.10320
GBB	0.01680	0.05333	0.08987
LCA	-0.06987	-0.03333	0.00320
LCB	0.26013	0.29667	0.33320
LCCA	-0.05987	-0.02333	0.01320
LCCB	-0.04320	-0.00667	0.02987
PCA	-0.00653	0.03000	0.06653
PCB	0.00347	0.04000	0.07653
WFA	-0.02987	0.00667	0.04320
WFB	0.14013	0.17667	0.21320

```
Collection  --------+---------+---------+---------+-
GBA                             (*-)
GBB                            (-*)
LCA                        (*-)
LCB                                        (-*-)
LCCA                       (-*-)
LCCB                        (-*)
PCA                           (-*)
PCB                           (-*-)
WFA                          (*-)
WFB                                  (-*-)
            --------+---------+---------+---------+-
                 -0.20      0.00      0.20      0.40
```

Collection = GBA subtracted from:

Collection	Lower	Center	Upper
GBB	-0.04987	-0.01333	0.02320
LCA	-0.13653	-0.10000	-0.06347
LCB	0.19347	0.23000	0.26653
LCCA	-0.12653	-0.09000	-0.05347
LCCB	-0.10987	-0.07333	-0.03680
PCA	-0.07320	-0.03667	-0.00013
PCB	-0.06320	-0.02667	0.00987
WFA	-0.09653	-0.06000	-0.02347
WFB	0.07347	0.11000	0.14653

```
Collection  --------+---------+---------+---------+-
GBB                         (*-)
LCA                    (-*-)
LCB                                     (-*)
LCCA                    (-*)
LCCB                     (*-)
PCA                       (-*-)
PCB                        (-*)
WFA                      (-*-)
WFB                               (-*)
            --------+---------+---------+---------+-
                 -0.20      0.00      0.20      0.40
```

Collection = GBB subtracted from:

Collection	Lower	Center	Upper

```
LCA         -0.12320  -0.08667  -0.05013
LCB          0.20680   0.24333   0.27987
LCCA        -0.11320  -0.07667  -0.04013
LCCB        -0.09653  -0.06000  -0.02347
PCA         -0.05987  -0.02333   0.01320
PCB         -0.04987  -0.01333   0.02320
WFA         -0.08320  -0.04667  -0.01013
WFB          0.08680   0.12333   0.15987

Collection  --------+---------+---------+---------+-
LCA                     (-*)
LCB                                     (-*-)
LCCA                    (-*-)
LCCB                     (-*-)
PCA                        (-*-)
PCB                         (*-)
WFA                       (-*)
WFB                               (-*-)
            --------+---------+---------+---------+-
                 -0.20      0.00      0.20      0.40


Collection = LCA subtracted from:

Collection     Lower   Center    Upper
LCB          0.29347  0.33000  0.36653
LCCA        -0.02653  0.01000  0.04653
LCCB        -0.00987  0.02667  0.06320
PCA          0.02680  0.06333  0.09987
PCB          0.03680  0.07333  0.10987
WFA          0.00347  0.04000  0.07653
WFB          0.17347  0.21000  0.24653

Collection  --------+---------+---------+---------+-
LCB                                          (-*)
LCCA                         (-*)
LCCB                          (*-)
PCA                            (-*-)
PCB                             (-*)
WFA                           (-*-)
WFB                                    (-*)
            --------+---------+---------+---------+-
                 -0.20      0.00      0.20      0.40


Collection = LCB subtracted from:

Collection     Lower    Center     Upper
LCCA        -0.35653  -0.32000  -0.28347
LCCB        -0.33987  -0.30333  -0.26680
PCA         -0.30320  -0.26667  -0.23013
PCB         -0.29320  -0.25667  -0.22013
WFA         -0.32653  -0.29000  -0.25347
WFB         -0.15653  -0.12000  -0.08347

Collection  --------+---------+---------+---------+-
LCCA        (-*-)
LCCB         (-*-)
PCA            (-*)
PCB            (-*-)
WFA           (*-)
WFB                   (-*-)
            --------+---------+---------+---------+-
```

```
                 -0.20      0.00      0.20      0.40


Collection = LCCA subtracted from:

Collection     Lower   Center    Upper
LCCB        -0.01987  0.01667  0.05320
PCA          0.01680  0.05333  0.08987
PCB          0.02680  0.06333  0.09987
WFA         -0.00653  0.03000  0.06653
WFB          0.16347  0.20000  0.23653

Collection  --------+---------+---------+---------+-
LCCB                         (-*-)
PCA                            (-*)
PCB                            (-*-)
WFA                           (-*)
WFB                                   (-*-)
            --------+---------+---------+---------+-
                 -0.20      0.00      0.20      0.40


Collection = LCCB subtracted from:

Collection     Lower   Center    Upper
PCA          0.00013  0.03667  0.07320
PCB          0.01013  0.04667  0.08320
WFA         -0.02320  0.01333  0.04987
WFB          0.14680  0.18333  0.21987

Collection  --------+---------+---------+---------+-
PCA                           (-*-)
PCB                            (*-)
WFA                          (-*)
WFB                                  (-*-)
            --------+---------+---------+---------+-
                 -0.20      0.00      0.20      0.40


Collection = PCA subtracted from:

Collection     Lower    Center    Upper
PCB         -0.02653   0.01000  0.04653
WFA         -0.05987  -0.02333  0.01320
WFB          0.11013   0.14667  0.18320

Collection  --------+---------+---------+---------+-
PCB                          (-*)
WFA                        (-*-)
WFB                                 (*-)
            --------+---------+---------+---------+-
                 -0.20      0.00      0.20      0.40


Collection = PCB subtracted from:

Collection     Lower    Center    Upper
WFA         -0.06987  -0.03333  0.00320
WFB          0.10013   0.13667  0.17320

Collection  --------+---------+---------+---------+-
WFA                        (*-)
WFB                                (-*-)
```

```
            --------+---------+---------+---------+-
                 -0.20      0.00      0.20      0.40


Collection = WFA subtracted from:

Collection    Lower   Center    Upper  --------+---------+---------+---------+-
WFB         0.13347  0.17000  0.20653                              (-*)
                                       --------+---------+---------+---------+-
                                            -0.20      0.00      0.20      0.40
```

Table C9. Orthophosphate general linear model, one way ANOVA and Tukey's multiple comparison test

General Linear Model: Orthophosphates versus Site, Event

Factor	Type	Levels	Values
Site	fixed	8	Cedar Bayou near Crosby, Clear Creek @ State 35, Dickinson Bayou @ 517, Greeens bayou, Lake Creek near Egypt, Little Cypress Creek, Peach Creek, West Fork of the San Jacinto
Event	fixed	2	A, B

Analysis of Variance for Orthophosphates, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Site	7	159.711	159.711	22.816	324.10	0.000
Event	1	1.484	1.484	1.484	21.08	0.000
Site*Event	7	5.595	5.595	0.799	11.35	0.000
Error	32	2.253	2.253	0.070		
Total	47	169.043				

S = 0.265325   R-Sq = 98.67%   R-Sq(adj) = 98.04%

Unusual Observations for Orthophosphates

Obs	Orthophosphates	Fit	SE Fit	Residual	St Resid	
20	4.32000	4.77000	0.15319	-0.45000	-2.08	R
28	4.28000	4.78000	0.15319	-0.50000	-2.31	R
35	1.10000	1.59667	0.15319	-0.49667	-2.29	R
43	2.21000	1.59667	0.15319	0.61333	2.83	R

R denotes an observation with a large standardized residual.

One-way ANOVA: Orthophosphates versus Collection

Source	DF	SS	MS	F	P
Collection	15	166.7900	11.1193	157.95	0.000
Error	32	2.2527	0.0704		
Total	47	169.0427			

S = 0.2653   R-Sq = 98.67%   R-Sq(adj) = 98.04%

```
                          Individual 95% CIs For Mean Based on Pooled StDev
Level  N    Mean   StDev   -+---------+---------+---------+--------
CBA    3  0.2033  0.0802   (-*-)
CBB    3  1.5967  0.5641            (-*-)
CCA    3  3.7900  0.2771                          (-*-)
CCB    3  4.0467  0.2139                           (-*-)
DBA    3  0.9867  0.2454        (-*-)
DBB    3  1.0133  0.1258        (-*-)
GBA    3  5.9200  0.1153                                       (-*-)
GBB    3  4.8667  0.2810                                (-*-)
LCA    3  0.2233  0.1007   (-*-)
LCB    3  0.8467  0.3101       (-*-)
LCCA   3  1.7300  0.0624             (-*-)
LCCB   3  2.4800  0.2261                  (*-)
```

```
PCA    3  0.5967  0.0666      (-*-)
PCB    3  1.4033  0.0252           (-*-)
WFA    3  4.7700  0.3900                                (-*-)
WFB    3  4.7800  0.4386                                (-*-)
                           -+---------+---------+---------+--------
                           0.0       1.6       3.2       4.8

Pooled StDev = 0.2653


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Collection

Individual confidence level = 99.92%


Collection = CBA subtracted from:

Collection    Lower  Center   Upper  ---------+---------+---------+---------+
CBB          0.5906  1.3933  2.1960                      (-*-)
CCA          2.7840  3.5867  4.3894                            (-*--)
CCB          3.0406  3.8433  4.6460                             (-*-)
DBA         -0.0194  0.7833  1.5860                    (-*--)
DBB          0.0073  0.8100  1.6127                    (-*--)
GBA          4.9140  5.7167  6.5194                                  (-*--)
GBB          3.8606  4.6633  5.4660                               (-*--)
LCA         -0.7827  0.0200  0.8227                  (-*-)
LCB         -0.1594  0.6433  1.4460                    (-*-)
LCCA         0.7240  1.5267  2.3294                      (-*--)
LCCB         1.4740  2.2767  3.0794                        (--*-)
PCA         -0.4094  0.3933  1.1960                   (-*-)
PCB          0.3973  1.2000  2.0027                     (-*--)
WFA          3.7640  4.5667  5.3694                               (-*-)
WFB          3.7740  4.5767  5.3794                               (-*-)
                                     ---------+---------+---------+---------+
                                           -3.5       0.0       3.5       7.0


Collection = CBB subtracted from:

Collection    Lower   Center    Upper  ---------+---------+---------+---------+
CCA          1.3906   2.1933   2.9960                        (-*--)
CCB          1.6473   2.4500   3.2527                         (-*-)
DBA         -1.4127  -0.6100   0.1927                (-*--)
DBB         -1.3860  -0.5833   0.2194                (-*--)
GBA          3.5206   4.3233   5.1260                              (-*--)
GBB          2.4673   3.2700   4.0727                           (-*--)
LCA         -2.1760  -1.3733  -0.5706              (-*-)
LCB         -1.5527  -0.7500   0.0527                (-*-)
LCCA        -0.6694   0.1333   0.9360                  (-*--)
LCCB         0.0806   0.8833   1.6860                    (--*-)
PCA         -1.8027  -1.0000  -0.1973               (-*-)
PCB         -0.9960  -0.1933   0.6094                 (-*--)
WFA          2.3706   3.1733   3.9760                           (-*-)
WFB          2.3806   3.1833   3.9860                           (-*-)
                                       ---------+---------+---------+---------+
                                             -3.5       0.0       3.5       7.0


Collection = CCA subtracted from:

Collection    Lower   Center    Upper  ---------+---------+---------+---------+
CCB         -0.5460   0.2567   1.0594                  (--*-)
```

```
DBA         -3.6060  -2.8033  -2.0006           (-*-)
DBB         -3.5794  -2.7767  -1.9740           (-*-)
GBA          1.3273   2.1300   2.9327                         (-*-)
GBB          0.2740   1.0767   1.8794                      (-*-)
LCA         -4.3694  -3.5667  -2.7640         (-*-)
LCB         -3.7460  -2.9433  -2.1406          (--*-)
LCCA        -2.8627  -2.0600  -1.2573             (-*-)
LCCB        -2.1127  -1.3100  -0.5073               (-*--)
PCA         -3.9960  -3.1933  -2.3906          (-*-)
PCB         -3.1894  -2.3867  -1.5840            (-*-)
WFA          0.1773   0.9800   1.7827                      (-*-)
WFB          0.1873   0.9900   1.7927                      (-*-)
                                       ---------+---------+---------+---------+
                                             -3.5       0.0       3.5       7.0


Collection = CCB subtracted from:

Collection    Lower   Center    Upper  ---------+---------+---------+---------+
DBA         -3.8627  -3.0600  -2.2573          (-*--)
DBB         -3.8360  -3.0333  -2.2306          (-*--)
GBA          1.0706   1.8733   2.6760                        (-*--)
GBB          0.0173   0.8200   1.6227                     (-*--)
LCA         -4.6260  -3.8233  -3.0206        (-*-)
LCB         -4.0027  -3.2000  -2.3973          (-*-)
LCCA        -3.1194  -2.3167  -1.5140            (-*--)
LCCB        -2.3694  -1.5667  -0.7640              (--*-)
PCA         -4.2527  -3.4500  -2.6473         (-*-)
PCB         -3.4460  -2.6433  -1.8406           (-*--)
WFA         -0.0794   0.7233   1.5260                     (-*-)
WFB         -0.0694   0.7333   1.5360                     (-*-)
                                       ---------+---------+---------+---------+
                                             -3.5       0.0       3.5       7.0


Collection = DBA subtracted from:

Collection    Lower   Center   Upper  ---------+---------+---------+---------+
DBB         -0.7760   0.0267  0.8294                   (-*-)
GBA          4.1306   4.9333  5.7360                                 (-*-)
GBB          3.0773   3.8800  4.6827                              (-*-)
LCA         -1.5660  -0.7633  0.0394                 (-*-)
LCB         -0.9427  -0.1400  0.6627                  (--*-)
LCCA        -0.0594   0.7433  1.5460                     (-*-)
LCCB         0.6906   1.4933  2.2960                       (-*--)
PCA         -1.1927  -0.3900  0.4127                  (-*-)
PCB         -0.3860   0.4167  1.2194                    (-*-)
WFA          2.9806   3.7833  4.5860                              (-*-)
WFB          2.9906   3.7933  4.5960                              (-*-)
                                      ---------+---------+---------+---------+
                                            -3.5       0.0       3.5       7.0


Collection = DBB subtracted from:

Collection    Lower   Center   Upper  ---------+---------+---------+---------+
GBA          4.1040   4.9067  5.7094                                 (-*-)
GBB          3.0506   3.8533  4.6560                              (-*-)
LCA         -1.5927  -0.7900  0.0127                (--*-)
LCB         -0.9694  -0.1667  0.6360                  (--*-)
LCCA        -0.0860   0.7167  1.5194                     (-*-)
LCCB         0.6640   1.4667  2.2694                       (-*-)
PCA         -1.2194  -0.4167  0.3860                  (-*-)
```

```
PCB         -0.4127   0.3900  1.1927                    (-*-)
WFA          2.9540   3.7567  4.5594                             (--*-)
WFB          2.9640   3.7667  4.5694                             (--*-)
                                      ---------+---------+---------+---------+
                                            -3.5       0.0       3.5       7.0


Collection = GBA subtracted from:

Collection    Lower   Center    Upper  ---------+---------+---------+---------+
GBB         -1.8560  -1.0533  -0.2506                (-*-)
LCA         -6.4994  -5.6967  -4.8940  (--*-)
LCB         -5.8760  -5.0733  -4.2706    (--*-)
LCCA        -4.9927  -4.1900  -3.3873       (-*-)
LCCB        -4.2427  -3.4400  -2.6373         (-*-)
PCA         -6.1260  -5.3233  -4.5206   (--*-)
PCB         -5.3194  -4.5167  -3.7140      (-*-)
WFA         -1.9527  -1.1500  -0.3473               (--*-)
WFB         -1.9427  -1.1400  -0.3373               (--*-)
                                       ---------+---------+---------+---------+
                                             -3.5       0.0       3.5       7.0


Collection = GBB subtracted from:

Collection    Lower   Center    Upper  ---------+---------+---------+---------+
LCA         -5.4460  -4.6433  -3.8406     (--*-)
LCB         -4.8227  -4.0200  -3.2173       (--*-)
LCCA        -3.9394  -3.1367  -2.3340          (-*-)
LCCB        -3.1894  -2.3867  -1.5840            (-*-)
PCA         -5.0727  -4.2700  -3.4673       (-*-)
PCB         -4.2660  -3.4633  -2.6606         (-*-)
WFA         -0.8994  -0.0967   0.7060                  (--*-)
WFB         -0.8894  -0.0867   0.7160                  (--*-)
                                       ---------+---------+---------+---------+
                                             -3.5       0.0       3.5       7.0


Collection = LCA subtracted from:

Collection    Lower  Center   Upper  ---------+---------+---------+---------+
LCB         -0.1794  0.6233  1.4260                    (--*-)
LCCA         0.7040  1.5067  2.3094                       (-*--)
LCCB         1.4540  2.2567  3.0594                         (-*--)
PCA         -0.4294  0.3733  1.1760                    (-*-)
PCB          0.3773  1.1800  1.9827                      (-*--)
WFA          3.7440  4.5467  5.3494                                (-*-)
WFB          3.7540  4.5567  5.3594                                (-*-)
                                     ---------+---------+---------+---------+
                                           -3.5       0.0       3.5       7.0


Collection = LCB subtracted from:

Collection    Lower   Center   Upper  ---------+---------+---------+---------+
LCCA         0.0806   0.8833  1.6860                     (--*-)
LCCB         0.8306   1.6333  2.4360                       (--*-)
PCA         -1.0527  -0.2500  0.5527                  (-*--)
PCB         -0.2460   0.5567  1.3594                    (--*-)
WFA          3.1206   3.9233  4.7260                              (-*--)
WFB          3.1306   3.9333  4.7360                              (-*--)
                                      ---------+---------+---------+---------+
                                            -3.5       0.0       3.5       7.0
```

```
Collection = LCCA subtracted from:

Collection    Lower   Center    Upper  ---------+---------+---------+---------+
LCCB        -0.0527   0.7500   1.5527                     (-*-)
PCA         -1.9360  -1.1333  -0.3306               (--*-)
PCB         -1.1294  -0.3267   0.4760                  (-*-)
WFA          2.2373   3.0400   3.8427                           (--*-)
WFB          2.2473   3.0500   3.8527                           (--*-)
                                       ---------+---------+---------+---------+
                                             -3.5       0.0       3.5       7.0
```

```
Collection = LCCB subtracted from:

Collection    Lower   Center    Upper  ---------+---------+---------+---------+
PCA         -2.6860  -1.8833  -1.0806             (--*-)
PCB         -1.8794  -1.0767  -0.2740                (-*-)
WFA          1.4873   2.2900   3.0927                         (--*-)
WFB          1.4973   2.3000   3.1027                         (--*-)
                                       ---------+---------+---------+---------+
                                             -3.5       0.0       3.5       7.0
```

```
Collection = PCA subtracted from:

Collection   Lower  Center   Upper  ---------+---------+---------+---------+
PCB         0.0040  0.8067  1.6094                     (-*--)
WFA         3.3706  4.1733  4.9760                               (-*-)
WFB         3.3806  4.1833  4.9860                               (-*-)
                                    ---------+---------+---------+---------+
                                          -3.5       0.0       3.5       7.0
```

```
Collection = PCB subtracted from:

Collection   Lower  Center   Upper  ---------+---------+---------+---------+
WFA         2.5640  3.3667  4.1694                            (--*-)
WFB         2.5740  3.3767  4.1794                            (--*-)
                                    ---------+---------+---------+---------+
                                          -3.5       0.0       3.5       7.0
```

```
Collection = WFA subtracted from:

Collection    Lower  Center   Upper  ---------+---------+---------+---------+
WFB        -0.7927  0.0100  0.8127                   (-*-)
                                     ---------+---------+---------+---------+
                                           -3.5       0.0       3.5       7.0
```

Table C10. Chlorphyll-*a* general linear model, one way ANOVA and Tukey's multiple comparison test

General Linear Model: Chlorophyll versus Site, Event

Factor	Type	Levels	Values
Site	fixed	8	Cedar Bayou near Crosby, Clear Creek @ State 35, Dickinson Bayou @ 517, Greeens bayou, Lake Creek near Egypt, Little Cypress Creek, Peach Creek, West Fork of the San Jacinto
Event	fixed	2	A, B

Analysis of Variance for Chlorophyll, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Site	7	554.662	554.662	79.237	171.27	0.000
Event	1	62.245	62.245	62.245	134.54	0.000
Site*Event	7	153.589	153.589	21.941	47.43	0.000
Error	32	14.805	14.805	0.463		
Total	47	785.301				

S = 0.680184   R-Sq = 98.11%   R-Sq(adj) = 97.23%

Unusual Observations for Chlorophyll

Obs	Chlorophyll	Fit	SE Fit	Residual	St Resid
7	1.6783	0.5632	0.3927	1.1150	2.01 R
8	3.2894	2.1378	0.3927	1.1517	2.07 R
32	3.1328	5.3517	0.3927	-2.2189	-4.00 R
48	6.6186	5.3517	0.3927	1.2669	2.28 R

R denotes an observation with a large standardized residual.

One-way ANOVA: Chlorophyll versus Collection

Source	DF	SS	MS	F	P
Collection	15	770.497	51.366	111.03	0.000
Error	32	14.805	0.463		
Total	47	785.301			

S = 0.6802   R-Sq = 98.11%   R-Sq(adj) = 97.23%

```
                         Individual 95% CIs For Mean Based on Pooled StDev
Level  N    Mean  StDev    +---------+---------+---------+---------
CBA    3   3.054  0.269         (*-)
CBB    3   3.290  0.517         (-*)
CCA    3   1.501  0.353     (-*-)
CCB    3   1.652  0.261      (*-)
DBA    3   0.697  0.008    (*-)
DBB    3   0.774  0.134    (-*)
GBA    3   1.191  0.224     (*-)
GBB    3   1.663  0.037      (*-)
LCA    3   6.169  0.278               (*-)
LCB    3  17.389  0.598                                    (-*)
LCCA   3   2.138  1.005       (*-)
LCCB   3   5.352  1.928             (-*)
```

```
PCA    3   0.563  1.024    (*-)
PCB    3   0.705  0.354    (*-)
WFA    3   1.495  0.167     (-*-)
WFB    3   4.202  0.661           (*-)
                           +---------+---------+---------+---------
                         0.0       5.0      10.0      15.0

Pooled StDev = 0.680


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Collection

Individual confidence level = 99.92%


Collection = CBA subtracted from:

Collection   Lower  Center   Upper  ---------+---------+---------+---------+
CBB         -1.822   0.235   2.293                 (-*-)
CCA         -3.612  -1.554   0.504               (-*--)
CCB         -3.460  -1.403   0.655                (-*-)
DBA         -4.415  -2.358  -0.300               (-*-)
DBB         -4.338  -2.280  -0.222               (-*-)
GBA         -3.921  -1.864   0.194               (-*-)
GBB         -3.449  -1.391   0.667                (-*-)
LCA          1.056   3.114   5.172                    (-*-)
LCB         12.277  14.335  16.393                               (-*-)
LCCA        -2.974  -0.917   1.141                (-*-)
LCCB         0.239   2.297   4.355                   (-*-)
PCA         -4.549  -2.491  -0.433              (--*-)
PCB         -4.407  -2.349  -0.291               (-*-)
WFA         -3.617  -1.559   0.498               (-*-)
WFB         -0.910   1.147   3.205                  (-*-)
                                    ---------+---------+---------+---------+
                                           -10         0        10        20


Collection = CBB subtracted from:

Collection   Lower  Center   Upper  ---------+---------+---------+---------+
CCA         -3.847  -1.789   0.268               (-*-)
CCB         -3.696  -1.638   0.420               (-*-)
DBA         -4.651  -2.593  -0.535              (-*-)
DBB         -4.573  -2.516  -0.458              (-*--)
GBA         -4.157  -2.099  -0.041               (-*-)
GBB         -3.684  -1.626   0.431               (-*-)
LCA          0.821   2.879   4.936                    (-*-)
LCB         12.042  14.099  16.157                               (-*-)
LCCA        -3.210  -1.152   0.906                (-*-)
LCCB         0.004   2.062   4.120                   (-*-)
PCA         -4.784  -2.727  -0.669              (-*-)
PCB         -4.642  -2.585  -0.527              (-*-)
WFA         -3.852  -1.795   0.263               (-*-)
WFB         -1.146   0.912   2.970                  (-*-)
                                    ---------+---------+---------+---------+
                                           -10         0        10        20


Collection = CCA subtracted from:

Collection   Lower  Center   Upper  ---------+---------+---------+---------+
CCB         -1.906   0.151   2.209                 (-*-)
```

```
DBA         -2.861  -0.804   1.254                  (-*-)
DBB         -2.784  -0.726   1.332                  (-*-)
GBA         -2.367  -0.310   1.748                   (-*-)
GBB         -1.895   0.163   2.221                   (-*-)
LCA          2.610   4.668   6.726                        (-*-)
LCB         13.831  15.889  17.947                                   (-*-)
LCCA        -1.421   0.637   2.695                    (-*-)
LCCB         1.793   3.851   5.909                       (-*-)
PCA         -2.995  -0.937   1.120                  (-*-)
PCB         -2.853  -0.795   1.262                  (-*-)
WFA         -2.063  -0.005   2.052                   (-*-)
WFB          0.644   2.701   4.759                      (-*-)
                                    ---------+---------+---------+---------+
                                           -10         0        10        20


Collection = CCB subtracted from:

Collection   Lower  Center   Upper  ---------+---------+---------+---------+
DBA         -3.013  -0.955   1.103                  (-*-)
DBB         -2.935  -0.878   1.180                  (-*-)
GBA         -2.519  -0.461   1.597                  (--*-)
GBB         -2.046   0.012   2.069                   (-*-)
LCA          2.459   4.517   6.575                       (--*-)
LCB         13.680  15.738  17.795                                   (-*-)
LCCA        -1.572   0.486   2.544                   (-*--)
LCCB         1.642   3.700   5.758                       (-*-)
PCA         -3.146  -1.089   0.969                  (-*-)
PCB         -3.004  -0.947   1.111                  (-*-)
WFA         -2.214  -0.157   1.901                   (-*-)
WFB          0.492   2.550   4.608                     (--*-)
                                    ---------+---------+---------+---------+
                                           -10         0        10        20


Collection = DBA subtracted from:

Collection   Lower  Center   Upper  ---------+---------+---------+---------+
DBB         -1.980   0.077   2.135                   (-*-)
GBA         -1.564   0.494   2.552                   (-*--)
GBB         -1.091   0.967   3.024                    (-*-)
LCA          3.414   5.472   7.529                        (-*--)
LCB         14.635  16.693  18.750                                    (-*-)
LCCA        -0.617   1.441   3.499                    (-*-)
LCCB         2.597   4.655   6.713                        (-*-)
PCA         -2.191  -0.134   1.924                   (-*-)
PCB         -2.049   0.008   2.066                   (-*-)
WFA         -1.259   0.798   2.856                    (-*-)
WFB          1.447   3.505   5.563                      (--*-)
                                    ---------+---------+---------+---------+
                                           -10         0        10        20


Collection = DBB subtracted from:

Collection   Lower  Center   Upper  ---------+---------+---------+---------+
GBA         -1.641   0.417   2.474                   (-*-)
GBB         -1.169   0.889   2.947                    (-*-)
LCA          3.337   5.394   7.452                        (-*-)
LCB         14.557  16.615  18.673                                    (-*-)
LCCA        -0.694   1.363   3.421                    (-*-)
LCCB         2.520   4.577   6.635                        (-*-)
PCA         -2.269  -0.211   1.847                   (-*-)
```

```
PCB         -2.127  -0.069   1.989                   (-*-)
WFA         -1.337   0.721   2.779                    (-*-)
WFB          1.370   3.428   5.485                      (-*-)
                                    ---------+---------+---------+---------+
                                           -10         0        10        20


Collection = GBA subtracted from:

Collection   Lower  Center   Upper  ---------+---------+---------+---------+
GBB         -1.585   0.473   2.530                   (-*--)
LCA          2.920   4.978   7.036                        (-*-)
LCB         14.141  16.199  18.256                                   (-*-)
LCCA        -1.111   0.947   3.005                    (-*-)
LCCB         2.103   4.161   6.219                       (-*-)
PCA         -2.685  -0.628   1.430                  (-*-)
PCB         -2.543  -0.486   1.572                  (--*-)
WFA         -1.753   0.304   2.362                   (-*-)
WFB          0.953   3.011   5.069                      (-*-)
                                    ---------+---------+---------+---------+
                                           -10         0        10        20


Collection = GBB subtracted from:

Collection   Lower  Center   Upper  ---------+---------+---------+---------+
LCA          2.447   4.505   6.563                       (--*-)
LCB         13.668  15.726  17.784                                   (-*-)
LCCA        -1.583   0.474   2.532                   (-*--)
LCCB         1.631   3.688   5.746                       (-*-)
PCA         -3.158  -1.100   0.958                  (-*-)
PCB         -3.016  -0.958   1.100                  (-*-)
WFA         -2.226  -0.168   1.890                   (-*-)
WFB          0.481   2.539   4.596                     (--*-)
                                    ---------+---------+---------+---------+
                                           -10         0        10        20


Collection = LCA subtracted from:

Collection   Lower  Center   Upper  ---------+---------+---------+---------+
LCB          9.163  11.221  13.279                              (-*-)
LCCA        -6.089  -4.031  -1.973               (-*-)
LCCB        -2.875  -0.817   1.241                  (-*-)
PCA         -7.663  -5.605  -3.548             (-*-)
PCB         -7.521  -5.463  -3.406             (--*-)
WFA         -6.731  -4.673  -2.616              (-*-)
WFB         -4.024  -1.967   0.091                 (-*-)
                                    ---------+---------+---------+---------+
                                           -10         0        10        20


Collection = LCB subtracted from:

Collection    Lower   Center    Upper  ---------+---------+---------+---------+
LCCA        -17.309  -15.252  -13.194    (-*-)
LCCB        -14.095  -12.038   -9.980       (-*-)
PCA         -18.884  -16.826  -14.768  (-*-)
PCB         -18.742  -16.684  -14.626  (-*-)
WFA         -17.952  -15.894  -13.836   (-*-)
WFB         -15.245  -13.187  -11.130      (-*-)
                                       ---------+---------+---------+---------+
                                              -10         0        10        20
```

```
Collection = LCCA subtracted from:

Collection   Lower  Center  Upper  ---------+---------+---------+---------+
LCCB         1.156   3.214  5.272                      (-*-)
PCA         -3.632  -1.575  0.483                 (-*-)
PCB         -3.490  -1.433  0.625                  (-*-)
WFA         -2.700  -0.643  1.415                  (-*-)
WFB          0.006   2.064  4.122                     (-*-)
                                   ---------+---------+---------+---------+
                                          -10         0        10        20


Collection = LCCB subtracted from:

Collection   Lower  Center   Upper  ---------+---------+---------+---------+
PCA         -6.846  -4.788  -2.731              (-*-)
PCB         -6.704  -4.646  -2.589              (-*-)
WFA         -5.914  -3.857  -1.799               (-*-)
WFB         -3.208  -1.150   0.908                  (-*-)
                                    ---------+---------+---------+---------+
                                           -10         0        10        20


Collection = PCA subtracted from:

Collection   Lower  Center  Upper  ---------+---------+---------+---------+
PCB         -1.916   0.142  2.200                    (-*-)
WFA         -1.126   0.932  2.990                     (-*-)
WFB          1.581   3.639  5.696                        (-*-)
                                   ---------+---------+---------+---------+
                                          -10         0        10        20


Collection = PCB subtracted from:

Collection   Lower  Center  Upper  ---------+---------+---------+---------+
WFA         -1.268   0.790  2.848                     (-*-)
WFB          1.439   3.497  5.554                       (-*--)
                                   ---------+---------+---------+---------+
                                          -10         0        10        20


Collection = WFA subtracted from:

Collection  Lower  Center  Upper  ---------+---------+---------+---------+
WFB         0.649   2.707  4.764                      (-*-)
                                  ---------+---------+---------+---------+
                                         -10         0        10        20
```

Table C11 Turbidity general linear model, one way ANOVA and Tukey's multiple comparison test

General Linear Model: Turbidity versus Site, Event

```
Factor  Type   Levels  Values
Site    fixed       8  Cedar Bayou near Crosby, Clear Creek @ State 35,
                       Dickinson Bayou @ 517, Greeens bayou, Lake Creek near
                       Egypt, Little Cypress Creek, Peach Creek, West Fork of
                       the San Jacinto
Event   fixed       2  A, B


Analysis of Variance for Turbidity, using Adjusted SS for Tests

Source      DF   Seq SS   Adj SS  Adj MS       F      P
Site         7  1157.09  1157.09  165.30  462.11  0.000
Event        1    17.10    17.10   17.10   47.81  0.000
Site*Event   7   528.73   528.73   75.53  211.16  0.000
Error       32    11.45    11.45    0.36
Total       47  1714.37


S = 0.598082   R-Sq = 99.33%   R-Sq(adj) = 99.02%


Unusual Observations for Turbidity

Obs  Turbidity      Fit  SE Fit  Residual  St Resid
  6     6.8300   5.6200  0.3453    1.2100      2.48 R
  7    17.9900  19.1300  0.3453   -1.1400     -2.33 R
 22     4.5500   5.6200  0.3453   -1.0700     -2.19 R
 45     6.9100   8.0300  0.3453   -1.1200     -2.29 R

R denotes an observation with a large standardized residual.
```

One-way ANOVA: Turbidity versus Collection

```
Source      DF        SS       MS       F      P
Collection  15  1702.927  113.528  317.38  0.000
Error       32    11.446    0.358
Total       47  1714.373

S = 0.5981   R-Sq = 99.33%   R-Sq(adj) = 99.02%


                         Individual 95% CIs For Mean Based on
                         Pooled StDev
Level  N    Mean  StDev  --------+---------+---------+---------+-
CBA    3   1.833  0.240  (*)
CBB    3   7.597  0.307           (-*)
CCA    3   8.063  0.512            (*-)
CCB    3   5.087  0.460       (*-)
DBA    3  18.333  0.306                             (-*)
DBB    3   5.770  0.110        (-*)
GBA    3   5.620  1.146        (*-)
GBB    3   7.113  0.080           (*)
```

```
LCA    3   8.240  0.350             (*)
LCB    3   8.030  0.992            (*-)
LCCA   3   8.270  0.320             (*)
LCCB   3   9.910  0.655               (-*)
PCA    3  19.130  0.988                               (*)
PCB    3  23.833  0.702                                       (*)
WFA    3   3.900  0.449     (-*)
WFB    3  15.600  0.600                         (*)
                         --------+---------+---------+---------+-
                               6.0      12.0      18.0      24.0

Pooled StDev = 0.598


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Collection

Individual confidence level = 99.92%


Collection = CBA subtracted from:

Collection   Lower  Center   Upper  --------+---------+---------+---------+-
CBB          3.954   5.763   7.573                       (-*)
CCA          4.421   6.230   8.039                        (*-)
CCB          1.444   3.253   5.063                     (-*)
DBA         14.691  16.500  18.309                                (-*)
DBB          2.127   3.937   5.746                      (*-)
GBA          1.977   3.787   5.596                      (*-)
GBB          3.471   5.280   7.089                       (*-)
LCA          4.597   6.407   8.216                        (*-)
LCB          4.387   6.197   8.006                        (*-)
LCCA         4.627   6.437   8.246                        (*-)
LCCB         6.267   8.077   9.886                         (-*)
PCA         15.487  17.297  19.106                                 (*-)
PCB         20.191  22.000  23.809                                     (*-)
WFA          0.257   2.067   3.876                    (-*)
WFB         11.957  13.767  15.576                              (*-)
                                    --------+---------+---------+---------+-
                                          -12         0        12        24


Collection = CBB subtracted from:

Collection   Lower  Center   Upper  --------+---------+---------+---------+-
CCA         -1.343   0.467   2.276                   (*-)
CCB         -4.319  -2.510  -0.701                (-*)
DBA          8.927  10.737  12.546                           (-*)
DBB         -3.636  -1.827  -0.017                 (*-)
GBA         -3.786  -1.977  -0.167                 (*-)
GBB         -2.293  -0.483   1.326                  (-*)
LCA         -1.166   0.643   2.453                   (-*)
LCB         -1.376   0.433   2.243                   (*-)
LCCA        -1.136   0.673   2.483                   (-*)
LCCB         0.504   2.313   4.123                    (-*)
PCA          9.724  11.533  13.343                            (-*)
PCB         14.427  16.237  18.046                                (-*)
WFA         -5.506  -3.697  -1.887               (-*)
WFB          6.194   8.003   9.813                         (-*)
                                    --------+---------+---------+---------+-
                                          -12         0        12        24
```

```
Collection = CCA subtracted from:

Collection   Lower  Center   Upper  --------+---------+---------+---------+-
CCB         -4.786  -2.977  -1.167                (-*)
DBA          8.461  10.270  12.079                           (-*)
DBB         -4.103  -2.293  -0.484                 (*-)
GBA         -4.253  -2.443  -0.634                (-*)
GBB         -2.759  -0.950   0.859                  (*-)
LCA         -1.633   0.177   1.986                   (*-)
LCB         -1.843  -0.033   1.776                  (-*)
LCCA        -1.603   0.207   2.016                   (*-)
LCCB         0.037   1.847   3.656                    (-*)
PCA          9.257  11.067  12.876                            (*-)
PCB         13.961  15.770  17.579                                (*-)
WFA         -5.973  -4.163  -2.354               (-*)
WFB          5.727   7.537   9.346                         (*-)
                                    --------+---------+---------+---------+-
                                          -12         0        12        24


Collection = CCB subtracted from:

Collection   Lower  Center   Upper  --------+---------+---------+---------+-
DBA         11.437  13.247  15.056                              (*-)
DBB         -1.126   0.683   2.493                   (-*)
GBA         -1.276   0.533   2.343                   (*-)
GBB          0.217   2.027   3.836                    (-*)
LCA          1.344   3.153   4.963                     (-*)
LCB          1.134   2.943   4.753                     (*-)
LCCA         1.374   3.183   4.993                     (-*)
LCCB         3.014   4.823   6.633                       (*-)
PCA         12.234  14.043  15.853                              (-*)
PCB         16.937  18.747  20.556                                  (-*)
WFA         -2.996  -1.187   0.623                  (*-)
WFB          8.704  10.513  12.323                           (-*)
                                    --------+---------+---------+---------+-
                                          -12         0        12        24


Collection = DBA subtracted from:

Collection    Lower   Center    Upper  --------+---------+---------+---------+-
DBB         -14.373  -12.563  -10.754        (-*)
GBA         -14.523  -12.713  -10.904        (*-)
GBB         -13.029  -11.220   -9.411         (-*)
LCA         -11.903  -10.093   -8.284          (-*)
LCB         -12.113  -10.303   -8.494          (*-)
LCCA        -11.873  -10.063   -8.254          (-*)
LCCB        -10.233   -8.423   -6.614           (-*)
PCA          -1.013    0.797    2.606                   (-*)
PCB           3.691    5.500    7.309                       (-*)
WFA         -16.243  -14.433  -12.624      (-*)
WFB          -4.543   -2.733   -0.924                (-*)
                                       --------+---------+---------+---------+-
                                             -12         0        12        24


Collection = DBB subtracted from:

Collection   Lower  Center   Upper  --------+---------+---------+---------+-
GBA         -1.959  -0.150   1.659                  (-*)
GBB         -0.466   1.343   3.153                    (*-)
LCA          0.661   2.470   4.279                     (*-)
```

```
LCB          0.451   2.260   4.069                    (-*)
LCCA         0.691   2.500   4.309                     (*-)
LCCB         2.331   4.140   5.949                      (*-)
PCA         11.551  13.360  15.169                              (*-)
PCB         16.254  18.063  19.873                                  (*-)
WFA         -3.679  -1.870  -0.061                 (*-)
WFB          8.021   9.830  11.639                           (*-)
                                    --------+---------+---------+---------+-
                                          -12         0        12        24


Collection = GBA subtracted from:

Collection   Lower  Center   Upper  --------+---------+---------+---------+-
GBB         -0.316   1.493   3.303                    (*-)
LCA          0.811   2.620   4.429                     (*-)
LCB          0.601   2.410   4.219                     (*-)
LCCA         0.841   2.650   4.459                     (*-)
LCCB         2.481   4.290   6.099                      (-*)
PCA         11.701  13.510  15.319                              (*-)
PCB         16.404  18.213  20.023                                  (*-)
WFA         -3.529  -1.720   0.089                 (-*)
WFB          8.171   9.980  11.789                           (*-)
                                    --------+---------+---------+---------+-
                                          -12         0        12        24


Collection = GBB subtracted from:

Collection   Lower  Center   Upper  --------+---------+---------+---------+-
LCA         -0.683   1.127   2.936                   (-*)
LCB         -0.893   0.917   2.726                   (-*)
LCCA        -0.653   1.157   2.966                   (-*)
LCCB         0.987   2.797   4.606                     (*-)
PCA         10.207  12.017  13.826                             (*-)
PCB         14.911  16.720  18.529                                058(-*)
WFA         -5.023  -3.213  -1.404                (*-)
WFB          6.677   8.487  10.296                          (*-)
                                    --------+---------+---------+---------+-
                                          -12         0        12        24


Collection = LCA subtracted from:

Collection   Lower  Center   Upper  --------+---------+---------+---------+-
LCB         -2.019  -0.210   1.599                  (-*)
LCCA        -1.779   0.030   1.839                   (*-)
LCCB        -0.139   1.670   3.479                    (*-)
PCA          9.081  10.890  12.699                            (*-)
PCB         13.784  15.593  17.403                               (-*-)
WFA         -6.149  -4.340  -2.531               (*-)
WFB          5.551   7.360   9.169                         (*-)
                                    --------+---------+---------+---------+-
                                          -12         0        12        24


Collection = LCB subtracted from:

Collection   Lower  Center   Upper  --------+---------+---------+---------+-
LCCA        -1.569   0.240   2.049                   (*-)
LCCB         0.071   1.880   3.689                    (-*)
PCA          9.291  11.100  12.909                            (*-)
PCB         13.994  15.803  17.613                                (*-)
```

```
WFA         -5.939  -4.130  -2.321              (-*)
WFB          5.761   7.570   9.379                        (*-)
                                    ---------+---------+---------+---------+-
                                          -12         0        12        24

Collection = LCCA subtracted from:

Collection   Lower  Center   Upper  ---------+---------+---------+---------+-
LCCB        -0.169   1.640   3.449                       (*-)
PCA          9.051  10.860  12.669                               (*-)
PCB         13.754  15.563  17.373                                  (-*)
WFA         -6.179  -4.370  -2.561              (*-)
WFB          5.521   7.330   9.139                        (*-)
                                    ---------+---------+---------+---------+-
                                          -12         0        12        24

Collection = LCCB subtracted from:

Collection   Lower  Center   Upper  ---------+---------+---------+---------+-
PCA          7.411   9.220  11.029                              (-*)
PCB         12.114  13.923  15.733                                  (-*)
WFA         -7.819  -6.010  -4.201            (-*)
WFB          3.881   5.690   7.499                      (-*)
                                    ---------+---------+---------+---------+-
                                          -12         0        12        24

Collection = PCA subtracted from:

Collection    Lower   Center    Upper  ---------+---------+---------+---------+-
PCB           2.894    4.703    6.513                          (-*)
WFA         -17.039  -15.230  -13.421      (*-)
WFB          -5.339   -3.530   -1.721                 (*-)
                                       ---------+---------+---------+---------+-
                                             -12         0        12        24

Collection = PCB subtracted from:

Collection    Lower   Center    Upper  ---------+---------+---------+---------+-
WFA         -21.743  -19.933  -18.124  (*-)
WFB         -10.043   -8.233   -6.424            (*-)
                                       ---------+---------+---------+---------+-
                                             -12         0        12        24

Collection = WFA subtracted from:

Collection  Lower  Center   Upper  ---------+---------+---------+---------+-
WFB         9.891  11.700  13.509                                (-*)
                                   ---------+---------+---------+---------+-
                                         -12         0        12        24
```

Table C12. Alkalinity general linear model, one way ANOVA and Tukey's multiple comparison test

General Linear Model: Chlorophyll versus Site, Event

```
Factor  Type   Levels  Values
Site    fixed       8  Cedar Bayou near Crosby, Clear Creek @ State 35,
                       Dickinson Bayou @ 517, Greeens bayou, Lake Creek near
                       Egypt, Little Cypress Creek, Peach Creek, West Fork of
                       the San Jacinto
Event   fixed       2  A, B


Analysis of Variance for Alkalinity, using Adjusted SS for Tests

Source      DF  Seq SS  Adj SS  Adj MS        F      P
Site         7  302870  302870   43267  1312.72  0.000
Event        1      40      40      40     1.20  0.281
Site*Event   7    6251    6251     893    27.09  0.000
Error       32    1055    1055      33
Total       47  310215


S = 5.74108   R-Sq = 99.66%   R-Sq(adj) = 99.50%


Unusual Observations for Alkalinity

Obs  Alkalinity      Fit  SE Fit  Residual  St Resid
  4     100.000  112.133   3.315   -12.133     -2.59 R
  9     218.400  207.200   3.315    11.200      2.39 R
 17     197.200  207.200   3.315   -10.000     -2.13 R
 20     129.600  112.133   3.315    17.467      3.73 R

R denotes an observation with a large standardized residual.
```

One-way ANOVA: Alkalinity versus Collection

```
Source      DF        SS       MS       F      P
Collection  15  309159.9  20610.7  625.32  0.000
Error       32    1054.7     33.0
Total       47  310214.6

S = 5.741   R-Sq = 99.66%   R-Sq(adj) = 99.50%


Individual 95% CIs For Mean Based on
                         Pooled StDev
Level  N    Mean  StDev  ------+---------+---------+---------+---
CBA    3  109.07   2.66             (*)
CBB    3   86.13   1.80         (*)
CCA    3  233.07   6.66                              (*)
CCB    3  222.67   1.29                             (*)
DBA    3  207.20  10.65                           (*)
DBB    3  193.73   1.67                         (*)
GBA    3  140.27   3.61                 (*)
GBB    3  116.53   5.69              (*)
LCA    3   34.67   1.15  (*)
```

```
LCB    3   32.13   1.40  (*)
LCCA   3  236.67   7.20                             (*)
LCCB   3  288.13   2.57                                    (*)
PCA    3   40.53   0.61   (*)
PCB    3   35.87   1.29  (*)
WFA    3  112.13  15.50            (*)
WFB    3  123.87   2.27              (*)
                         ------+---------+---------+---------+---
                              70       140       210       280

Pooled StDev = 5.74


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Collection

Individual confidence level = 99.92%


Collection = CBA subtracted from:

Collection   Lower  Center   Upper  --------+---------+---------+---------+-
CBB         -40.30  -22.93   -5.56                (*-)
CCA         106.63  124.00  141.37                          (*)
CCB          96.23  113.60  130.97                         (-*)
DBA          80.76   98.13  115.50                        (-*)
DBB          67.30   84.67  102.04                       (-*)
GBA          13.83   31.20   48.57                    (*)
GBB          -9.90    7.47   24.84                  (*-)
LCA         -91.77  -74.40  -57.03             (*)
LCB         -94.30  -76.93  -59.56             (*)
LCCA        110.23  127.60  144.97                          (-*)
LCCB        161.70  179.07  196.44                              (*)
PCA         -85.90  -68.53  -51.16             (*-)
PCB         -90.57  -73.20  -55.83             (*)
WFA         -14.30    3.07   20.44                  (*)
WFB          -2.57   14.80   32.17                   (*)
                                    --------+---------+---------+---------+-
                                         -150         0       150       300


Collection = CBB subtracted from:

Collection   Lower  Center   Upper  --------+---------+---------+---------+-
CCA         129.56  146.93  164.30                            (*)
CCB         119.16  136.53  153.90                           (*)
DBA         103.70  121.07  138.44                          (*)
DBB          90.23  107.60  124.97                         (*)
GBA          36.76   54.13   71.50                     (-*)
GBB          13.03   30.40   47.77                    (*)
LCA         -68.84  -51.47  -34.10              (-*)
LCB         -71.37  -54.00  -36.63              (*-)
LCCA        133.16  150.53  167.90                            (*)
LCCB        184.63  202.00  219.37                               (*-)
PCA         -62.97  -45.60  -28.23               (*)
PCB         -67.64  -50.27  -32.90              (-*)
WFA           8.63   26.00   43.37                    (*)
WFB          20.36   37.73   55.10                    (-*)
                                    --------+---------+---------+---------+-
                                         -150         0       150       300


Collection = CCA subtracted from:
```

```
Collection    Lower   Center    Upper  --------+---------+---------+---------+-
CCB          -27.77   -10.40     6.97                  (*)
DBA          -43.24   -25.87    -8.50                 (*)
DBB          -56.70   -39.33   -21.96                (*-)
GBA         -110.17   -92.80   -75.43             (*)
GBB         -133.90  -116.53   -99.16           (*)
LCA         -215.77  -198.40  -181.03      (*)
LCB         -218.30  -200.93  -183.56     (-*)
LCCA         -13.77     3.60    20.97                   (*)
LCCB          37.70    55.07    72.44                       (*)
PCA         -209.90  -192.53  -175.16      (*)
PCB         -214.57  -197.20  -179.83      (*)
WFA         -138.30  -120.93  -103.56           (*)
WFB         -126.57  -109.20   -91.83            (*)
                                       --------+---------+---------+---------+-
                                            -150         0       150       300
```

Collection = CCB subtracted from:

```
Collection    Lower   Center    Upper  --------+---------+---------+---------+-
DBA          -32.84   -15.47     1.90                  (*)
DBB          -46.30   -28.93   -11.56                 (*)
GBA          -99.77   -82.40   -65.03             (-*)
GBB         -123.50  -106.13   -88.76            (*)
LCA         -205.37  -188.00  -170.63      (*-)
LCB         -207.90  -190.53  -173.16      (*)
LCCA          -3.37    14.00    31.37                    (*)
LCCB          48.10    65.47    82.84                       (*-)
PCA         -199.50  -182.13  -164.76       (*)
PCB         -204.17  -186.80  -169.43      (-*)
WFA         -127.90  -110.53   -93.16           (-*)
WFB         -116.17   -98.80   -81.43            (*-)
                                       --------+---------+---------+---------+-
                                            -150         0       150       300
```

Collection = DBA subtracted from:

```
Collection    Lower   Center    Upper  --------+---------+---------+---------+-
DBB          -30.84   -13.47     3.90                  (*)
GBA          -84.30   -66.93   -49.56              (-*)
GBB         -108.04   -90.67   -73.30             (*)
LCA         -189.90  -172.53  -155.16       (*-)
LCB         -192.44  -175.07  -157.70       (*)
LCCA          12.10    29.47    46.84                     (*)
LCCB          63.56    80.93    98.30                        (*-)
PCA         -184.04  -166.67  -149.30        (*)
PCB         -188.70  -171.33  -153.96       (-*)
WFA         -112.44   -95.07   -77.70             (*)
WFB         -100.70   -83.33   -65.96             (*-)
                                       --------+---------+---------+---------+-
                                            -150         0       150       300
```

Collection = DBB subtracted from:

```
Collection    Lower   Center    Upper  --------+---------+---------+---------+-
GBA          -70.84   -53.47   -36.10               (*-)
GBB          -94.57   -77.20   -59.83              (*)
LCA         -176.44  -159.07  -141.70        (*-)
LCB         -178.97  -161.60  -144.23        (*)
```

```
LCCA          25.56    42.93    60.30                      (*)
LCCB          77.03    94.40   111.77                         (*)
PCA         -170.57  -153.20  -135.83         (*)
PCB         -175.24  -157.87  -140.50        (*-)
WFA          -98.97   -81.60   -64.23             (-*)
WFB          -87.24   -69.87   -52.50              (*-)
                                       --------+---------+---------+---------+-
                                            -150         0       150       300


Collection = GBA subtracted from:

Collection    Lower   Center   Upper  --------+---------+---------+---------+-
GBB          -41.10   -23.73   -6.36                 (*-)
LCA         -122.97  -105.60  -88.23            (*)
LCB         -125.50  -108.13  -90.76            (*)
LCCA          79.03    96.40  113.77                         (*-)
LCCB         130.50   147.87  165.24                             (*)
PCA         -117.10   -99.73  -82.36            (*-)
PCB         -121.77  -104.40  -87.03            (*)
WFA          -45.50   -28.13  -10.76                 (*)
WFB          -33.77   -16.40    0.97                  (*)
                                      --------+---------+---------+---------+-
                                           -150         0       150       300


Collection = GBB subtracted from:

Collection    Lower  Center   Upper  --------+---------+---------+---------+-
LCA          -99.24  -81.87  -64.50             (-*)
LCB         -101.77  -84.40  -67.03             (*-)
LCCA         102.76  120.13  137.50                           (*)
LCCB         154.23  171.60  188.97                              (*-)
PCA          -93.37  -76.00  -58.63              (*)
PCB          -98.04  -80.67  -63.30             (-*)
WFA          -21.77   -4.40   12.97                   (*)
WFB          -10.04    7.33   24.70                   (*-)
                                     --------+---------+---------+---------+-
                                          -150         0       150       300


Collection = LCA subtracted from:

Collection   Lower  Center   Upper  --------+---------+---------+---------+-
LCB         -19.90   -2.53   14.84                   (*)
LCCA        184.63  202.00  219.37                                (*-)
LCCB        236.10  253.47  270.84                                    (*)
PCA         -11.50    5.87   23.24                   (*-)
PCB         -16.17    1.20   18.57                   (*)
WFA          60.10   77.47   94.84                        (*)
WFB          71.83   89.20  106.57                         (*)
                                    --------+---------+---------+---------+-
                                         -150         0       150       300


Collection = LCB subtracted from:

Collection   Lower  Center   Upper  --------+---------+---------+---------+-
LCCA        187.16  204.53  221.90                                (-*)
LCCB        238.63  256.00  273.37                                    (*)
PCA          -8.97    8.40   25.77                   (-*)
PCB         -13.64    3.73   21.10                   (*)
WFA          62.63   80.00   97.37                        (*)
```

```
WFB          74.36   91.73  109.10                              (*)
                                     --------+---------+---------+---------+-
                                          -150         0       150       300


Collection = LCCA subtracted from:

Collection    Lower   Center    Upper  --------+---------+---------+---------+-
LCCB          34.10    51.47    68.84                      (*-)
PCA         -213.50  -196.13  -178.76     (*)
PCB         -218.17  -200.80  -183.43    (-*)
WFA         -141.90  -124.53  -107.16          (*)
WFB         -130.17  -112.80   -95.43          (*-)
                                       --------+---------+---------+---------+-
                                            -150         0       150       300


Collection = LCCB subtracted from:

Collection    Lower   Center    Upper  --------+---------+---------+---------+-
PCA         -264.97  -247.60  -230.23  (*-)
PCB         -269.64  -252.27  -234.90  (*)
WFA         -193.37  -176.00  -158.63      (*)
WFB         -181.64  -164.27  -146.90       (*)
                                       --------+---------+---------+---------+-
                                            -150         0       150       300


Collection = PCA subtracted from:

Collection   Lower  Center   Upper  --------+---------+---------+---------+-
PCB         -22.04   -4.67   12.70                   (*)
WFA          54.23   71.60   88.97                        (*)
WFB          65.96   83.33  100.70                        (-*)
                                    --------+---------+---------+---------+-
                                         -150         0       150       300


Collection = PCB subtracted from:

Collection  Lower  Center   Upper  --------+---------+---------+---------+-
WFA         58.90   76.27   93.64                        (*)
WFB         70.63   88.00  105.37                         (*)
                                   --------+---------+---------+---------+-
                                        -150         0       150       300


Collection = WFA subtracted from:

Collection  Lower  Center  Upper  --------+---------+---------+---------+-
WFB         -5.64   11.73  29.10                   (*)
                                  --------+---------+---------+---------+-
                                       -150         0       150       300
```

Table C13. Total suspended solids (TSS) general linear model, one way ANOVA and Tukey's multiple comparison test

General Linear Model: TSS versus Site, Event

```
Factor  Type   Levels  Values
Site    fixed       8  Cedar Bayou near Crosby, Clear Creek @ State 35,
                       Dickinson Bayou @ 517, Greeens bayou, Lake Creek near
                       Egypt, Little Cypress Creek, Peach Creek, West Fork of
                       the San Jacinto
Event   fixed       2  A, B


Analysis of Variance for TSS, using Adjusted SS for Tests

Source      DF   Seq SS   Adj SS  Adj MS       F      P
Site         7  1139.43  1139.43  162.78  117.73  0.000
Event        1   275.15   275.15  275.15  199.01  0.000
Site*Event   7  1116.40  1116.40  159.49  115.35  0.000
Error       32    44.24    44.24    1.38
Total       47  2575.23


S = 1.17585   R-Sq = 98.28%   R-Sq(adj) = 97.48%


Unusual Observations for TSS

Obs     TSS     Fit  SE Fit  Residual  St Resid
  4  1.8571  4.9048  0.6789   -3.0476     -3.17 R
  8  8.1111  5.8519  0.6789    2.2593      2.35 R
 24  3.0000  5.8519  0.6789   -2.8519     -2.97 R

R denotes an observation with a large standardized residual.
```

One-way ANOVA: TSS versus Collection

```
Source      DF       SS      MS       F      P
Collection  15  2530.98  168.73  122.04  0.000
Error       32    44.24    1.38
Total       47  2575.23

S = 1.176   R-Sq = 98.28%   R-Sq(adj) = 97.48%


                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level  N    Mean  StDev  ---------+---------+---------+---------+
CBA    3   2.000  0.866  (-*-)
CBB    3   4.264  0.907     (-*-)
CCA    3   9.206  1.206            (-*-)
CCB    3   5.086  0.258      (-*-)
DBA    3   9.633  0.777             (-*-)
DBB    3   2.767  0.551   (-*-)
GBA    3   3.633  0.306    (-*-)
GBB    3   7.833  0.416          (-*-)
LCA    3   2.567  0.666   (-*-)
LCB    3  21.619  1.003                              (-*-)
```

```
LCCA   3   5.852  2.607       (-*-)
LCCB   3   3.131  0.794   (-*-)
PCA    3  14.167  0.569                   (-*-)
PCB    3  19.692  0.671                           (-*-)
WFA    3   4.905  2.655      (-*-)
WFB    3  25.878  1.077                                    (-*-)
                         ---------+---------+---------+---------+
                                7.0      14.0      21.0      28.0

Pooled StDev = 1.176


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Collection

Individual confidence level = 99.92%


Collection = CBA subtracted from:

Collection   Lower  Center   Upper  --------+---------+---------+---------+-
CBB         -1.293   2.264   5.821                   (--*-)
CCA          3.649   7.206  10.763                      (--*-)
CCB         -0.471   3.086   6.643                    (-*-)
DBA          4.076   7.633  11.191                       (-*-)
DBB         -2.791   0.767   4.324                  (--*-)
GBA         -1.924   1.633   5.191                   (-*-)
GBB          2.276   5.833   9.391                      (-*-)
LCA         -2.991   0.567   4.124                  (-*--)
LCB         16.062  19.619  23.176                               (-*-)
LCCA         0.295   3.852   7.409                    (--*-)
LCCB        -2.427   1.131   4.688                  (--*-)
PCA          8.609  12.167  15.724                          (-*-)
PCB         14.135  17.692  21.250                             (--*-)
WFA         -0.653   2.905   6.462                    (-*-)
WFB         20.321  23.878  27.435                                  (-*-)
                                    --------+---------+---------+---------+-
                                          -15         0        15        30


Collection = CBB subtracted from:

Collection   Lower  Center   Upper  --------+---------+---------+---------+-
CCA          1.385   4.942   8.499                     (-*--)
CCB         -2.736   0.822   4.379                  (--*-)
DBA          1.812   5.369   8.926                     (--*-)
DBB         -5.055  -1.498   2.060                 (-*-)
GBA         -4.188  -0.631   2.926                 (--*-)
GBB          0.012   3.569   7.126                    (-*--)
LCA         -5.255  -1.698   1.860                027(--*-)
LCB         13.798  17.355  20.912                             (--*-)
LCCA        -1.970   1.588   5.145                   (-*-)
LCCB        -4.691  -1.134   2.424                 (-*--)
PCA          6.345   9.902  13.460                        (--*-)
PCB         11.871  15.428  18.985                            (-*--)
WFA         -2.917   0.641   4.198                  (-*--)
WFB         18.057  21.614  25.171                                (-*--)
                                    --------+---------+---------+---------+-
                                          -15         0        15        30


Collection = CCA subtracted from:
```

```
Collection    Lower  Center   Upper  --------+---------+---------+---------+-
CCB          -7.677  -4.120  -0.563               (-*--)
DBA          -3.130   0.427   3.985                  (-*--)
DBB          -9.997  -6.439  -2.882             (--*-)
GBA          -9.130  -5.573  -2.015              (-*--)
GBB          -4.930  -1.373   2.185                 (-*-)
LCA         -10.197  -6.639  -3.082             (--*-)
LCB           8.856  12.413  15.970                          (-*--)
LCCA         -6.912  -3.354   0.203               (--*-)
LCCB         -9.633  -6.075  -2.518              (-*-)
PCA           1.403   4.961   8.518                     (-*--)
PCB           6.929  10.486  14.044                         (-*-)
WFA          -7.859  -4.301  -0.744               (-*--)
WFB          13.115  16.672  20.229                             (-*-)
                                     --------+---------+---------+---------+-
                                           -15         0        15        30
```

Collection = CCB subtracted from:

```
Collection   Lower  Center   Upper  --------+---------+---------+---------+-
DBA          0.990   4.547   8.105                     (-*-)
DBB         -5.877  -2.319   1.238                (-*--)
GBA         -5.010  -1.453   2.105                 (-*-)
GBB         -0.810   2.747   6.305                   (--*-)
LCA         -6.077  -2.519   1.038                (-*--)
LCB         12.976  16.533  20.090                             (-*-)
LCCA        -2.791   0.766   4.323                  (--*-)
LCCB        -5.513  -1.955   1.602                (--*-)
PCA          5.523   9.081  12.638                        (-*-)
PCB         11.049  14.606  18.164                           (--*-)
WFA         -3.739  -0.181   3.376                  (-*-)
WFB         17.235  20.792  24.349                               (--*-)
                                    --------+---------+---------+---------+-
                                          -15         0        15        30
```

Collection = DBA subtracted from:

```
Collection    Lower  Center   Upper  --------+---------+---------+---------+-
DBB         -10.424  -6.867  -3.309             (-*--)
GBA          -9.557  -6.000  -2.443              (-*-)
GBB          -5.357  -1.800   1.757                (--*-)
LCA         -10.624  -7.067  -3.509             (-*--)
LCB           8.428  11.986  15.543                          (-*-)
LCCA         -7.339  -3.781  -0.224               (-*--)
LCCB        -10.060  -6.503  -2.945             (--*-)
PCA           0.976   4.533   8.091                     (-*-)
PCB           6.502  10.059  13.616                        (--*-)
WFA          -8.286  -4.729  -1.171              (--*-)
WFB          12.687  16.245  19.802                            (--*-)
                                     --------+---------+---------+---------+-
                                           -15         0        15        30
```

Collection = DBB subtracted from:

```
Collection   Lower  Center   Upper  --------+---------+---------+---------+-
GBA         -2.691   0.867   4.424                  (--*-)
GBB          1.509   5.067   8.624                     (-*--)
LCA         -3.757  -0.200   3.357                 (--*-)
LCB         15.295  18.852  22.410                              (--*-)
LCCA        -0.472   3.085   6.642                    (-*-)
```

```
LCCB        -3.193   0.364   3.921                   (-*--)
PCA          7.843  11.400  14.957                          (--*-)
PCB         13.368  16.926  20.483                              (-*--)
WFA         -1.419   2.138   5.695                    (-*--)
WFB         19.554  23.111  26.669                                  (-*--)
                                    ---------+---------+---------+---------+-
                                           -15         0        15        30


Collection = GBA subtracted from:

Collection   Lower  Center   Upper  ---------+---------+---------+---------+-
GBB          0.643   4.200   7.757                     (--*-)
LCA         -4.624  -1.067   2.491                  (-*--)
LCB         14.428  17.986  21.543                               (-*-)
LCCA        -1.339   2.219   5.776                    (-*--)
LCCB        -4.060  -0.503   3.055                  (--*-)
PCA          6.976  10.533  14.091                          (-*-)
PCB         12.502  16.059  19.616                             (--*-)
WFA         -2.286   1.271   4.829                   (--*-)
WFB         18.687  22.245  25.802                                 (--*-)
                                    ---------+---------+---------+---------+-
                                           -15         0        15        30


Collection = GBB subtracted from:

Collection   Lower  Center   Upper  ---------+---------+---------+---------+-
LCA         -8.824  -5.267  -1.709               (-*--)
LCB         10.228  13.786  17.343                            (-*--)
LCCA        -5.539  -1.981   1.576                 (--*-)
LCCB        -8.260  -4.703  -1.145               (--*-)
PCA          2.776   6.333   9.891                       (-*--)
PCB          8.302  11.859  15.416                           (-*-)
WFA         -6.486  -2.929   0.629                 (-*-)
WFB         14.487  18.045  21.602                               (-*-)
                                    ---------+---------+---------+---------+-
                                           -15         0        15        30


Collection = LCA subtracted from:

Collection   Lower  Center   Upper  ---------+---------+---------+---------+-
LCB         15.495  19.052  22.610                               (--*-)
LCCA        -0.272   3.285   6.842                     (-*--)
LCCB        -2.993   0.564   4.121                   (-*--)
PCA          8.043  11.600  15.157                          (--*-)
PCB         13.568  17.126  20.683                              (-*--)
WFA         -1.219   2.338   5.895                    (--*-)
WFB         19.754  23.311  26.869                                  (--*-)
                                    ---------+---------+---------+---------+-
                                           -15         0        15        30


Collection = LCB subtracted from:

Collection    Lower   Center    Upper  ---------+---------+---------+---------+-
LCCA        -19.325  -15.767  -12.210        (-*--)
LCCB        -22.046  -18.488  -14.931      (--*-)
PCA         -11.010   -7.452   -3.895              (-*-)
PCB          -5.484   -1.927    1.631                 (--*-)
WFA         -20.272  -16.714  -13.157       (--*-)
WFB           0.702    4.259    7.816                     (--*-)
```

```
                                        --------+---------+---------+---------+-
                                              -15         0        15        30


Collection = LCCA subtracted from:

Collection   Lower  Center   Upper  --------+---------+---------+---------+-
LCCB        -6.279  -2.721   0.836              (-*--)
PCA          4.758   8.315  11.872                     (--*-)
PCB         10.283  13.840  17.398                         (-*--)
WFA         -4.504  -0.947   2.610               (-*--)
WFB         16.469  20.026  23.584                             (-*--)
                                    --------+---------+---------+---------+-
                                          -15         0        15        30


Collection = LCCB subtracted from:

Collection   Lower  Center   Upper  --------+---------+---------+---------+-
PCA          7.479  11.036  14.593                       (-*--)
PCB         13.004  16.562  20.119                           (-*-)
WFA         -1.783   1.774   5.331                 (-*--)
WFB         19.190  22.747  26.305                               (-*--)
                                    --------+---------+---------+---------+-
                                          -15         0        15        30


Collection = PCA subtracted from:

Collection    Lower  Center   Upper  --------+---------+---------+---------+-
PCB           1.968   5.526   9.083                     (--*-)
WFA         -12.819  -9.262  -5.705           (--*-)
WFB           8.154  11.711  15.269                         (--*-)
                                     --------+---------+---------+---------+-
                                           -15         0        15        30


Collection = PCB subtracted from:

Collection    Lower   Center    Upper  --------+---------+---------+---------+-
WFA         -18.345  -14.788  -11.230        (-*--)
WFB           2.628    6.186    9.743                      (-*-)
                                       --------+---------+---------+---------+-
                                             -15         0        15        30


Collection = WFA subtracted from:

Collection   Lower  Center   Upper  --------+---------+---------+---------+-
WFB         17.416  20.973  24.531                              (-*-)
                                    --------+---------+---------+---------+-
                                          -15         0        15        30
```

Appendix D. Principal components analysis of land use, physical habitat and water quality variables.

Eigenanalysis of the Correlation Matrix

Eigenvalue	4.9597	3.4946	2.2849	1.6372	1.0708	0.7768	0.7033	0.5157
Proportion	0.310	0.218	0.143	0.102	0.067	0.049	0.044	0.032
Cumulative	0.310	0.528	0.671	0.774	0.840	0.889	0.933	0.965

Eigenvalue	0.2378	0.1458	0.0834	0.0454	0.0335	0.0101	0.0010	0.0000
Proportion	0.015	0.009	0.005	0.003	0.002	0.001	0.000	0.000
Cumulative	0.980	0.989	0.994	0.997	0.999	1.000	1.000	1.000

Variable	PC1	PC2	PC3	PC4	PC5	PC6
Instantaneous Flow (cfs)	-0.405	-0.183	0.066	-0.036	-0.060	-0.072
Turbidity mean	0.146	-0.134	0.565	0.014	-0.224	0.101
Mean NO3+NO2	-0.292	-0.059	0.044	-0.211	0.356	0.421
Mean NH4	0.045	-0.449	-0.078	-0.330	-0.007	0.057
Mean Alk	-0.075	0.357	-0.078	-0.121	-0.494	-0.026
mean PO4	-0.382	-0.107	-0.073	-0.049	-0.356	0.143
mean CHLO	0.217	-0.264	-0.319	-0.390	0.056	-0.005
mean TSS	0.111	-0.401	0.252	-0.118	-0.302	0.208
PIA	-0.392	0.058	0.033	-0.294	-0.022	-0.005
Watershed Size (km 2)	0.048	-0.414	-0.180	0.327	-0.219	0.206
Mean % Substrate Gravel or Larg	-0.164	-0.104	0.187	0.434	0.425	0.285
Mean % instream cover	0.292	0.136	-0.156	-0.287	0.109	0.510
Mean % Bank Erosion	0.045	0.262	-0.230	0.270	-0.297	0.561
Mean Bank Slope	-0.029	0.197	0.557	-0.230	-0.056	0.162
Mean % Tree Canopy	0.380	0.184	0.145	-0.155	0.115	0.026
Riparian	0.319	-0.170	0.117	0.220	-0.096	-0.116

Variable	PC7	PC8	PC9	PC10	PC11	PC12
Instantaneous Flow (cfs)	-0.061	-0.250	0.046	-0.262	0.020	0.254
Turbidity mean	0.055	-0.183	-0.049	0.251	-0.044	-0.043
Mean NO3+NO2	0.476	-0.086	-0.338	0.397	-0.060	0.046
Mean NH4	-0.175	0.285	-0.288	-0.032	-0.007	0.261
Mean Alk	0.304	0.543	-0.154	-0.003	0.148	-0.003
mean PO4	0.153	0.173	0.228	-0.057	-0.544	-0.042
mean CHLO	-0.094	0.011	-0.149	-0.254	-0.194	0.069
mean TSS	-0.226	0.195	0.083	0.200	0.371	-0.182
PIA	-0.146	-0.196	-0.214	-0.282	0.178	-0.702
Watershed Size (km 2)	0.180	-0.173	0.220	-0.048	-0.205	-0.224
Mean % Substrate Gravel or Larg	-0.136	0.550	-0.018	-0.294	0.009	-0.107
Mean % instream cover	0.232	-0.050	0.473	-0.237	0.261	-0.056
Mean % Bank Erosion	-0.382	-0.230	-0.413	-0.034	-0.016	0.148
Mean Bank Slope	-0.045	-0.070	0.085	-0.411	-0.161	0.323
Mean % Tree Canopy	-0.161	0.114	-0.100	0.082	-0.573	-0.367
Riparian	0.510	-0.087	-0.432	-0.448	0.065	-0.073

Variable	PC13	PC14	PC15	PC16
Instantaneous Flow (cfs)	0.084	-0.425	0.544	0.321
Turbidity mean	0.528	-0.355	-0.239	-0.115
Mean NO3+NO2	-0.025	0.156	0.122	0.097
Mean NH4	-0.334	-0.365	-0.404	0.078
Mean Alk	0.201	-0.051	0.020	0.353
mean PO4	-0.093	-0.036	0.047	-0.519
mean CHLO	0.613	0.308	0.124	-0.046
mean TSS	-0.167	0.300	0.430	-0.073
PIA	-0.004	-0.019	-0.212	-0.006
Watershed Size (km 2)	-0.023	0.157	-0.246	0.553
Mean % Substrate Gravel or Larg	0.234	-0.054	0.008	-0.009

Mean % instream cover	-0.019	-0.320	0.010	-0.083
Mean % Bank Erosion	-0.010	-0.027	0.037	-0.078
Mean Bank Slope	-0.155	0.410	-0.173	0.180
Mean % Tree Canopy	-0.183	-0.216	0.320	0.249
Riparian	-0.192	-0.035	0.164	-0.232

Appendix E. All fish captured at all sites, including abundance, tolerance level and trophic guild.

Table E1. All fish captured at Cedar Bayou during the first and second sampling events, including abundance, tolerance level and trophic guild.

Cedar Bayou 1	**Collection date: 5/3/2011**			
Scientific Name	Common Name	Total Abundance	Tolerance	Trophic Guild
Aphredoderus sayanus	Pirate perch	2		IF
Lepomis cyanellus	Green sunfish	3	T	P
Lepomis macrochirus	Bluegill sunfish	14	T	IF
Lepomis megalotis	Longear sunfish	65		IF
Lepomis miniatus	Redspotted sunfish	39		IF
Micropterus salmoides	Largemouth bass	2		P
Cyprinella venusta	Blacktail shiner	102		IF
Elassoma zonatum	Banded pygmy sunfish	2		IF
Fundulus chrysotus	Golden topminnow	2		IF
Fundulus notatus	Blackstripe topminnow	122		IF
Noturus gyrinus	Tadpole madtom	1	I	IF
Noturus nocturnus	Freckled madtom	2	I	IF
Etheostoma gracile	Slough darter	1		IF
Gambusia affinis	Western mosquofish	38		IF
	Total:	395		

Cedar Bayou 2	**Collection date:7/21/2011**			
Scientific Name	Common Name	Total Abundance	Tolerance	Trophic Guild
Lepomis cyanellus	Green sunfish	1	T	P
Lepomis macrochirus	Bluegill sunfish	1	T	IF
Lepomis megalotis	Longear sunfish	1		IF
Lepomis microlophus	Redear sunfish	1		IF
Cyprinella venusta	Blacktail shiner	19		IF
Notemigonus crysoleucas	Golden shiner	1	T	IF
Fundulus chrysotus	Golden topminnow	15		IF
Fundulus notatus	Blackstripe topminnow	144		IF
Gambusia affinis	Western mosquofish	531		IF
Poecilia latipinna	Sailfin molly	5	T	O
	Total:	719		

Table E2. All fish captured at Clear Creek during the first and second sampling events, including abundance, tolerance level and trophic guild.

Clear Creek 1	**Collection date: 4/28/2011**			
Scientific Name	Common Name	Total Abundance	Tolerance	Trophic Guild
Menida beryllina	Inland silverside	14		IF
Lepomis cyanellus	Green sunfish	7	T	P
Lepomis gulosus	Warmouth	2	T	P
Lepomis macrochirus	Bluegill sunfish	1	T	IF
Lepomis megalotis	Longear sunfish	49		IF
Lepomis miniatus	Redspotted sunfish	1		IF
Micropterus salmoides	Largemouth bass	1		P
Cichlasomo cyanoguttatum	Rio Grande cichlid	1		IF
Cyprinella lutrensis	Red shiner	30	T	IF
Cyprinella venusta	Blacktail shiner	4		IF
Pimephales vigilax	Bullhead minnow	61		IF
Fundulus notatus	Blackstripe topminnow	111		IF
Noturus gyrinus	Tadpole madtom	1	I	IF
Lepisosteus oculatus	Spotted gar	2	T	P
Gambusia affinis	Western mosquofish	534		IF
	Total:	819		

Clear Creek 2	**Collection date: 7/15/2011**			
Scientific Name	Common Name	Total Abundance	Tolerance	Trophic Guild
Menida beryllina	Inland silverside	106		IF
Lepomis auritus	Redbreast sunfish	2		IF
Lepomis macrochirus	Bluegill sunfish	5	T	IF
Lepomis megalotis	Longear sunfish	19		IF
Micropterus salmoides	Largemouth bass	1		P
Cichlasomo cyanoguttatum	Rio Grande cichlid	9		IF
Cyprinella lutrensis	Red shiner	110	T	IF
Notropis atrocaudalis	Blackspot shiner	1		IF
Pimephales vigilax	Bullhead minnow	32		IF
Fundulus notatus	Blackstripe topminnow	258		IF
Ameiurus natalis	Yellow bullhead	1		O
Noturus gyrinus	Tadpole madtom	1	I	IF
Gambusia affinis	Western mosquofish	188		IF
	Total:	733		

Table E3. All fish captured at Dickinson Bayou during the first and second sampling events, including abundance, tolerance level and trophic guild.

Dickinson Bayou 1	**Collection date: 4/26/2011**			
Scientific Name	Common Name	Total Abundance	Tolerance	Trophic Guild
Lepomis cyanellus	Green sunfish	7	T	P
Lepomis gulosus	Warmouth	1	T	P
Lepomis macrochirus	Bluegill sunfish	4	T	IF
Lepomis megalotis	Longear sunfish	17		IF
Lepomis miniatus	Redspotted sunfish	3		IF
Micropterus salmoides	Largemouth bass	1		P
Cyprinella venusta	Blacktail shiner	1		IF
Fundulus notatus	Blackstripe topminnow	17		IF
Mugil cephalus	Striped mullet	1		O
Gambusia affinis	Western mosquofish	1		IF
	Total:	54		

Dickinson Bayou 2	**Collection date:7/14/2011**			
Scientific Name	Common Name	Total Abundance	Tolerance	Trophic Guild
Lepomis cyanellus	Green sunfish	10	T	P
Lepomis macrochirus	Bluegill sunfish	33	T	IF
Lepomis megalotis	Longear sunfish	18		IF
Lepomis microlophus	Redear sunfish	2		IF
Lepomis miniatus	Redspotted sunfish	3		IF
Micropterus salmoides	Largemouth bass	2		P
Pimephales vigilax	Bullhead minnow	1		IF
Fundulus notatus	Blackstripe topminnow	113		IF
Ameiurus natalis	Yellow bullhead	5		O
Noturus gyrinus	Tadpole madtom	1	I	IF
Gambusia affinis	Western mosquofish	114		IF
	Total:	302		

Table E4. All fish captured at Greens Bayou during the first and second sampling events, including abundance, tolerance level and trophic guild.

Greens Bayou 1	**Collection date: 6/15/11**			
Scientific Name	Common Name	Total Abundance	Tolerance	Trophic Guild
Lepomis megalotis	Longear sunfish	3		IF
Pimephales vigilax	Bullhead minnow	74		IF
Ameiurus natalis	Yellow bullhead	1		O
Pterygoplichthys gibbiceps	Sailfin pleco	14	T	H
Gambusia affinis	Western mosquofish	277		IF
Poecilia latipinna	Sailfin molly	4	T	O
	Total:	373		

Greens 2	**Collection date: 8/1/11**			
Scientific Name	Common Name	Total Abundance	Tolerance	Trophic Guild
Lepomis megalotis	Longear sunfish	4		IF
Cichlasomo cyanoguttatum	Rio Grande cichlid	62		IF
Oreochromis aurea	Blue tilapia	1	T	O
Pimephales vigilax	Bullhead minnow	81		IF
Ameiurus natalis	Yellow bullhead	1		O
Pterygoplichthys gibbiceps	Sailfin pleco	4	T	H
Gambusia affinis	Western mosquofish	224		IF
Poecilia latipinna	Sailfin molly	8	T	O
	Total:	385		

Table E5. All fish captured at Lake Creek during the first and second sampling events, including abundance, tolerance level and trophic guild.

Lake Creek 1	**Collection date: 5/10/2011**			
Scientific Name	Common Name	Total Abundance	Tolerance	Trophic Guild
Aphredoderus sayanus	Pirate perch	1		IF
Labidesthes sicculus	Brook silverside	33	I	IF
Moxostoma poecilurum	Blacktail Redhorse	8		IF
Lepomis auritus	Redbreast sunfish	2		IF
Lepomis cyanellus	Green sunfish	8	T	P
Lepomis gulosus	Warmouth	1	T	P
Lepomis macrochirus	Bluegill sunfish	3	T	IF
Lepomis megalotis	Longear sunfish	35		IF
Lepomis miniatus	Redspotted sunfish	2		IF
Micropterus punctulatus	Spotted bass	27		P
Micropterus salmoides	Largemouth bass	12		P
Cyprinella venusta	Blacktail shiner	55		IF
Cyprinus carpio	Common carp	1	T	O
Notemigonus crysoleucas	Golden shiner	1	T	IF
Notropis atrocaudalis	Blackspot shiner	57		IF
Notropis texanus	Weed shiner	5		IF
Pimephales vigilax	Bullhead minnow	11		IF
Fundulus notatus	Blackstripe topminnow	27		IF
Ameiurus natalis	Yellow bullhead	3		O
Noturus nocturnus	Freckled madtom	1	I	IF
Etheostoma chlorosomum	Bluntnose darter	6		IF
Percina sciera	Dusky darter	2	I	IF
Gambusia affinis	Western mosquofish	1		IF
Aplodinotus grunniens	Freshwater drum	1	T	IF
	Total:	303		

Lake Creek 2	**Collection date: 7/22/2011**			
Scientific Name	Common Name	Total Abundance	Tolerance	Trophic Guild
Aphredoderus sayanus	Pirate perch	1		IF
Menida beryllina	Inland silverside	83		IF
Moxostoma poecilurum	Blacktail Redhorse	2		IF
Lepomis cyanellus	Green sunfish	3	T	P
Lepomis macrochirus	Bluegill sunfish	9	T	IF
Lepomis megalotis	Longear sunfish	46		IF
Lepomis microlophus	Redear sunfish	2		IF
Lepomis miniatus	Redspotted sunfish	2		IF
Micropterus punctulatus	Spotted bass	3		P
Micropterus salmoides	Largemouth bass	1		P
Cyprinella lutrensis	Red shiner	1	T	IF
Cyprinella venusta	Blacktail shiner	199		IF
Hybopsis amnis	Pallid shiner	6		IF
Notropis atrocaudalis	Blackspot shiner	4		IF
Notropis texanus	Weed shiner	7		IF
Esox americanus	Redfin pickerel	1		P
Fundulus notatus	Blackstripe topminnow	245		IF
Gambusia affinis	Western mosquofish	21		IF
Lepisosteus oculatus	Spotted gar	1	T	P
	Total:	637		

Table E6. All fish captured at Little Cypress Creek during the first and second sampling events, including abundance, tolerance level and trophic guild.

Little Cypress Creek 1	**Collection date: 6/14/11**			
Scientific Name	Common Name	Total Abundance	Tolerance	Trophic Guild
Aphredoderus sayanus	Pirate perch	3		IF
Lepomis auritus	Redbreast sunfish	6		IF
Lepomis cyanellus	Green sunfish	13	T	P
Lepomis macrochirus	Bluegill sunfish	11	T	IF
Lepomis megalotis	Longear sunfish	9		IF
Lepomis microlophus	Redear sunfish	1		IF
Cyprinella venusta	Blacktail shiner	5		IF
Fundulus notatus	Blackstripe topminnow	34		IF
Ameiurus natalis	Yellow bullhead	2		O
Gambusia affinis	Western mosquofish	263		IF
	Total:	347		

Little Cypress Creek 2	**Collection date: 8/3/11**			
Scientific Name	Common Name	Total Abundance	Tolerance	Trophic Guild
Aphredoderus sayanus	Pirate perch	1		IF
Erimyzon sucetta	Lake chubsucker	1		O
Lepomis cyanellus	Green sunfish	8	T	P
Lepomis gulosus	Warmouth	1	T	P
Lepomis macrochirus	Bluegill sunfish	3	T	IF
Lepomis megalotis	Longear sunfish	8		IF
Micropterus salmoides	Largemouth bass	2		P
Cyprinella venusta	Blacktail shiner	5		IF
Fundulus notatus	Blackstripe topminnow	21		IF
Ameiurus natalis	Yellow bullhead	1		O
Gambusia affinis	Western mosquofish	993		IF
	Total:	1044		

Table E7. All fish captured at Peach Creek during the first and second sampling events, including abundance, tolerance level and trophic guild.

Peach Creek 1	**Collection date: 6/15/11**			
Scientific Name	Common Name	Total Abundance	Tolerance	Trophic Guild
Aphredoderus sayanus	Pirate perch	1		IF
Moxostoma poecilurum	Blacktail Redhorse	20		IF
Lepomis auritus	Redbreast sunfish	1		IF
Lepomis cyanellus	Green sunfish	1	T	P
Lepomis macrochirus	Bluegill sunfish	5	T	IF
Lepomis megalotis	Longear sunfish	12		IF
Lepomis miniatus	Redspotted sunfish	1		IF
Micropterus punctulatus	Spotted bass	10		P
Micropterus salmoides	Largemouth bass	5		P
Cyprinella venusta	Blacktail shiner	95		IF
Hybopsis amnis	Pallid shiner	1		IF
Lythurus umbratilis	Redfin shiner	2		IF
Notemigonus crysoleucas	Golden shiner	3	T	IF
Notropis atrocaudalis	Blackspot shiner	10		IF
Notropis sabinae	Sabine shiner	54		IF
Pimephales vigilax	Bullhead minnow	1		IF
Fundulus notatus	Blackstripe topminnow	67		IF
Ameiurus natalis	Yellow bullhead	2		O
Percina sciera	Dusky darter	3	I	IF
Ammocrypta vivax	Scaly sand darter	12		IF
	Total:	306		

Peach Creek 2	**Collection date: 8/1/11**			
Scientific Name	Common Name	Total Abundance	Tolerance	Trophic Guild
Aphredoderus sayanus	Pirate perch	8		IF
Moxostoma poecilurum	Blacktail Redhorse	7		IF
Lepomis cyanellus	Green sunfish	2	T	P
Lepomis gulosus	Warmouth	1	T	P
Lepomis macrochirus	Bluegill sunfish	9	T	IF
Lepomis megalotis	Longear sunfish	11		IF
Lepomis microlophus	Redear sunfish	7		IF
Lepomis miniatus	Redspotted sunfish	2		IF
Micropterus salmoides	Largemouth bass	4		P
Cyprinella venusta	Blacktail shiner	81		IF
Lythurus umbratilis	Redfin shiner	2		IF
Notemigonus crysoleucas	Golden shiner	3	T	IF
Notropis sabinae	Sabine shiner	14		IF
Pimephales vigilax	Bullhead minnow	4		IF
Fundulus notatus	Blackstripe topminnow	87		IF
Ameiurus natalis	Yellow bullhead	4		O
Noturus gyrinus	Tadpole madtom	2	I	IF
Noturus nocturnus	Freckled madtom	1	I	IF
Percina sciera	Dusky darter	3	I	IF
Ammocrypta vivax	Scaly sand darter	1		IF
Gambusia affinis	Western mosquofish	5		IF
	Total:	258		

Table E8. All fish captured at the West Fork of the San Jacinto River during the first and second sampling events, including abundance, tolerance level and trophic guild.

West Fork of San Jacinto 1	**Collection date: 5/6/11**			
Scientific Name	Common Name	Total Abundance	Tolerance	Trophic Guild
Labidesthes sicculus	Brook silverside	5	I	IF
Carpiodes carpio	River carpsucker	10	T	O
Lepomis auritus	Redbreast sunfish	2		IF
Lepomis cyanellus	Green sunfish	3	T	P
Lepomis humilis	Orangespotted sunfish	1		IF
Lepomis macrochirus	Bluegill sunfish	15	T	IF
Lepomis megalotis	Longear sunfish	55		IF
Lepomis microlophus	Redear sunfish	16		IF
Lepomis miniatus	Redspotted sunfish	5		IF
Micropterus punctulatus	Spotted bass	7		P
Micropterus salmoides	Largemouth bass	3		P
Dorosoma cepedianum	Gizzard shad	5	T	O
Ctenopharyngodon idella	Grass carp	1	T	H
Cyprinella venusta	Blacktail shiner	147		IF
Notemigonus crysoleucas	Golden shiner	1	T	IF
Fundulus chrysotus	Golden topminnow	1		IF
Fundulus notatus	Blackstripe topminnow	27		IF
Ictalurus furcatus	Blue catfish	1		P
Ictalurus punctatus	Channel catfish	6	T	O
Noturus nocturnus	Freckled madtom	1	I	IF
Etheostoma gracile	Slough darter	1		IF
Percina sciera	Dusky darter	1	I	IF
Gambusia affinis	Western mosquofish	6		IF
	Total:	320		

West Fork of San Jacinto 2	Collection date: 7/27/11			
Scientific Name	Common Name	Total Abundance	Tolerance	Trophic Guild
Aphredoderus sayanus	Pirate perch	1		IF
Menida beryllina	Inland silverside	8		IF
Carpiodes carpio	River carpsucker	7	T	O
Lepomis cyanellus	Green sunfish	6	T	P
Lepomis gulosus	Warmouth	2	T	P
Lepomis macrochirus	Bluegill sunfish	22	T	IF
Lepomis megalotis	Longear sunfish	34		IF
Lepomis microlophus	Redear sunfish	4		IF
Lepomis miniatus	Redspotted sunfish	5		IF
Micropterus punctulatus	Spotted bass	6		P
Micropterus salmoides	Largemouth bass	6		P
Dorosoma cepedianum	Gizzard shad	5	T	O
Cyprinella venusta	Blacktail shiner	801		IF
Cyprinus carpio	Common carp	1	T	O
Lythrurus fumeus	Ribbon shiner	9		IF
Notropis volucellus	Mimic shiner	30	I	IF
Fundulus chrysotus	Golden topminnow	3		IF
Fundulus notatus	Blackstripe topminnow	309		IF
Ictalurus punctatus	Channel catfish	6	T	O
Atractosteus spatula	Alligator gar	2	T	P
Percina sciera	Dusky darter	1	I	IF
Gambusia affinis	Western mosquofish	10		IF
	Total:	1278		

Appendix F. IBI calculations for all sites and sampling events

Table F1. IBI calculation of both sampling events at Cedar Bayou

Cedar Bayou 1					**Ecoregion 34**
Metric Category	**Intermediate Totals for Metrics**		**Metric Name**	**Raw Value**	**IBI Score**
	Drainage Basin Size (km^2)	168			
Species Richness and Composition	Number of Fish Species	14	Number of Fish Species	14	5
	Number of Native Cyprinid Species	1	Number of Native Cyprinid Species	1	1
	Number of Benthic Invertivore Species	3	Number of Benthic Invertivore Species	3	5
	Number of Sunfish Species	5	Number of Sunfish Species	5	5
	Number of Intolerant Species	2	Number of Intolerant Species	2	5
	Number of Individuals as Tolerants[a]	17	% of Individuals as Tolerant Species[a]	4.3	5
Trophic Composition	Number of Individuals as Omnivores	0	% of Individuals as Omnivores	0.0	5
	Number of Individuals as Invertivores	387	% of Individuals as Invertivores	98.7	5
Fish Abundance and Condition	Number of Individuals (Seine)	240	Number of Individuals in Sample		2
	Number of Individuals (Shock)	152	Number of Individuals/seine haul	26.7	1
	Number of Individuals in Sample	392	Number of Individuals/min electrofishing	7.58	3
	# of Individuals as Non-native species	0	% of Individuals as Non-native Species	0.0	5
	# of Individuals With Disease/Anomaly	0	% of Individuals With Disease/Anomaly	0.0	5
			Index of Biotic Integrity Numeric Score:		**48**
			Aquatic Life Use:		**High**
This data should be incorporated with water quality, habitat, and other available biological data to assign an overall stream score.					

Cedar Bayou 2				**Ecoregion 34**	
Metric Category	**Intermediate Totals for Metrics**		**Metric Name**	**Raw Value**	**IBI Score**
	Drainage Basin Size (km^2)	168			
Species Richness and Composition	Number of Fish Species	10	Number of Fish Species	10	5
	Number of Native Cyprinid Species	2	Number of Native Cyprinid Species	2	3
	Number of Benthic Invertivore Species	0	Number of Benthic Invertivore Species	0	1
	Number of Sunfish Species	4	Number of Sunfish Species	4	5
	Number of Intolerant Species	0	Number of Intolerant Species	0	1
	Number of Individuals as Tolerants[a]	8	% of Individuals as Tolerant Species[a]	1.1	5
Trophic Composition	Number of Individuals as Omnivores	5	% of Individuals as Omnivores	0.7	5
	Number of Individuals as Invertivores	713	% of Individuals as Invertivores	99.2	5
Fish Abundance and Condition	Number of Individuals (Seine)	638	Number of Individuals in Sample		1
	Number of Individuals (Shock)	81	Number of Individuals/seine haul	70.9	1
	Number of Individuals in Sample	719	Number of Individuals/min electrofishing	3.67	1
	# of Individuals as Non-native species	0	% of Individuals as Non-native Species	0.0	5
	# of Individuals With Disease/Anomaly	0	% of Individuals With Disease/Anomaly	0.0	5
			Index of Biotic Integrity Numeric Score:		**41**
			Aquatic Life Use:		**High**
This data should be incorporated with water quality, habitat, and other available biological data to assign an overall stream score.					

Table F2. IBI calculation of both sampling events at Clear Creek.

Clear Creek 1				Ecoregion 34	
Metric Category	**Intermediate Totals for Metrics**		**Metric Name**	**Raw Value**	**IBI Score**
	Drainage Basin Size (km^2)	103.9			
Species Richness and Composition	Number of Fish Species	15	Number of Fish Species	15	5
	Number of Native Cyprinid Species	3	Number of Native Cyprinid Species	3	5
	Number of Benthic Invertivore Species	1	Number of Benthic Invertivore Species	1	3
	Number of Sunfish Species	5	Number of Sunfish Species	5	5
	Number of Intolerant Species	1	Number of Intolerant Species	1	5
	Number of Individuals as Tolerants[a]	42	% of Individuals as Tolerant Species[a]	5.2	5
Trophic Composition	Number of Individuals as Omnivores	0	% of Individuals as Omnivores	0.0	5
	Number of Individuals as Invertivores	797	% of Individuals as Invertivores	98.5	5
Fish Abundance and Condition	Number of Individuals (Seine)	675	Number of Individuals in Sample		3
	Number of Individuals (Shock)	134	Number of Individuals/seine haul	84.4	1
	Number of Individuals in Sample	809	Number of Individuals/min electrofishing	8.92	5
	# of Individuals as Non-native species	0	% of Individuals as Non-native Species	0.0	5
	# of Individuals With Disease/Anomaly	0	% of Individuals With Disease/Anomaly	0.0	5
			Index of Biotic Integrity Numeric Score:		**51**
			Aquatic Life Use:		**Exceptional**
This data should be incorporated with water quality, habitat, and other available biological data to assign an overall stream score.					

Clear Creek 2				Ecoregion 34	
Metric Category	**Intermediate Totals for Metrics**		**Metric Name**	**Raw Value**	**IBI Score**
	Drainage Basin Size (km^2)	103.9			
Species Richness and Composition	Number of Fish Species	19	Number of Fish Species	19	5
	Number of Native Cyprinid Species	5	Number of Native Cyprinid Species	5	5
	Number of Benthic Invertivore Species	1	Number of Benthic Invertivore Species	1	3
	Number of Sunfish Species	5	Number of Sunfish Species	5	5
	Number of Intolerant Species	0	Number of Intolerant Species	0	1
	Number of Individuals as Tolerants[a]	14	% of Individuals as Tolerant Species[a]	2.2	5
Trophic Composition	Number of Individuals as Omnivores	0	% of Individuals as Omnivores	0.0	5
	Number of Individuals as Invertivores	629	% of Individuals as Invertivores	98.6	5
Fish Abundance and Condition	Number of Individuals (Seine)	568	Number of Individuals in Sample		1
	Number of Individuals (Shock)	70	Number of Individuals/seine haul	81.1	1
	Number of Individuals in Sample	638	Number of Individuals/min electrofishing	2.96	1
	# of Individuals as Non-native species	0	% of Individuals as Non-native Species	0.0	5
	# of Individuals With Disease/Anomaly	0	% of Individuals With Disease/Anomaly	0.0	5
			Index of Biotic Integrity Numeric Score:		**45**
			Aquatic Life Use:		**High**
This data should be incorporated with water quality, habitat, and other available biological data to assign an overall stream score.					

Table F3. IBI calculation of both sampling events at Dickinson Bayou.

Dickinson Bayou 1					**Ecoregion 34**
Metric Category	**Intermediate Totals for Metrics**		**Metric Name**	**Raw Value**	**IBI Score**
	Drainage Basin Size (km^2)	44.5095			
Species Richness and Composition	Number of Fish Species	10	Number of Fish Species	10	5
	Number of Native Cyprinid Species	1	Number of Native Cyprinid Species	1	1
	Number of Benthic Invertivore Species	0	Number of Benthic Invertivore Species	0	1
	Number of Sunfish Species	5	Number of Sunfish Species	5	5
	Number of Intolerant Species	0	Number of Intolerant Species	0	1
	Number of Individuals as Tolerants[a]	12	% of Individuals as Tolerant Species[a]	22.6	5
Trophic Composition	Number of Individuals as Omnivores	1	% of Individuals as Omnivores	1.9	5
	Number of Individuals as Invertivores	43	% of Individuals as Invertivores	81.1	5
Fish Abundance and Condition	Number of Individuals (Seine)	12	Number of Individuals in Sample		1
	Number of Individuals (Shock)	41	Number of Individuals/seine haul	4.0	1
	Number of Individuals in Sample	53	Number of Individuals/min electrofishing	2.05	1
	# of Individuals as Non-native species	0	% of Individuals as Non-native Species	0.0	5
	# of Individuals With Disease/Anomaly	0	% of Individuals With Disease/Anomaly	0.0	5
				Index of Biotic Integrity Numeric Score:	**39**
				Aquatic Life Use:	**High**
This data should be incorporated with water quality, habitat, and other available biological data to assign an overall stream score.					

Dickinson Bayou 2				Ecoregion 34	
Metric Category	**Intermediate Totals for Metrics**		**Metric Name**	**Raw Value**	**IBI Score**
	Drainage Basin Size (km^2)	44.51			
Species Richness and Composition	Number of Fish Species	11	Number of Fish Species	11	5
	Number of Native Cyprinid Species	1	Number of Native Cyprinid Species	1	1
	Number of Benthic Invertivore Species	1	Number of Benthic Invertivore Species	1	3
	Number of Sunfish Species	5	Number of Sunfish Species	5	5
	Number of Intolerant Species	1	Number of Intolerant Species	1	5
	Number of Individuals as Tolerants[a]	42	% of Individuals as Tolerant Species[a]	14.0	5
Trophic Composition	Number of Individuals as Omnivores	5	% of Individuals as Omnivores	1.7	5
	Number of Individuals as Invertivores	284	% of Individuals as Invertivores	94.4	5
Fish Abundance and Condition	Number of Individuals (Seine)	256	Number of Individuals in Sample		1
	Number of Individuals (Shock)	45	Number of Individuals/seine haul	32.0	1
	Number of Individuals in Sample	301	Number of Individuals/min electrofishing	2.07	1
	# of Individuals as Non-native species	0	% of Individuals as Non-native Species	0.0	5
	# of Individuals With Disease/Anomaly	0	% of Individuals With Disease/Anomaly	0.0	5
			Index of Biotic Integrity Numeric Score:		**45**
			Aquatic Life Use:		**High**
This data should be incorporated with water quality, habitat, and other available biological data to assign an overall stream score.					

Table F4. IBI calculation of both sampling events at Greens Bayou.

Greens Bayou 1				Ecoregion 34	
Metric Category	**Intermediate Totals for Metrics**		**Metric Name**	**Raw Value**	**IBI Score**
	Drainage Basin Size (km^2)	139.12			
Species Richness and Composition	Number of Fish Species	6	Number of Fish Species	6	3
	Number of Native Cyprinid Species	1	Number of Native Cyprinid Species	1	1
	Number of Benthic Invertivore Species	0	Number of Benthic Invertivore Species	0	1
	Number of Sunfish Species	1	Number of Sunfish Species	1	1
	Number of Intolerant Species	0	Number of Intolerant Species	0	1
	Number of Individuals as Tolerants[a]	18	% of Individuals as Tolerant Species[a]	4.8	5
Trophic Composition	Number of Individuals as Omnivores	5	% of Individuals as Omnivores	1.3	5
	Number of Individuals as Invertivores	354	% of Individuals as Invertivores	94.9	5
Fish Abundance and Condition	Number of Individuals (Seine)	364	Number of Individuals in Sample		1
	Number of Individuals (Shock)	9	Number of Individuals/seine haul	36.4	1
	Number of Individuals in Sample	373	Number of Individuals/min electrofishing	0.39	1
	# of Individuals as Non-native species	14	% of Individuals as Non-native Species	3.8	1
	# of Individuals With Disease/Anomaly	0	% of Individuals With Disease/Anomaly	0.0	5
			Index of Biotic Integrity Numeric Score:		**29**
			Aquatic Life Use:		**Limited**
This data should be incorporated with water quality, habitat, and other available biological data to assign an overall stream score.					

Greens Bayou 2				Ecoregion 34	
Metric Category	**Intermediate Totals for Metrics**		**Metric Name**	**Raw Value**	**IBI Score**
	Drainage Basin Size (km^2)	139.12			
Species Richness and Composition	Number of Fish Species	8	Number of Fish Species	8	3
	Number of Native Cyprinid Species	1	Number of Native Cyprinid Species	1	1
	Number of Benthic Invertivore Species	0	Number of Benthic Invertivore Species	0	1
	Number of Sunfish Species	1	Number of Sunfish Species	1	1
	Number of Intolerant Species	0	Number of Intolerant Species	0	1
	Number of Individuals as Tolerants[a]	13	% of Individuals as Tolerant Species[a]	3.4	5
Trophic Composition	Number of Individuals as Omnivores	10	% of Individuals as Omnivores	2.6	5
	Number of Individuals as Invertivores	371	% of Individuals as Invertivores	96.4	5
Fish Abundance and Condition	Number of Individuals (Seine)	383	Number of Individuals in Sample		1
	Number of Individuals (Shock)	2	Number of Individuals/seine haul	38.3	1
	Number of Individuals in Sample	385	Number of Individuals/min electrofishing	0.11	1
	# of Individuals as Non-native species	5	% of Individuals as Non-native Species	1.3	5
	# of Individuals With Disease/Anomaly	0	% of Individuals With Disease/Anomaly	0.0	5
			Index of Biotic Integrity Numeric Score:		**33**
			Aquatic Life Use:		**Intermediate**
This data should be incorporated with water quality, habitat, and other available biological data to assign an overall stream score.					

Table F5. IBI calculation of both sampling events at Little Cypress Creek.

Little Cypress Creek 1				**Ecoregion 34**	
Metric Category	**Intermediate Totals for Metrics**		**Metric Name**	**Raw Value**	**IBI Score**
	Drainage Basin Size (km^2)	116.2			
Species Richness and Composition	Number of Fish Species	10	Number of Fish Species	10	5
	Number of Native Cyprinid Species	1	Number of Native Cyprinid Species	1	1
	Number of Benthic Invertivore Species	0	Number of Benthic Invertivore Species	0	1
	Number of Sunfish Species	5	Number of Sunfish Species	5	5
	Number of Intolerant Species	0	Number of Intolerant Species	0	1
	Number of Individuals as Tolerants[a]	24	% of Individuals as Tolerant Species[a]	6.9	5
Trophic Composition	Number of Individuals as Omnivores	2	% of Individuals as Omnivores	0.6	5
	Number of Individuals as Invertivores	332	% of Individuals as Invertivores	95.7	5
Fish Abundance and Condition	Number of Individuals (Seine)	296	Number of Individuals in Sample		1
	Number of Individuals (Shock)	51	Number of Individuals/seine haul	29.6	1
	Number of Individuals in Sample	347	Number of Individuals/min electrofishing	3.00	1
	# of Individuals as Non-native species	6	% of Individuals as Non-native Species	1.7	3
	# of Individuals With Disease/Anomaly	0	% of Individuals With Disease/Anomaly	0.0	5
			Index of Biotic Integrity Numeric Score:		**37**
			Aquatic Life Use:		**Intermediate**
This data should be incorporated with water quality, habitat, and other available biological data to assign an overall stream score.					

Little Cypress Creek 2				Ecoregion 34	
Metric Category	**Intermediate Totals for Metrics**		**Metric Name**	**Raw Value**	**IBI Score**
	Drainage Basin Size (km^2)	116.2			
Species Richness and Composition	Number of Fish Species	11	Number of Fish Species	11	5
	Number of Native Cyprinid Species	1	Number of Native Cyprinid Species	1	1
	Number of Benthic Invertivore Species	0	Number of Benthic Invertivore Species	0	1
	Number of Sunfish Species	4	Number of Sunfish Species	4	5
	Number of Intolerant Species	0	Number of Intolerant Species	0	1
	Number of Individuals as Tolerants[a]	12	% of Individuals as Tolerant Species[a]	1.1	5
Trophic Composition	Number of Individuals as Omnivores	2	% of Individuals as Omnivores	0.2	5
	Number of Individuals as Invertivores	1032	% of Individuals as Invertivores	98.8	5
Fish Abundance and Condition	Number of Individuals (Seine)	1017	Number of Individuals in Sample		2
	Number of Individuals (Shock)	28	Number of Individuals/seine haul	101.7	3
	Number of Individuals in Sample	1045	Number of Individuals/min electrofishing	1.24	1
	# of Individuals as Non-native species	0	% of Individuals as Non-native Species	0.0	5
	# of Individuals With Disease/Anomaly	0	% of Individuals With Disease/Anomaly	0.0	5
			Index of Biotic Integrity Numeric Score:		**40**
			Aquatic Life Use:		**High**

This data should be incorporated with water quality, habitat, and other available biological data to assign an overall stream score.

Table F6. IBI calculation of both sampling events at Lake Creek.

Lake Creek 1				Ecoregions 33 & 35	
Metric Category	**Intermediate Totals for Metrics**		**Metric Name**	**Raw Value**	**IBI Score**
	Drainage Basin Size (km^2)	754.79			
Species Richness and Composition	Number of Fish Species	24	Number of Fish Species	24	5
	Number of Native Cyprinid Species	5	Number of Native Cyprinid Species	5	5
	Number of Benthic Invertivore Species	4	Number of Benthic Invertivore Species	4	3
	Number of Sunfish Species	6	Number of Sunfish Species	6	5
	Number of Intolerant Species	3	Number of Intolerant Species	3	3
	Number of Individuals as Tolerants[a]	15	% of Individuals as Tolerant Species[a]	5.0	5
Trophic Composition	Number of Individuals as Omnivores	4	% of Individuals as Omnivores	1.3	5
	Number of Individuals as Invertivores	246	% of Individuals as Invertivores	82.6	5
	Number of Individuals as Piscivores	48	% of Individuals as Piscivores	16.1	5
Fish Abundance and Condition	Number of Individuals (Seine)	234	Number of Individuals in Sample		3
	Number of Individuals (Shock)	64	Number of Individuals/seine haul	39.0	5
	Number of Individuals in Sample	298	Number of Individuals/min electrofishing	2.99	1
	# of Individuals as Non-native species	2	% of Individuals as Non-native Species	0.7	5
	# of Individuals With Disease/Anomaly	0	% of Individuals With Disease/Anomaly	0.0	5
			Index of Biotic Integrity Numeric Score:		**54**
			Aquatic Life Use:		**Exceptional**
This data should be incorporated with water quality, habitat, and other available biological data to assign an overall stream score.					

Lake Creek 2				Ecoregions 33 & 35	
Metric Category	**Intermediate Totals for Metrics**		**Metric Name**	**Raw Value**	**IBI Score**
	Drainage Basin Size (km^2)	754.7895			
Species Richness and Composition	Number of Fish Species	19	Number of Fish Species	19	5
	Number of Native Cyprinid Species	5	Number of Native Cyprinid Species	5	5
	Number of Benthic Invertivore Species	1	Number of Benthic Invertivore Species	1	1
	Number of Sunfish Species	5	Number of Sunfish Species	5	5
	Number of Intolerant Species	0	Number of Intolerant Species	0	1
	Number of Individuals as Tolerants[a]	14	% of Individuals as Tolerant Species[a]	2.2	5
Trophic Composition	Number of Individuals as Omnivores	0	% of Individuals as Omnivores	0.0	5
	Number of Individuals as Invertivores	628	% of Individuals as Invertivores	98.6	5
	Number of Individuals as Piscivores	9	% of Individuals as Piscivores	1.4	1
Fish Abundance and Condition	Number of Individuals (Seine)	567	Number of Individuals in Sample		4
	Number of Individuals (Shock)	70	Number of Individuals/seine haul	81.0	5
	Number of Individuals in Sample	637	Number of Individuals/min electrofishing	4.21	3
	# of Individuals as Non-native species	0	% of Individuals as Non-native Species	0.0	5
	# of Individuals With Disease/Anomaly	0	% of Individuals With Disease/Anomaly	0.0	5
			Index of Biotic Integrity Numeric Score:		**47**
			Aquatic Life Use:		**High**
This data should be incorporated with water quality, habitat, and other available biological data to assign an overall stream score.					

Table F7. IBI calculation of both sampling events at Peach Creek

Peach Creek 1				**Ecoregions 33 & 35**	
Metric Category	**Intermediate Totals for Metrics**		**Metric Name**	**Raw Value**	**IBI Score**
	Drainage Basin Size (km^2)	403.47			
Species Richness and Composition	Number of Fish Species	20	Number of Fish Species	20	5
	Number of Native Cyprinid Species	7	Number of Native Cyprinid Species	7	5
	Number of Benthic Invertivore Species	3	Number of Benthic Invertivore Species	3	3
	Number of Sunfish Species	5	Number of Sunfish Species	5	5
	Number of Intolerant Species	1	Number of Intolerant Species	1	1
	Number of Individuals as Tolerants[a]	9	% of Individuals as Tolerant Species[a]	2.9	5
Trophic Composition	Number of Individuals as Omnivores	2	% of Individuals as Omnivores	0.7	5
	Number of Individuals as Invertivores	289	% of Individuals as Invertivores	94.1	5
	Number of Individuals as Piscivores	16	% of Individuals as Piscivores	5.2	3
Fish Abundance and Condition	Number of Individuals (Seine)	267	Number of Individuals in Sample		2
	Number of Individuals (Shock)	40	Number of Individuals/seine haul	26.7	3
	Number of Individuals in Sample	307	Number of Individuals/min electrofishing	1.98	1
	# of Individuals as Non-native species	1	% of Individuals as Non-native Species	0.3	5
	# of Individuals With Disease/Anomaly	0	% of Individuals With Disease/Anomaly	0.0	5
			Index of Biotic Integrity Numeric Score:		**49**
			Aquatic Life Use:		**High**
This data should be incorporated with water quality, habitat, and other available biological data to assign an overall stream score.					

Peach Creek 2				Ecoregions 33 & 35	
Metric Category	**Intermediate Totals for Metrics**		**Metric Name**	**Raw Value**	**IBI Score**
	Drainage Basin Size (km^2)	403.47			
Species Richness and Composition	Number of Fish Species	21	Number of Fish Species	21	5
	Number of Native Cyprinid Species	5	Number of Native Cyprinid Species	5	5
	Number of Benthic Invertivore Species	5	Number of Benthic Invertivore Species	5	5
	Number of Sunfish Species	6	Number of Sunfish Species	6	5
	Number of Intolerant Species	3	Number of Intolerant Species	3	3
	Number of Individuals as Tolerants[a]	7	% of Individuals as Tolerant Species[a]	2.8	5
Trophic Composition	Number of Individuals as Omnivores	4	% of Individuals as Omnivores	1.6	5
	Number of Individuals as Invertivores	239	% of Individuals as Invertivores	95.6	5
	Number of Individuals as Piscivores	7	% of Individuals as Piscivores	2.8	1
Fish Abundance and Condition	Number of Individuals (Seine)	198	Number of Individuals in Sample		2
	Number of Individuals (Shock)	52	Number of Individuals/seine haul	19.8	3
	Number of Individuals in Sample	250	Number of Individuals/min electrofishing	2.43	1
	# of Individuals as Non-native species	0	% of Individuals as Non-native Species	0.0	5
	# of Individuals With Disease/Anomaly	0	% of Individuals With Disease/Anomaly	0.0	5
				Index of Biotic Integrity Numeric Score:	**51**
				Aquatic Life Use:	**High**

This data should be incorporated with water quality, habitat, and other available biological data to assign an overall stream score.

Table F8. IBI calculation of both sampling events at West Fork San Jacinto

West Fork San Jacinto 1				**Ecoregions 33 & 35**	
Metric Category	**Intermediate Totals for Metrics**		**Metric Name**	**Raw Value**	**IBI Score**
	Drainage Basin Size (km^2)	1329.971			
Species Richness and Composition	Number of Fish Species	23	Number of Fish Species	23	5
	Number of Native Cyprinid Species	2	Number of Native Cyprinid Species	2	3
	Number of Benthic Invertivore Species	3	Number of Benthic Invertivore Species	3	3
	Number of Sunfish Species	7	Number of Sunfish Species	7	5
	Number of Intolerant Species	3	Number of Intolerant Species	3	3
	Number of Individuals as Tolerants[a]	41	% of Individuals as Tolerant Species[a]	12.8	5
Trophic Composition	Number of Individuals as Omnivores	21	% of Individuals as Omnivores	6.6	5
	Number of Individuals as Invertivores	284	% of Individuals as Invertivores	88.8	5
	Number of Individuals as Piscivores	14	% of Individuals as Piscivores	4.4	1
Fish Abundance and Condition	Number of Individuals (Seine)	157	Number of Individuals in Sample		4
	Number of Individuals (Shock)	163	Number of Individuals/seine haul	26.2	3
	Number of Individuals in Sample	320	Number of Individuals/min electrofishing	8.13	5
	# of Individuals as Non-native species	3	% of Individuals as Non-native Species	0.9	5
	# of Individuals With Disease/Anomaly	0	% of Individuals With Disease/Anomaly	0.0	5
			Index of Biotic Integrity Numeric Score:		**49**
			Aquatic Life Use:		**High**
This data should be incorporated with water quality, habitat, and other available biological data to assign an overall stream score.					

West Fork San Jacinto 2				Ecoregions 33 & 35	
Metric Category	**Intermediate Totals for Metrics**		**Metric Name**	**Raw Value**	**IBI Score**
	Drainage Basin Size (km^2)	1329.97			
Species Richness and Composition	Number of Fish Species	22	Number of Fish Species	22	5
	Number of Native Cyprinid Species	3	Number of Native Cyprinid Species	3	3
	Number of Benthic Invertivore Species	1	Number of Benthic Invertivore Species	1	1
	Number of Sunfish Species	6	Number of Sunfish Species	6	5
	Number of Intolerant Species	2	Number of Intolerant Species	2	3
	Number of Individuals as Tolerants[a]	51	% of Individuals as Tolerant Species[a]	4.0	5
Trophic Composition	Number of Individuals as Omnivores	19	% of Individuals as Omnivores	1.5	5
	Number of Individuals as Invertivores	1237	% of Individuals as Invertivores	97.2	5
	Number of Individuals as Piscivores	17	% of Individuals as Piscivores	1.3	1
Fish Abundance and Condition	Number of Individuals (Seine)	1165	Number of Individuals in Sample		4
	Number of Individuals (Shock)	108	Number of Individuals/seine haul	166.4	5
	Number of Individuals in Sample	1273	Number of Individuals/min electrofishing	5.90	3
	# of Individuals as Non-native species	1	% of Individuals as Non-native Species	0.1	5
	# of Individuals With Disease/Anomaly	0	% of Individuals With Disease/Anomaly	0.0	5
			Index of Biotic Integrity Numeric Score:		**47**
			Aquatic Life Use:		**High**
This data should be incorporated with water quality, habitat, and other available biological data to assign an overall stream score.					

Appendix G. Cluster analysis results

Table G1. Cluster analysis observations: seining

Squared Euclidean Distance, Ward Linkage
Amalgamation Steps

Step	Number of clusters	Similarity level	Distance level	Clusters joined		New cluster	Number of obs. in new cluster
1	15	99.8818	28.2	3	15	3	2
2	14	99.7383	62.4	6	14	6	2
3	13	99.6580	81.5	3	7	3	3
4	12	99.5595	105.0	6	8	6	3
5	11	99.5143	115.8	1	3	1	4
6	10	98.9167	258.3	1	5	1	5
7	9	98.8342	277.9	1	4	1	6
8	8	98.0769	458.4	6	9	6	4
9	7	97.7425	538.2	2	11	2	2
10	6	93.2629	1606.0	10	13	10	2
11	5	91.6721	1985.2	2	16	2	3
12	4	88.5000	2741.4	1	6	1	10
13	3	83.0557	4039.3	1	10	1	12
14	2	16.7555	19844.2	1	2	1	15
15	1	-3.4014	24649.3	1	12	1	16

Final Partition
Number of clusters: 3

	Number of observations	Within cluster sum of squares	Average distance from centroid	Maximum distance from centroid
Cluster1	12	4887.09	18.2154	36.0620
Cluster2	3	1261.70	18.3565	25.7244
Cluster3	1	0.00	0.0000	0.0000

Cluster Centroids

Variable	Cluster1	Cluster2	Cluster3	Grand centroid
Lepisosteus oculatus	0.0119	0.0476	0.000	0.0179
Cyprinella lutrensis	1.3095	0.7619	0.000	1.1250
Cyprinella venusta	6.9569	0.8704	114.000	12.5059
Notemigonus crysoleucas	0.0639	0.0370	0.000	0.0549
Notropis atrocaudalis	0.8929	0.0000	0.000	0.6696
Notropis sabinae	0.5667	0.0000	0.000	0.4250
Pimephales vigilax	1.7199	1.3810	0.000	1.5489
Moxostoma poecilurum	0.2508	0.0000	0.000	0.1881
Ameiurus natalis	0.0569	0.0000	0.000	0.0427
Noturus gyrinus	0.0197	0.0476	0.000	0.0237
Aphredoderus sayanus	0.0231	0.0000	0.000	0.0174
Fundulus chrysotus	0.0000	0.5185	0.429	0.1240

Fundulus notatus	10.9697	11.0212	41.857	12.9098
Gambusia affinis	10.2203	74.1725	1.429	21.6619
Poecilia latipinna	0.1000	0.1481	0.000	0.1028
Labidesthes sicculus	0.4861	0.0000	0.000	0.3646
Menida beryllina	2.2500	0.1905	1.143	1.7946
Lepomis cyanellus	0.1681	0.1810	0.286	0.1778
Lepomis macrochirus	0.5662	0.0810	1.286	0.5202
Lepomis megalotis	0.2764	0.0667	0.143	0.2287
Micropterus punctulatus	0.4758	0.0000	0.000	0.3568
Micropterus salmoides	0.1944	0.0667	0.286	0.1762
Ammocrypta vivax	0.1083	0.0000	0.000	0.0813
Percina sciera	0.0333	0.0000	0.000	0.0250
Cichlasomo cyanoguttatum	0.6119	0.0000	0.000	0.4589
sailfin pleco	0.1500	0.0000	0.000	0.1125

Distances Between Cluster Centroids

	Cluster1	Cluster2	Cluster3
Cluster1	0.000	64.298	111.796
Cluster2	64.298	0.000	138.007
Cluster3	111.796	138.007	0.000

Table G2. Cluster analysis observations: electrofishing

Squared Euclidean Distance, Ward Linkage
Amalgamation Steps

Step	Number of clusters	Similarity level	Distance level	Clusters joined		New cluster	Number of obs. in new cluster
1	15	99.6020	2.451	6	14	6	2
2	14	99.5129	3.000	1	9	1	2
3	13	98.3338	10.262	6	16	6	3
4	12	97.9298	12.750	1	7	1	3
5	11	96.7932	19.750	5	10	5	2
6	10	96.1691	23.594	1	15	1	4
7	9	94.3221	34.969	1	5	1	6
8	8	92.8097	44.284	6	8	6	4
9	7	91.2320	54.000	12	13	12	2
10	6	89.3251	65.744	1	6	1	10
11	5	84.9416	92.741	3	12	3	3
12	4	82.5188	107.662	3	4	3	4
13	3	43.8635	345.731	2	3	2	5
14	2	9.7707	555.700	1	11	1	11
15	1	-46.3091	901.081	1	2	1	16

Final Partition
Number of clusters: 4

	Number of observations	Within cluster sum of squares	Average distance from centroid	Maximum distance from centroid
Cluster1	10	108.401	3.17824	4.78555

Cluster2	1	0.000	0.00000	0.00000
Cluster3	4	127.201	5.60600	6.35400
Cluster4	1	0.000	0.00000	0.00000

Cluster Centroids

Variable	Cluster1	Cluster2	Cluster3	Cluster4	Grand centroid
Dorosoma cepedianum	0.00000	0.0000	0.7292	0.00	0.18229
Carpiodes carpio	0.00000	0.0000	1.1458	0.00	0.28646
Cyprinella lutrensis	0.02500	4.6667	0.0000	0.00	0.30729
Cyprinella venusta	0.32500	1.3333	3.3958	0.00	1.13542
Pimephales vigilax	0.20000	10.6667	0.0000	0.00	0.79167
Moxostoma poecilurum	0.22500	0.0000	0.0833	0.00	0.16146
Ameiurus natalis	0.40000	0.0000	0.0000	0.00	0.25000
Ictalurus punctatus	0.00000	0.0000	0.8750	0.00	0.21875
Noturus gyrinus	0.07500	0.0000	0.0000	0.00	0.04688
Noturus nocturnus	0.02500	0.0000	0.1875	0.00	0.06250
Aphredoderus sayanus	0.35000	0.0000	0.2292	0.00	0.27604
Fundulus chrysotus	0.00000	0.0000	0.1875	0.25	0.06250
Fundulus notatus	1.27500	1.3333	2.3125	0.50	1.48958
Gambusia affinis	1.02500	6.6667	0.4792	18.25	2.31771
Lepomis auritus	0.24167	0.0000	0.1250	0.00	0.18229
Lepomis cyanellus	0.87500	2.0000	0.9583	0.25	0.92708
Lepomis gulosus	0.07500	0.6667	0.1667	0.00	0.13021
Lepomis macrochirus	0.88333	0.0000	2.8333	0.25	1.27604
Lepomis megalotis	2.85833	16.3333	12.2292	0.25	5.88021
Lepomis microlophus	0.25833	0.0000	1.4167	0.25	0.53125
Lepomis miniatus	0.25000	0.3333	2.5833	0.00	0.82292
Micropterus punctulatus	0.05000	0.0000	0.5625	0.00	0.17188
Micropterus salmoides	0.22500	0.0000	0.7292	0.00	0.32292
Etheostoma gracile	0.00000	0.0000	0.1250	0.00	0.03125
Percina sciera	0.10000	0.0000	0.1458	0.00	0.09896
Cichlasomo cyanoguttatum	0.02500	0.3333	0.0000	0.00	0.03646

Distances Between Cluster Centroids

	Cluster1	Cluster2	Cluster3	Cluster4
Cluster1	0.0000	18.6694	10.6152	17.4824
Cluster2	18.6694	0.0000	14.6997	23.1256
Cluster3	10.6152	14.6997	0.0000	22.2029
Cluster4	17.4824	23.1256	22.2029	0.0000

Appendix H. Box plots of cluster membership and impervious surfaces (PIA and TIA).

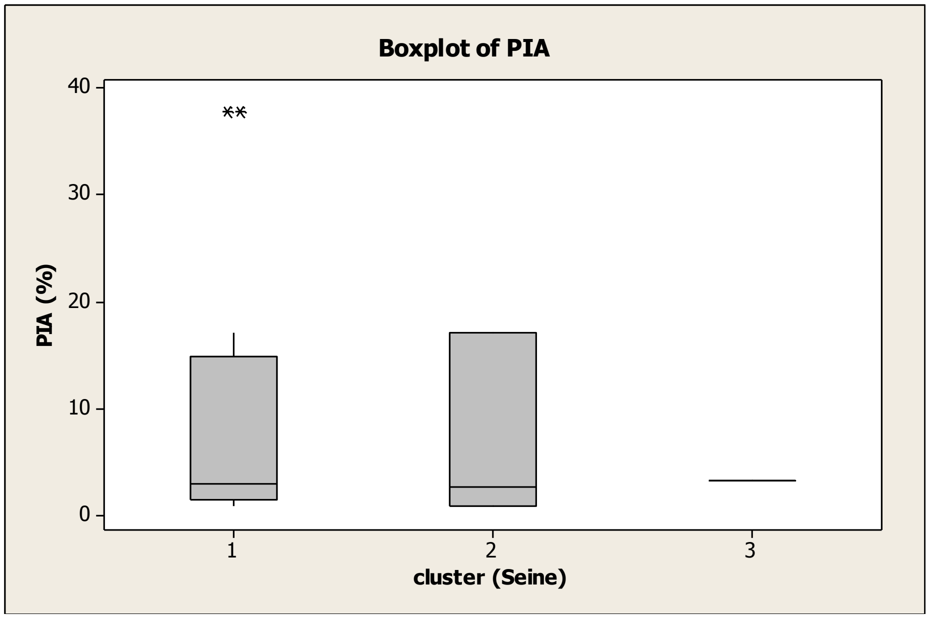

Figure H1. Boxplots of fish cluster membership (collected by seine) and PIA.

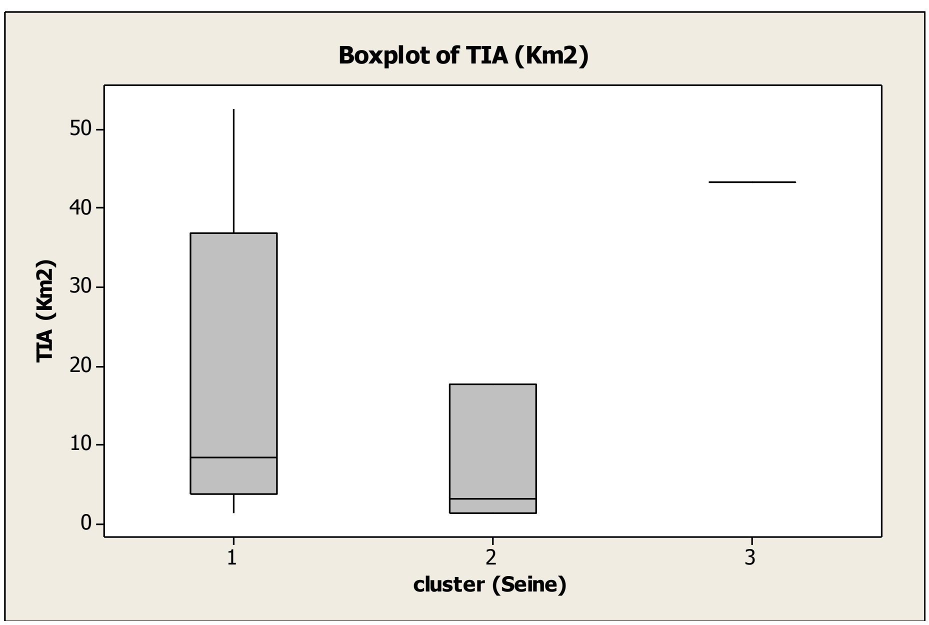

Figure H2. Boxplots of fish cluster membership (collected by seine) and TIA.

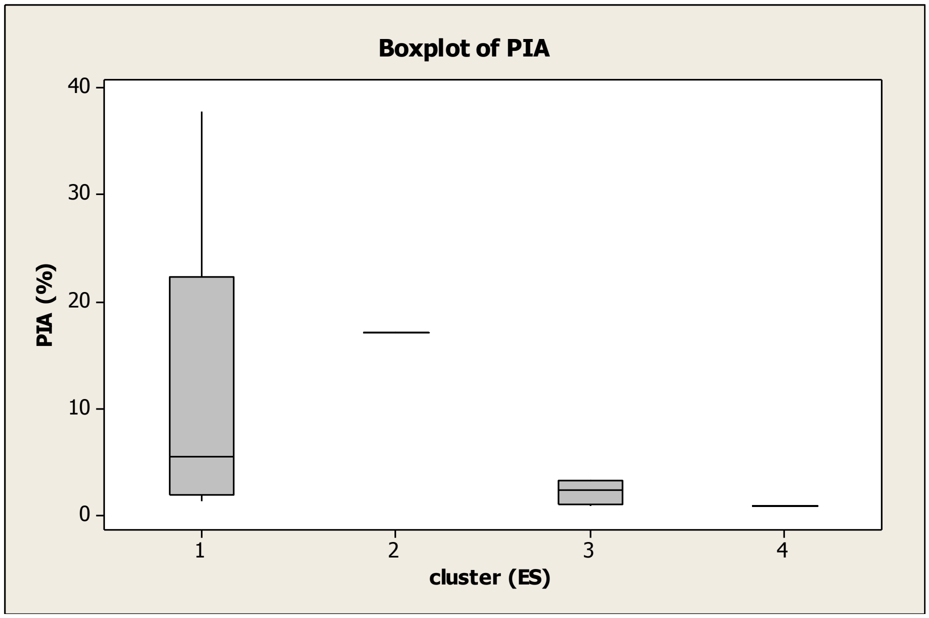

Figure H3. Boxplots of fish cluster membership (collected by electrofishing) and PIA.

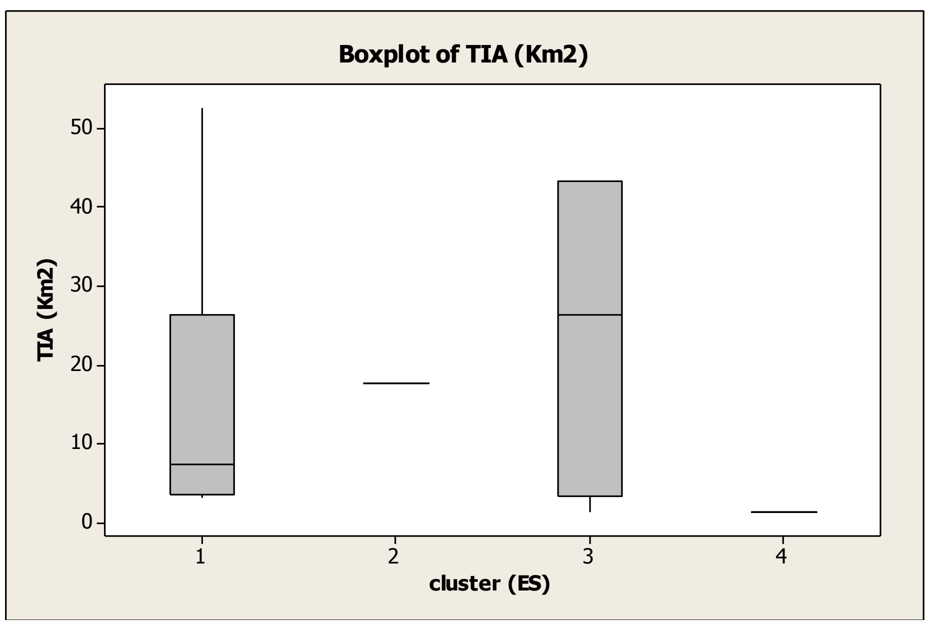

Figure H4. Boxplots of fish cluster membership (collected by electrofishing) and TIA.