Aquatic Life Monitoring Study Report

Prepared in cooperation with the Houston-Galveston Area Council and the Texas Commission on Environmental Quality
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Aquatic Life Monitoring Study Report

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EXECUTIVE SUMMARY

During 1997-1998, the United States Geological Survey (USGS), in cooperation with the Houston-Galveston Area Council (H-GAC) and the Texas Natural Resource Conservation Commission (TNRCC, predecessor agency to Texas Commission on Environmental Quality, TCEQ), under the authorization of the Texas Clean Rivers Act, conducted an investigation to define the status of in-stream biological resources including fish and macrobenthic community structure, and stream physical habitat conditions. The study objective was to conduct a status assessment of the in-stream biological resources at above-tidal stream sites throughout the H-GAC service area. The USGS compiled all the fish, benthic macroinvertebrate, stream habitat, and basic field chemistry data collected from the study into two reports. Fish community and stream habitat data were collected at multiple sites selected while benthic macroinvertebrate data were collected at selected sites. Each location was monitored only once. The USGS drew several conclusions from the comparison of stream-habitat and biological integrity scores computed. First, in drainage areas that were heavily forested and had fewer people per square mile, the reaches generally had larger stream-habitat integrity scores. They also found that stream-habitat integrity scores were significantly positively correlated with biological integrity scores. Finally, they found that smaller biological integrity scores were associated with more simplified stream-habitat conditions generally found in the urban reaches.

It has been twelve years since the previous studies were conducted and, since then, several of the areas have experienced population growth and development. The Environmental Institute of Houston at the University of Houston – Clear Lake (EIH) was contracted by H-GAC to conduct biological monitoring at five of the original USGS sites. The objective of this study was to determine whether selected reaches have experienced any changes in water quality or their biological integrity scores. Data describing the physical, chemical, and biological characteristics of each water body, including Cedar Bayou, Clear Creek, Dickinson Bayou, Lake Creek and the West Fork of the San Jacinto River was collected and compared against the assigned water quality standards for each segment. The secondary goal of this study was to determine whether the water quality and, hence, biotic integrity have changed over time. Sampling was conducted during the index and critical periods in 2011.

Several data availability issues were encountered during this study. This includes 1) lack of available 24-hr data for dissolved oxygen during the 1997-98 USGS study, 2) lack of benthic samples for one site monitored in 1997-98 and 3) lack of electrofishing data for two of the 1997 sites. As a result we were unable to directly compare 24-hr dissolved oxygen data collected during this study with the 1997-98 time period. We also had to exclude sites lacking historical benthic data from 1997-98 from our time series analysis. However, we conducted a supplemental analysis of the fish communities using the statewide fish IBI to compare sites since this method does not require electrofishing data.

Based on the results of this study we can conclude that most of the sites are supporting aquatic life and their respective assigned aquatic life use categories and water quality standards. This conclusion is based on the "weight of evidence" provided by 1) water quality data, 2) fish community data, 3) benthic community data and 4) habitat data. Aquatic life use assessments using the regionalized fish IBI suggest that all sites are meeting their assigned ALU rankings and

have either improved or remained constant during the period from 1997 to 2011. In contrast assessments of fish communities based on the statewide IBI generally resulted in lower ALU values compared to the regionalized IBI. This is likely due to the difference on how the IBI scores are calculated between these two methods. The current accepted regionalized fish IBI approach takes into account the maximum community integrity possible for a specific ecoregion. Based on multivariate analysis of community structure, fish communities did not appear to have changed much since originally surveyed in 1997.

Aquatic life use assessments based on benthic communities also documented that most sites showed similar attainment of assigned aquatic life uses and/or improvements since the 1997 USGS survey with the exception of Lake Creek. The Lake Creek site exhibited higher taxa richness during the initial USGS study in 1997 as compared to a decreased richness observed during the critical period of the EIH study in 2011. Our analysis indicated that there were significant differences in benthic species composition between the 1997 and 2011 collections. These changes probably contributed significantly to the higher Benthic IBI scores observed in 2011 at most sites. Interestingly the fish IBI score was not correlated with the benthic IBI scores. This probably reflects the fact that impacts on fish communities are normally detected only when watershed scale stressors are affecting them. This is due to their mobility and ability to recolonize disturbed areas. In contrast benthic organisms are more sensitive to localized impacts.

Physical habitat data collected by EIH calculated an intermediate habitat quality for most sites and sampling periods except for the critical period for Cedar Bayou which had a “high” rating, and the critical period for Clear Creek which exhibited a “limited” rating. Based on these rankings the majority of the sites monitored did not appear to have adequate habitat to support the higher designated aquatic life use, although based on the fish and benthic IBI’s these sites were meeting their designated use. This suggests that for coastal and inland streams located in the study area the existing physical habitat index of biotic integrity (PHIBI) algorithm may need to be further calibrated against existing biological community data.

In contrast to the biologically derived fish and benthic IBI scores, several of the streams studied do not appear to be supporting assigned aquatic life uses based on diel dissolved oxygen (D.O.) data alone. Only one site (Dickinson Bayou) met the standard for 24-hr average D.O. mg/L, however it did not meet absolute minima D.O. mg/L standard during the critical event. Only two sites, Cedar Bayou and the West Fork of the San Jacinto River, met the standard for the absolute minima D.O. mg/L standard during both sampling events. Due to lack of data we could not compare 24-hr data collected from this study with the 1997-98 time period. However, while comparisons of single data points cannot be statistically analyzed for significance, in every case the instantaneous D.O. measurements from the 1997-98 USGS data were greater than those of the EIH study from the same sample period nearly 14 years later. Dissolved oxygen is a limiting factor for fish and benthic macroinvertebrate communities. Based on the lack of a strong statistical correlation between any of the diel dissolved oxygen metrics and the fish and benthic IBI, fish and benthic invertebrates along the coastal regions in the study areas may be adapted to the suite of physico-chemical condition (e.g. low velocity, salt wedge, turbid water, and high temperatures) which limit dissolved oxygen reaeration and are commonly encountered in slow moving coastal water bodies. In contrast to 24-hr oxygen metrics, very few excursions were observed for the other remaining water chemistry parameters (*E. coli*, chlorides, and sulfates) which have listed standards for each water body.

Due to the drought conditions existing during the 2011 study and the lack of sufficient stream flow data during the USGS study, we highly recommend repeating this study within the next few years to evaluate the role of hydrology on the response variables including the 24-hr diel oxygen standards, water quality variables, physical habitat, biological communities and the various IBI metrics. In addition, multiple sites representing replicate samples within each watershed should be evaluated to determine support of designated aquatic life uses to reduce the influence of a single aberrant observation. Finally, we strongly recommend conducting a detailed analysis of changes in land-use and land-cover to evaluate the potential influence of this controlling variable on flow regime and resulting water quality and physical habitat. Based on our study there is evidence of potential degradation of aquatic life use in the Lake Creek watershed. This may be occurring due to changes in watershed scale land use and the resulting alterations in hydrology, physical habitat and water quality.

INTRODUCTION

Problem Statement

During 1997-1998, the USGS, in cooperation with the H-GAC and the TNRCC (predecessor agency to the TCEQ), under the authorization of the Texas Clean Rivers Act, conducted an investigation to define the status of in-stream biological resources including fish and macrobenthic community structure, and stream physical habitat conditions. The study objective was to conduct a status assessment of the in-stream biological resources at above-tidal stream sites throughout the H-GAC service area. The USGS compiled all the fish, benthic macroinvertebrate, stream habitat, and basic field chemistry data collected from the study into two reports: 1) *Fish, Benthic Macroinvertebrate, and Stream Habitat Data from the Houston-Galveston Area Council Service Area, Texas, 1997-1998* (USGS Open File Report 98-658) and 2) *Influence of Stream Habitat and Land Use on Benthic Macroinvertebrate Indicators of Stream Quality of Selected Above-Tidal Streams in the Houston-Galveston Area Council Service Area, Texas, 1997-1998* (USGS Water Resources Investigations Report 01-4010)((Moring 2001; Moring et al. 1998)) . Fish community and stream habitat data were collected at all 56 sites selected while benthic macroinvertebrate data were collected at only 39 of the sites. Each location was monitored once.

The USGS drew several conclusions from the comparison of stream-habitat and biological integrity scores computed for each of the 31 reaches discussed in the USGS Water-Resources Investigation Report 01-4010. First, in drainage areas that were heavily forested and had fewer people per square mile, the reaches generally had larger stream-habitat integrity scores. They also found that stream-habitat integrity scores were significantly positively correlated with biological integrity scores. Finally, they found that smaller biological integrity scores were associated with more simplified stream-habitat conditions generally found in the urban reaches.

It has been twelve years since the previous studies were conducted and, since then, several of the areas have experienced population growth and development. The Environmental Institute of Houston at the University of Houston – Clear Lake (EIH) was contracted by H-GAC to conduct biological monitoring at five of the original USGS sites. The objective of this study was to determine whether the reaches have experienced any changes in water quality or their biological integrity scores. Data describing the physical, chemical, and biological characteristics of each water body was collected and compared against the assigned water quality standards for each segment. The secondary goal of this study was to determine whether the water quality and, hence, biotic integrity have changed over time.

Study Objective

The overall goals of this study were two-fold. The first, major goal was to collect environmental data describing physical, chemical, and biological characteristics of each selected water body and compare this data against the assigned water quality standards for each stream segment and Aquatic Life Use (ALU) designations/dissolved oxygen (D.O.) criteria (using regional metrics). The second major goal was to compare current biological integrity scores with previously determined scores to identify which waterways may have exhibited a decline in water quality over time. The primary objective of this study was to collect sufficient water quality data from each of the 5 selected locations for completion of the two study goals. Additional objectives of this biological monitoring study were to: 1) produce a current inventory of fish and benthic macroinvertebrate communities; 2) collect data to be used for a community structure trend analysis; and 3) correlate water quality chemistry to biological information where possible. Measurement performance specifications to support project objectives for this study are outlined in H-GAC's Table SS-A7.1 (see Appendix 1). Fish data were compiled for each site, complete with vouchering of individual, representative fish species collected during seining and shocking efforts and all records were kept separate for each sampling type. Aquatic invertebrates were captured using TCEQ approved Rapid Bioassessment Protocols (RBPs) with 5-minutes of kick-netting at various habitats and were preserved and stored. Habitat assessment and diel data (along with additional field parameters and observations), water chemistry, bacteriological samples, and flow were also collected at the time of sampling. Representative data collected during this study were also submitted to the Surface Water Quality Monitoring Information Service (SQWMIS).

METHODOLOGY

Site Selection

Aquatic Life Monitoring (ALM) was conducted by EIH at 5 locations previously monitored by USGS in 1997-1998 (Figure 1). These sites were also selected because TCEQ's Integrated Report (IR) identified these sites has having various water quality issues (TCEQ 2008; TCEQ 2010). The sites monitored in this study are described in Table 1.

Cedar Bayou Above Tidal (Segment 0902; Site 11120)

Cedar Bayou Above Tidal is located in the coastal plain between the Trinity and San Jacinto rivers. Some residential development is located northwest of U.S. Highway 90, but the majority of the watershed is used for agricultural purposes with small ranchettess (defined as a small ranch a few acres in size) scattered throughout (Figure 2). Principal crops include turf/sod, rice, and hay. On-site sewage facilities (OSSFs) are the primary method used for sewage disposal throughout the watershed.

The segment is currently listed as a concern due to macrobenthic community impairment. Since most of this segment has been channelized for flood control at one time or another, finding an impaired benthic community is not unexpected ((HGAC 2011)). The segment is also identified as having a concern for dissolved oxygen based on single grab sample criteria.

Clear Creek (Segment 1102; Site 11452)

The Clear Creek Above Tidal watershed has experienced rapid residential and commercial development (Figure 3) (HGAC 2011). The assessment unit containing site 11452 is not supporting its contact recreation use designations, with impairments for *E. coli* bacteria, PCBs and Dioxins. The aquatic life use is also of concern as a result of a degraded habitat and an impaired fish community. While the fish community health has remained constant having been listed as a concern in both the 2008 and 2010 IRs the habitat has seen improvements and was downgraded from a listing of impairment to a listing of concern from 2008 to 2010 (TCEQ 2008; TCEQ 2010).

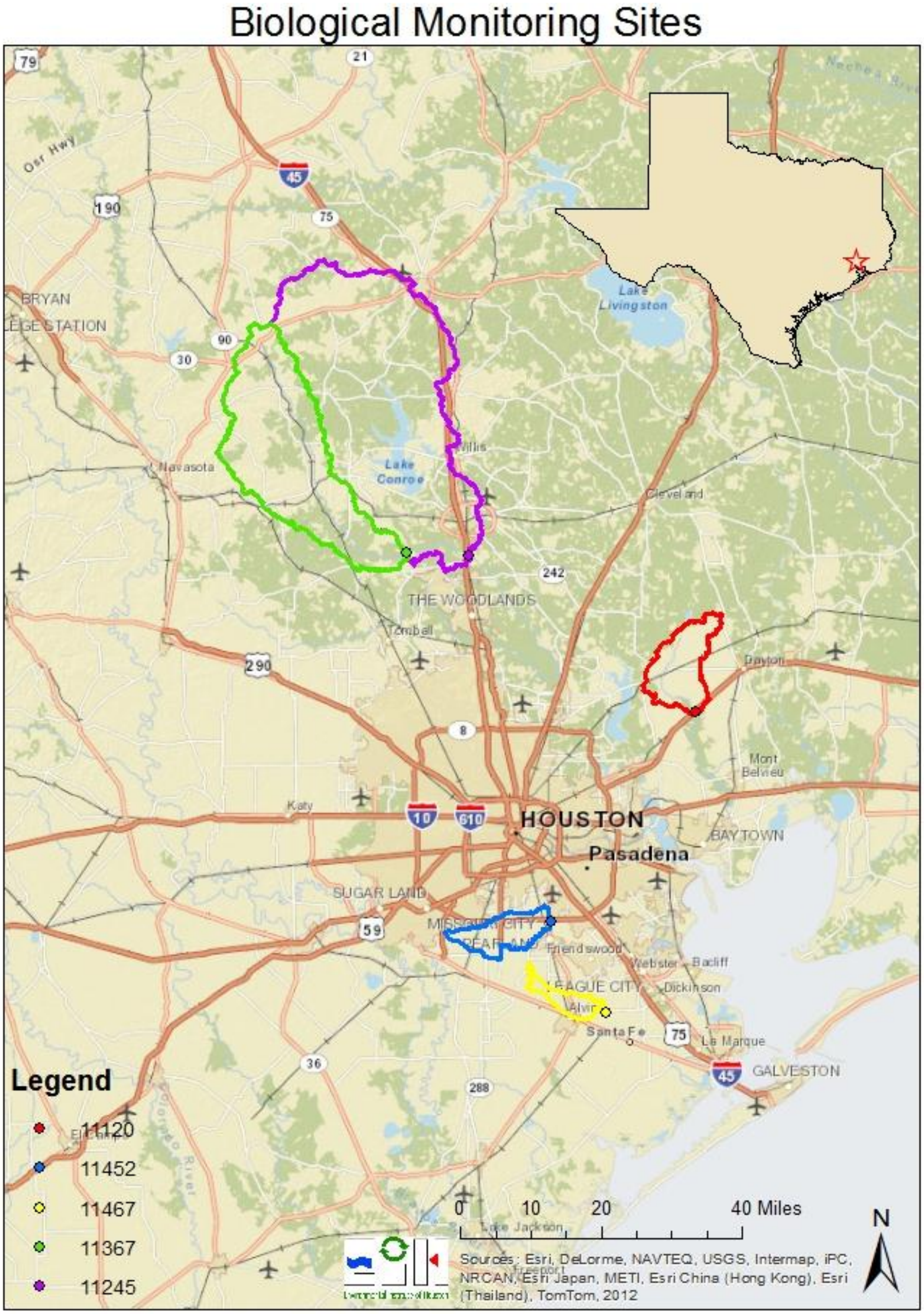

Figure 1. Aquatic Life Monitoring Sites and contributing watershed size (Corresponds to Table 1).

Table 1. Sample site descriptions with list of known/potential causes of ALU concern/impairment (Corresponds to Figure 1).

TCEQ ID	USGS Report ID	Site Name	Segment	Latitude	Longitude	Known/Potential Causes of ALU Concern/Impairment
11120	CEDR7500	Cedar Bayou near Crosby, TX	0902	29.97222	-94.9861	Removed from 303(d) list in 2010 for impaired benthic community due to a change in impairment criteria. Listed in 2010 Texas Integrated Report for depressed dissolved oxygen (concern for water quality based on screening levels) and macrobenthic community (concern for near non-attainment of water quality standards).
11452	CLER7000	Clear Creek at SH 35	1102	29.59722	-95.2864	Listed on 303(d) for PCB's in edible tissue since 2010.
11467	DICK0050	Dickinson Bayou at FM 517	1104	29.43444	-95.1697	Listed on 303(d) for bacteria since 1996 and depressed dissolved oxygen since 2006.
11367	LAKE1367	Lake Creek near Egypt, TX	1015	30.25583	-95.5861	Listed in 2010 Texas Integrated Report for depressed dissolved oxygen (concern for near non-attainment of water quality standards).
11245	WFSJ8000	West Fork San Jacinto River at IH 45	1004	30.2175	-95.4608	Listed on 303(d) for bacteria since 2002.

Dickinson Bayou (Site 11467)

The Dickinson Bayou Above Tidal watershed is not as developed as many of the surrounding watersheds. It includes portions of the cities of Santa Fe, League City, Friendswood, and Alvin (Figure 4). Residential and commercial development has occurred throughout the watershed along major thoroughfares such as FM517 and Texas Highway 6 (HGAC 2011). The predominant land use in the watershed is agriculture and grasslands especially in the north and western parts. The majority of the watershed uses OSSFs.

The aquatic life and recreational uses of Dickinson Bayou Above Tidal (1104) are currently not supported (TCEQ 2008; TCEQ 2010). High levels of *E. coli* bacteria were found resulting in the segment being listed as impaired. . Dissolved oxygen is also depressed throughout the segment resulting in the segment directly below site 11467 being listed as impaired.

Lake Creek (Site 11367)

The Lake Creek watershed is rural in nature and is dominated by forested land and grassland, with the major land cover used as pastureland for hay (Figure 5). Residential development is occurring rapidly in the watershed, particularly in the southern part of the watershed where growth is occurring just west of the City of Conroe, and I-45 between Texas Highway 2854 and Texas Highway 1488 (HGAC 2011). Lake Creek is one of lesser impacted waterways in the entire region.

West Fork San Jacinto River (Site 11245)

There are several concentrated urban areas in the West Fork of the San Jacinto River Watershed; including the Cities of Conroe and Willis in the north, Shenandoah with the surrounding Woodlands Developments and Oak Ridge North in the central area of the watershed; and Porter, the Kingwood community, and the City of Houston in the south (Figure 6) (HGAC 2011). There are numerous smaller subdivisions and ranchettes throughout the watershed. The segment is listed as impaired for bacteria (*E. coli*), and does not support the primary contact recreation use.

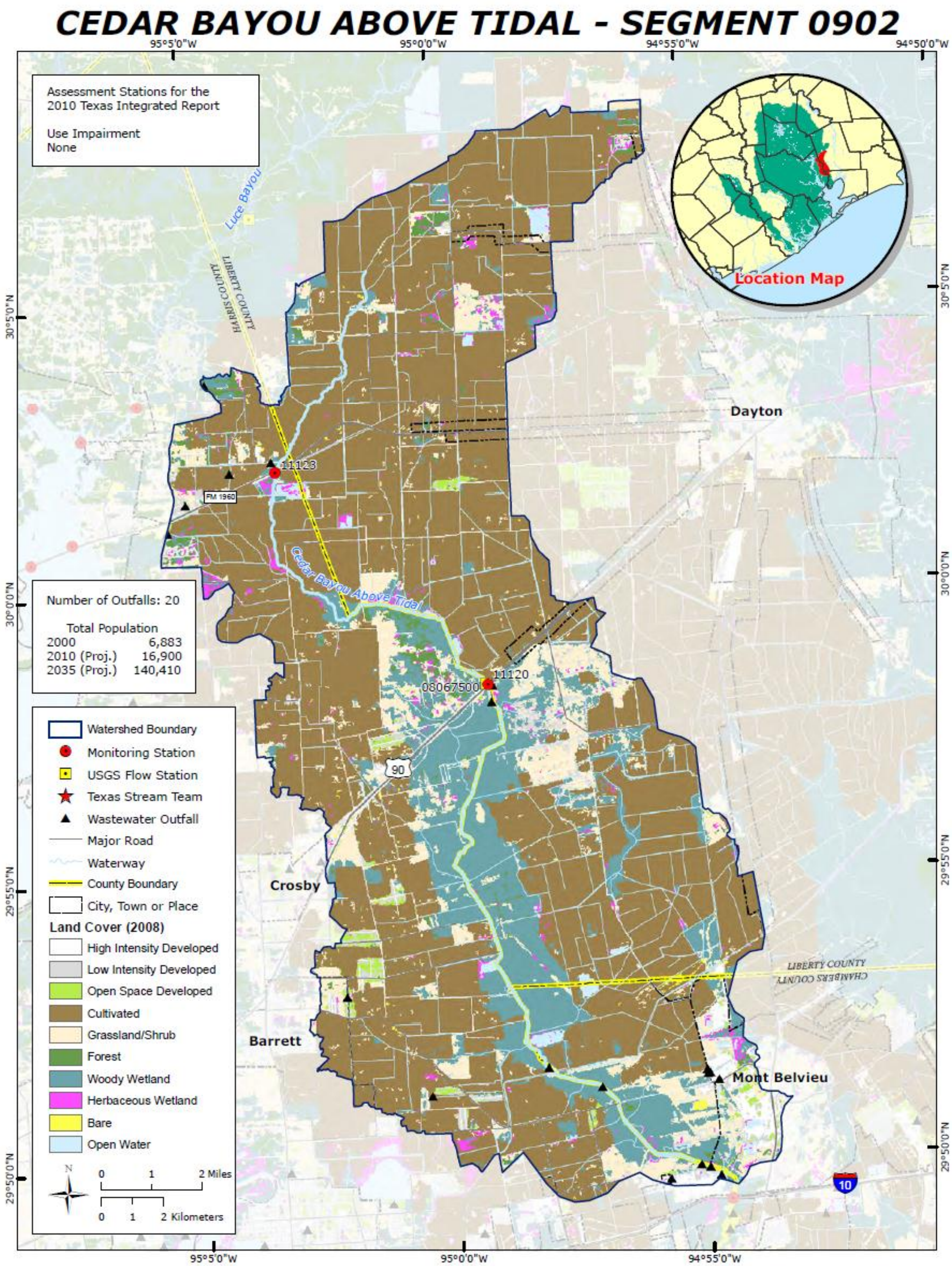

Figure 2. Cedar Bayou Above Tidal Watershed and field survey site 11120. H-GAC Basin Summary Report 2011
http://www.bsr2011.com/documents/Watershed_Summary_Maps/0902_Cedar_Bayou_Above_Tidal.pdf

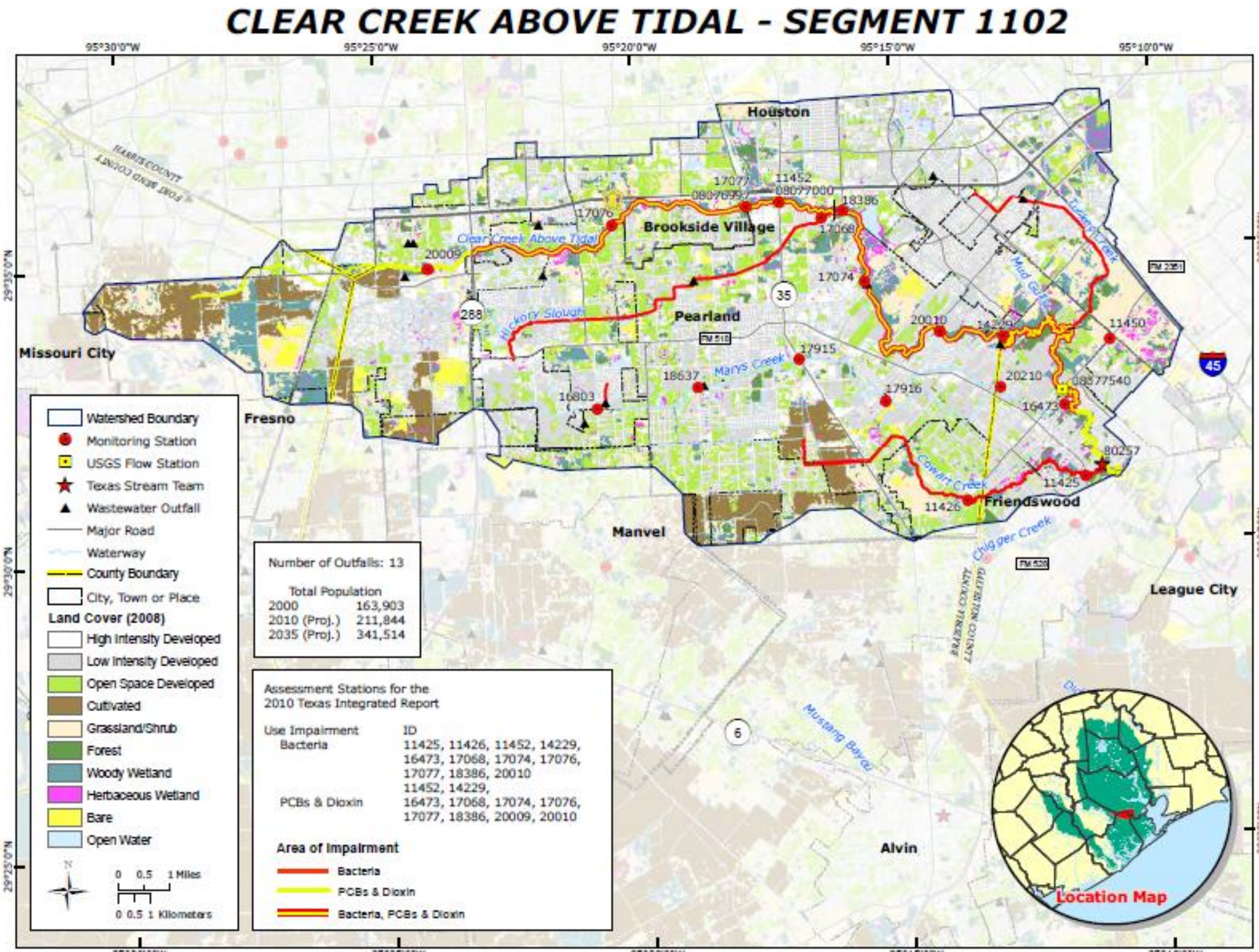

Figure 3. Clear Creek Above Tidal Watershed and field survey site 11452. H-GAC Basin Summary Report 2011
http://www.bsr2011.com/documents/Watershed_Summary_Maps/1102_Clear_Creek_Above_Tidal.pdf

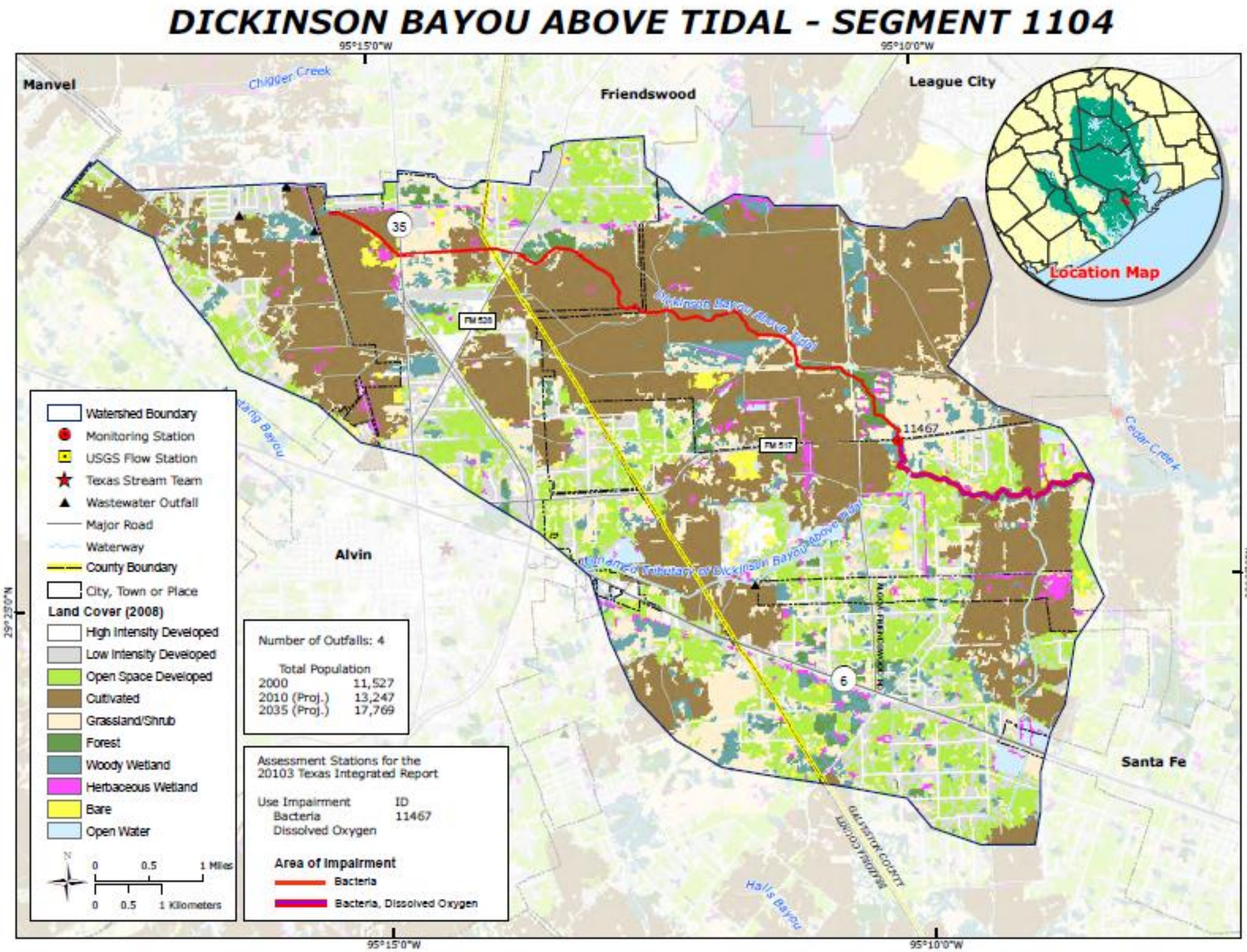

Figure 4. Dickinson Bayou Above Tidal Watershed and field survey site 11467. H-GAC Basin Summary Report 2011
http://www.bsr2011.com/documents/Watershed_Summary_Maps/1104_Dickinson_Bayou_Above_Tidal.pdf

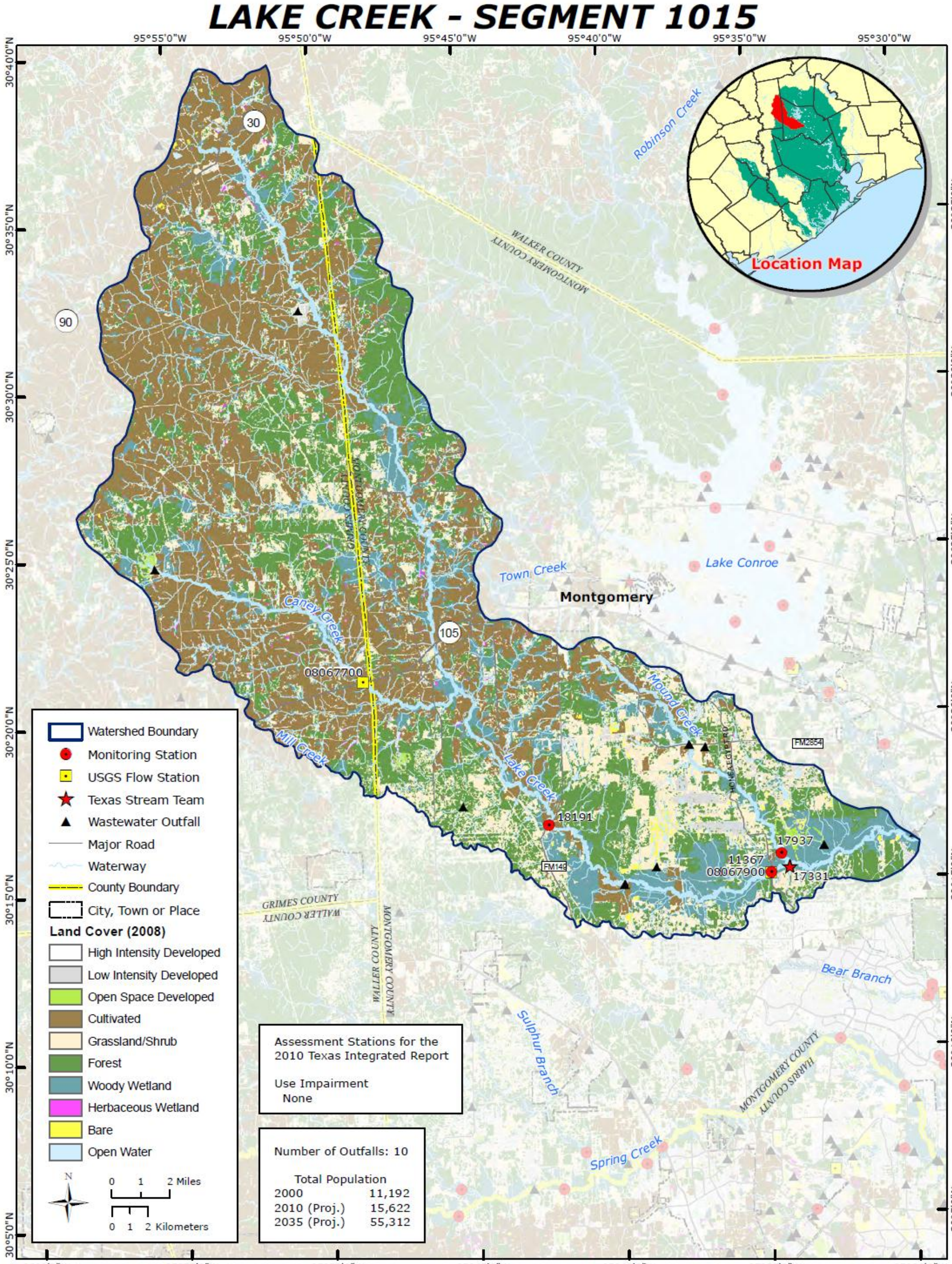

Figure 5. Lake Creek Watershed and field survey site 11367. H-GAC Basin Summary Report 2011
http://www.bsr2011.com/documents/Watershed_Summary_Maps/1015_Lake_Creek.pdf

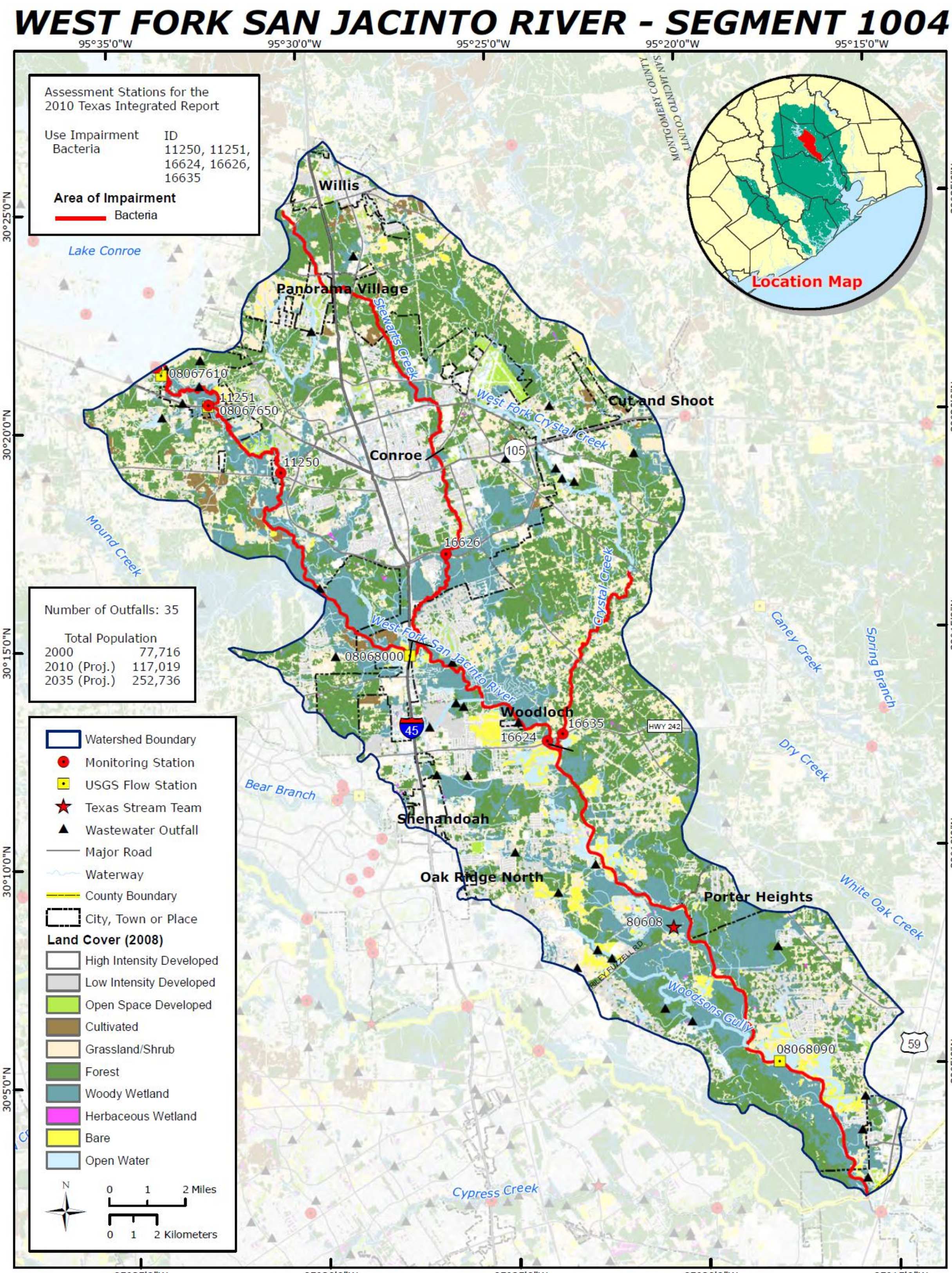

Figure 6. West Fork of the San Jacinto River Watershed and field survey site 11245. H-GAC Basin Summary Report 2011 http://www.bsr2011.com/documents/Watershed_Summary_Maps/1004_West_Fork_San_Jacinto_River.pdf

EIH Data

Data collected during this study, including the historical USGS data used for comparison, is outlined in Table 2. During the current study two sampling events were conducted at each of the 5 locations. One event at each site occurred during the index period (i.e. March 15 – October 15 but not including the critical period) and the second event occurred during the critical period (July 1 – September 30)(TCEQ 2007). All monitoring events were completed when stream conditions were reflective of base flow conditions, although it is important to note that in 2011 Texas suffered severe drought conditions for the majority of the year (Figure 7). Therefore results from this study were likely affected by the drought conditions. Biological data was analyzed using methods described by TCEQ to generate regionalized fish and benthic Index of Biotic Integrity (IBI) metric scores and associated aquatic life uses for Ecoregions 34 and 35 (Linam et al. 2002; TCEQ 2007). In addition, due to lack of electrofishing data at two of the historical USGS two sites, we also utilized statewide bioassessment methods outlined in TNRCC (1999).

USGS Historic Data

Specific data collection methodology used to collect historical USGS is described in USGS Open File Report 98-658 (Moring et al. 1998). Data files in Excel format were provided by the lead author of that report, Bruce Moring. All electronic data were compared with the data printed in the final USGS report to insure there were no errors. Raw data from the USGS Open File Report 98-658 was used to calculate TCEQ benthic and fish Indices of Biotic Integrity (IBI) using current approved TCEQ methods and are presented in the appropriate format to determine values for each site from the 1997-1998 study.

The previously collected USGS fish and other biological data were collected under H-GAC's Clean Rivers Program QAPP using techniques outlined in TCEQ's Receiving Water Assessment Procedures Manual, the predecessor guidance to *SWQM Procedures Manual, Volume II* and were originally analyzed using the Texas Statewide IBI method (Linam et al. 2002; TNRCC 1999; TCEQ 2007). However, in order to identify any changes that may have occurred over time at these 5 sites, the historic records were re-analyzed whenever possible using both the historic statewide and currently approved regional-IBI methodology as described in TCEQ's *Surface Water Quality Monitoring Procedures, Volume 2: Methods for Collecting and Analyzing Biological Assemblages and Habitat Data* (RG-416 June 2007) and compared to the 2011 biological data (TCEQ 2007).

Table 2. Data collected during the USGS 1997-98 and EIH 2011 study.

Site Number	Site Name	Downstream Reach Boundary Coordinates		Data Collected By	Sample Date	Type of Data Collected					
						Diel (24-hour)	Water Chemistry	Instantaneous Flow	Nekton	Benthic Macro-Invert	Physical Habitat
11120	Cedar Bayou near Crosby, TX	29.972222	-94.986111	USGS Report 98-658	8/25/1997				✓	✓	✓
		29.972164	-94.985312	EIH (Index)	5/3/2011	✓	✓	✓	✓	✓	✓
				EIH (Critical)	7/21/2011	✓	✓	✓	✓	✓	✓
11452	Clear Creek at SH 35	29.597222	-95.286389	USGS Report 98-658	8/25/1997				✓	✓	✓
		29.597550	-95.286097	EIH (Index)	4/28/2011	✓	✓	✓	✓	✓	✓
				EIH (Critical)	7/15/2011	✓	✓	✓	✓	✓	✓
11467	Dickinson Bayou at FM 517	29.434444	-95.169722	USGS Report 98-658	9/4/1997				✓	✓	✓
		29.434070	-95.169685	EIH (Index)	4/26/2011	✓	✓	✓	✓	✓	✓
				EIH (Critical)	7/14/2011	✓	✓	✓	✓	✓	✓
11367	Lake Creek near Egypt, TX	30.255889	-95.586333	USGS Report 98-658	9/19/1997				✓	✓	✓
		30.252532	-95.581873	EIH (Index)	5/10/2011	✓	✓	✓	✓	✓	✓
				EIH (Critical)	7/22/2011	✓	✓	✓	✓	✓	✓
11245	West Fork San Jacinto River at IH 45	30.247528	-95.460833	USGS Report 98-658	3/5/1998				✓		✓
		30.244760	-95.455679	EIH (Index)	5/6/2011	✓	✓	✓	✓	✓	✓
				EIH (Critical)	7/27/2011	✓	✓	✓	✓	✓	✓

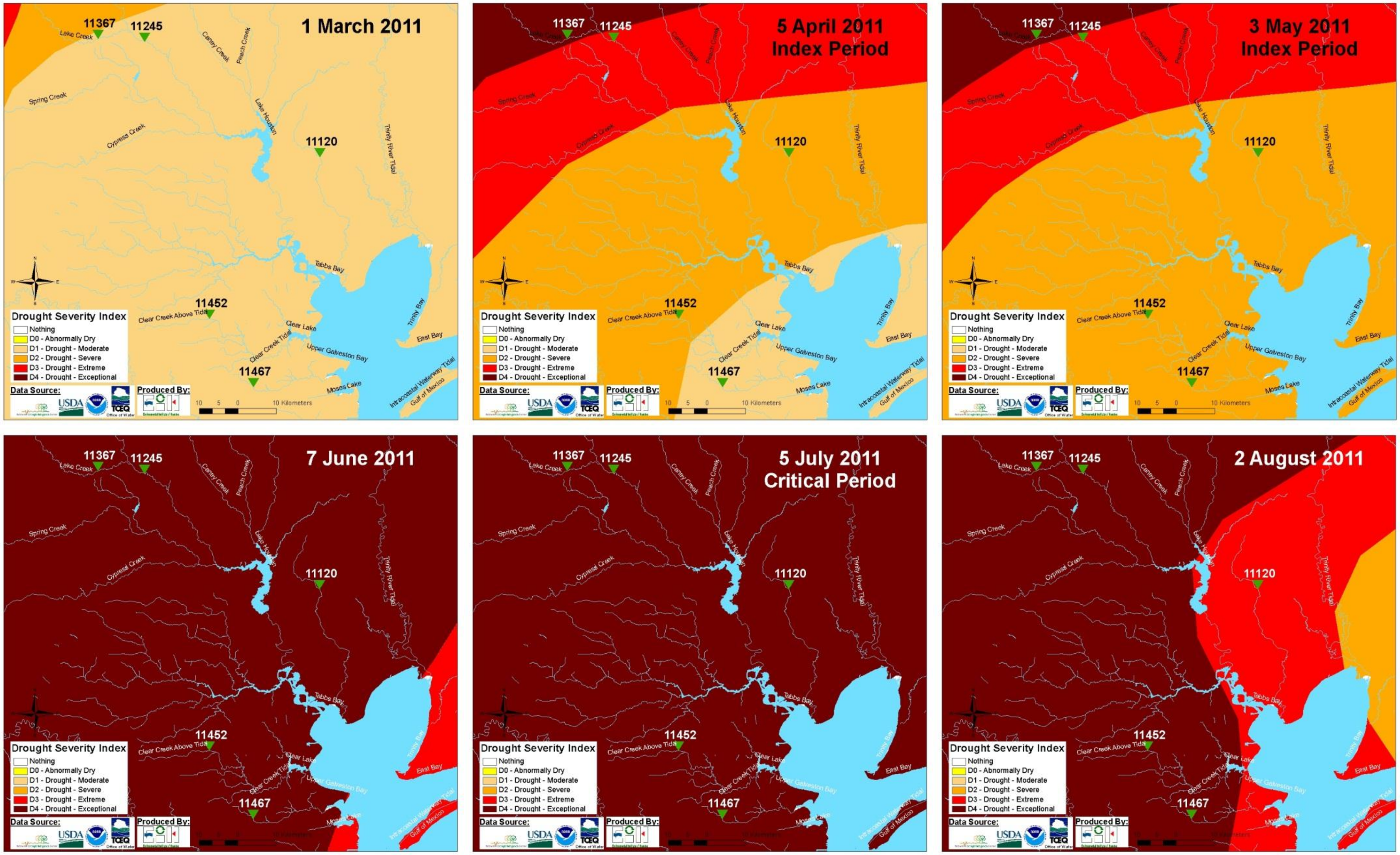

Figure 7. Drought conditions during 2011 sampling period. Data source: National Drought Mitigation Center.

Additional Data Analysis

Multivariate cluster analysis was conducted on the physico-chemical, fish and benthic community data to compare patterns in between collections. The analysis was conducted with the PRIMER © software package (Clarke and Gorley 2006). Cluster analysis is used to create groups of similar entities based on the similarity of their attributes. In our case the entities were collections at each site by date and the attributes were either; fish species, benthic invertebrate species, or quantitative physico-chemical variables.

Prior to analysis biological data (fish and benthic community) was transformed by reducing the number of species in the matrix to only commonly collected species which occurred in 20% or more of the collections. In addition, abundance data were log transformed (log X+1). Both of these steps are routinely conducted prior to conducting multivariate analyses to reduce variability and influence of rare or uncommon species with many zero occurrences (Clarke and Warwick 2001). For cluster analyses conducted on biological data we used the Bray-Curtis similarity metric and Group Average clustering algorithm which has been shown to be superior in dealing with data containing zero cells (no catch for a species). This method is recommended for abundance and biomass data.

For physico-chemical data we used the Euclidean distance measure and Group Average clustering algorithm which is recommended for environmental data (Clarke and Warwick 2001). Prior to conducting cluster analysis with physico-chemcal data, the values for each variable had their mean subtracted and were divided by their standard deviation. This is usually necessary for environmental data where variables are often on completely different scales, often with arbitrary origins. It then makes it possible to derive meaningful distances between samples, using Euclidean distance. The means and standard deviations are dependent on the actual data selection so all data for each variable was selected for this operation.

After the cluster analysis was conducted a dendrogram depicting the distances (Bray Curtis or Euclidean) between collections was produced, and the SIMPROF test for structure in the data was conducted to define groups of similar collections (Clarke and Gorley 2006). This procedure first creates a resemblance profile by ranking the resemblance matrix for the data. A mean profile is then calculated by randomising the order of each variables values and re-calculating the profile. A *pi* statistic is calculated as the deviation of the actual data profile with the mean one. This is compared with the deviations of further randomly generated profiles to test for significance. The null hypothesis is no structure.

RESULTS

Physical Habitat and Hydrology

Physical habitat data collected by EIH was used to calculate an intermediate habitat quality rating (HQR) for all sites and sampling periods except for the critical period for Cedar Bayou (site 11120) which had a “high” rating, and the critical period for Clear Creek (site 11452) which exhibited a “limited” rating (Table 3). Some of the habitat quality parameters collected are subjective, and based on the length of the stream reach sampled. Thus the scoring may vary slightly at the same site between each sample event.

Mean velocity was generally low during all sample periods for all sites surveyed (Table 4). Stream flow as instantaneous discharge (cfs) was not reported by USGS, however based solely on mean velocity data it appears that the flow conditions at each site were generally similar, except Clear Creek and the West Fork of the San Jacinto which each had a mean velocity of 0.00 ft/s during the 1997-98 USGS field surveys (Table 4 and Figure 8). Instantaneous stream flow (cfs) measurements conducted at the study sites during the past 30 years are illustrated in (Figure 9 - 13). Based on examination of the historical record, all field sampling events which occurred during this study and the USGS occurred at base flow conditions, never during a high flow event. Comparison of historical data suggests that the West Fork of the San Jacinto River has statistically higher average flows (primarily based on base flows) than the other sites, while the Dickinson Bayou site exhibited intermediate flows (Figure 14).

Mean wetted channel width appears to be quite uniform between the 1997-98 USGS data and the 2011 EIH data for each site. The West Fork of the San Jacinto (site 11245) is clearly a broader water body compared to the other sites surveyed (Table 4 & Figure 15). The uniform mean wetted channel width between sampling dates provides additional evidence that the flow regime was also similar between the two study periods. Additional physical habitat parameters collected in 2011 by EIH are provided in Table 5. These additional parameters were not collected by USGS in the 1997-98 study.

Table 3. Habitat quality ratings for the five field survey sites sampled by EIH in 2011. The USGS data did not have sufficient habitat data to complete the habitat quality index.

Site Name	HGAC ID	TCEQ ID	Sample Period	Sample Date	Available Instream Cover	Bottom Substrate Stability	Number of Riffles	Dimensions of Largest Pool	Channel Flow Status	Bank Stability	Channel Sinuosity	Riparian Buffer Vegetation	Aesthetics of Reach	Habitat Quality Score	Habitat Quality Rating
Cedar Bayou	cedr7500	11120	Index	05/03/2011	3	2	3	4	1	1.5	2	1	1	18.5	Intermediate
			Critical	07/21/2011	2	3	3	4	2	2	2	1	2	21	High
Clear Creek	cler7000	11452	Index	04/28/2011	3	3	2	2	1	0.5	3	0	1	15.5	Intermediate
			Critical	07/15/2011	2	1	1	1	2	1	2	0	1	11	Limited
Dickinson Bayou	dick0050	11467	Index	04/26/2011	3	1	1	3	1	0	3	3	2	17	Intermediate
			Critical	07/14/2011	2	1	1	1	2	0	3	3	1	14	Intermediate
Lake Creek	lake1367	11367	Index	05/10/2011	3	1	3	4	1	1.5	3	2	2	18.5	Intermediate
			Critical	07/22/2011	3	1	3	4	2	2	3	2	2	18.5	Intermediate
West Fork San Jacinto	wfsj8000	11245	Index	05/06/2011	2	3	3	3.5	2	2	3	3	2	18.5	Intermediate
			Critical	07/27/2011	2	3	3	1	1	2.5	2	2	2	18.5	Intermediate

Table 4. Physical stream characteristics of the five field survey sites studied by EIH and USGS. Note: streambed slope was used based on the original USGS survey data.

Site Name	HGAC ID	TCEQ ID	Reporting Agency	Sample Period	Sample Date	Stream Order	Streambed slope over evaluated reach (m/km)	Curvilinear reach length (m)	Mean stream bank slope (°)	Mean wetted channel width (m)	Mean channel depth (m)	Mean velocity (f/s)	Instantaneous flow (cfs)
Cedar Bayou	cedr7500	11120	USGS	Critical	08/25/1997	2	0.800	134.96	41.35	3.80	0.30	0.4265	*
			EIH	Index	05/03/2011			150.000	32.320	3.10	0.12	0.0614	0.022
				Critical	07/21/2011			253.000	39.167	4.92	0.26	0.8504	6.455
Clear Creek	cler7000	11452	USGS	Critical	08/25/1997	1	0.500	87.31	2.86	4.63	0.00	0.0000	*
			EIH	Index	04/28/2011			191.000	53.500	4.54	0.28	0.6352	5.909
				Critical	07/15/2011			191.000	44.200	5.12	0.40	0.6637	7.889
Dickinson Bayou	dick0050	11467	USGS	Critical	09/04/1997	1	0.700	87.94	24.7	3.38	0.72	0.1969	*
			EIH	Index	04/26/2011			190.000	63.500	4.52	0.53	0.0876	2.175
				Critical	07/14/2011			178.000	66.550	3.84	0.48	0.1280	0.577
Lake Creek	lake1367	11367	USGS	Critical	09/19/1997	3	0.100	215.76	40.7	6.27	0.46	0.6234	*
			EIH	Index	05/10/2011			295.000	33.450	6.80	0.37	0.1243	0.759
				Critical	07/22/2011			286.000	32.400	6.22	0.27	0.0846	0.408
West Fork San Jacinto	wfsj8000	11245	USGS	Non-Index	03/05/1998	4	0.300	425.75	11.31	28.00	0.00	0.0000	*
			EIH	Index	05/06/2011			493.000	19.583	18.18	0.30	0.6299	14.971
				Critical	07/27/2011			500.000	25.750	16.24	0.33	0.9091	15.160

* Value not reported by USGS

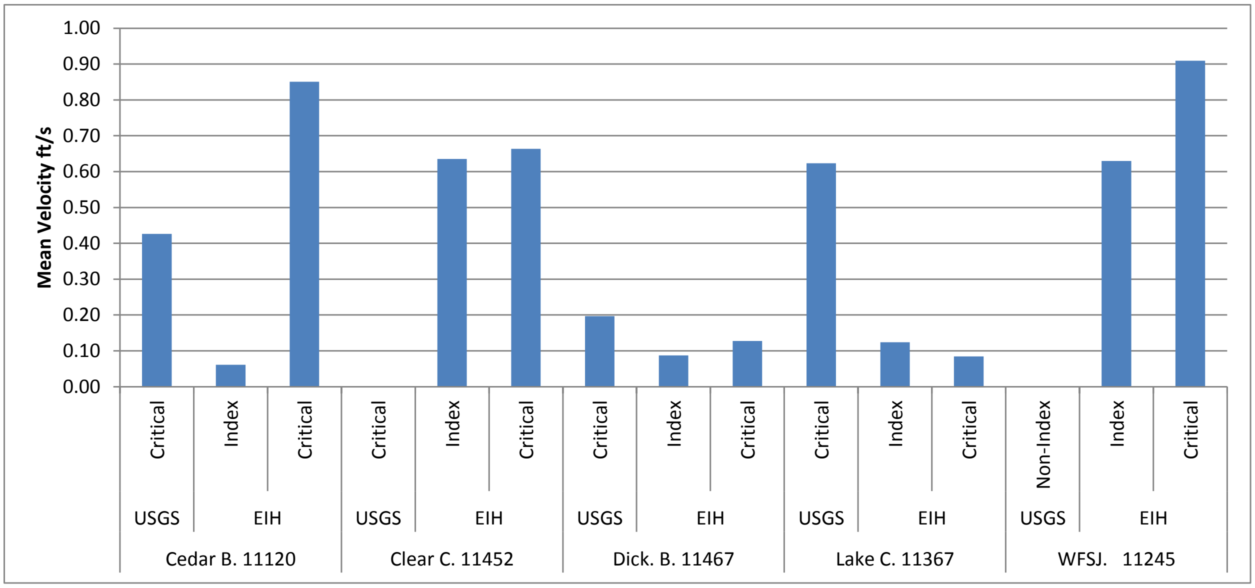

Figure 8. Mean velocity (ft/s) recorded at five field survey sites by EIH and USGS. Information corresponds to data in Table 4.

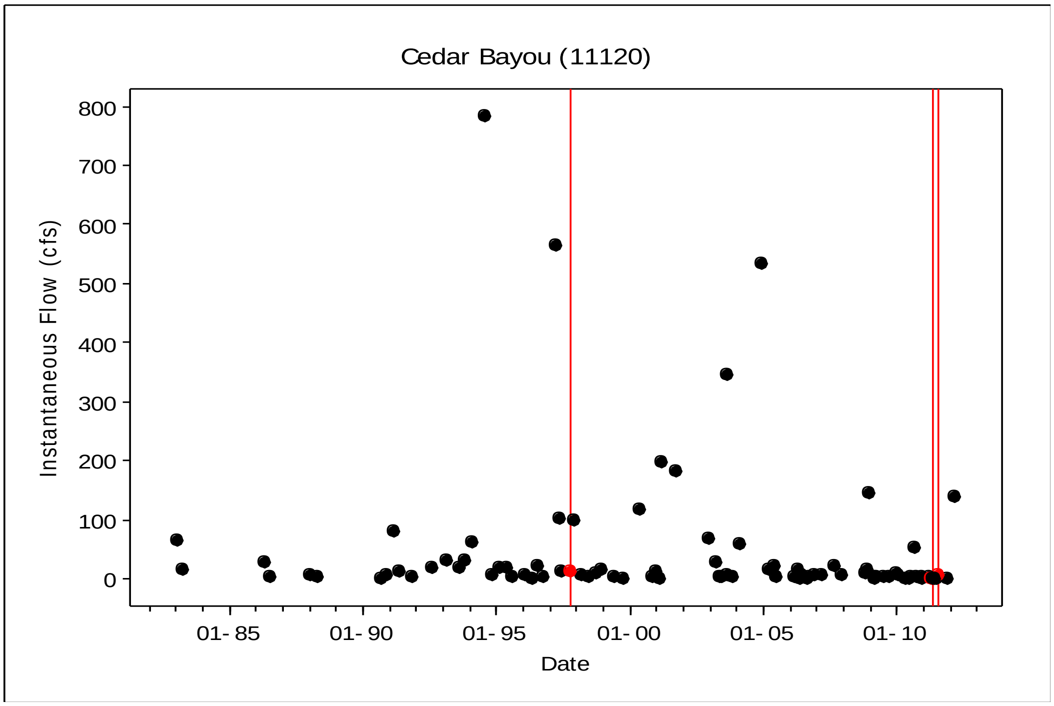

Figure 9. Historical instantaneous flow (cfs=cubic feet per second) measurements collected at the Cedar Bayou (11120) site. The vertical red lines show the sample dates reported during the USGS and current study. Note: there are periods of time where no flow data was recorded. Data source: H-GAC surface water monitoring data by basin: http://www.h-gac.com/community/water/rivers/data/surface_water_monitoring_data.aspx

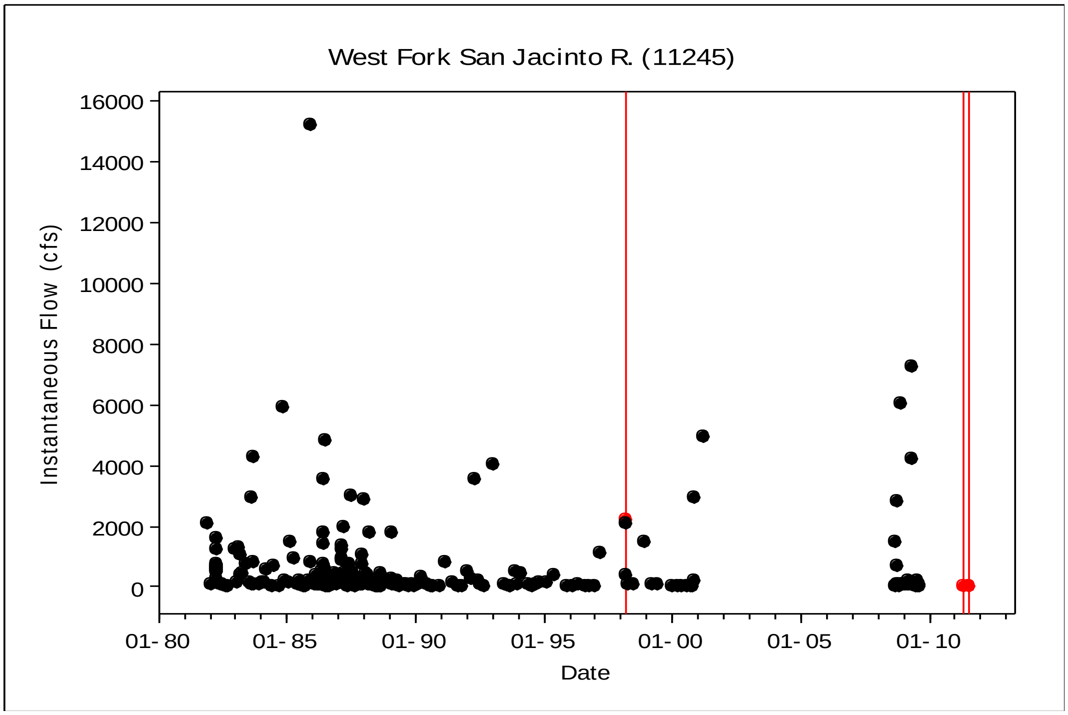

Figure 10. Historical instantaneous flow (cfs=cubic feet per second) measurements collected at the West Fork San Jacinto River (11245) site. The vertical red lines show the sample dates reported during the USGS and current study. Note: there are periods of time where no flow data was recorded. Data source: H-GAC surface water monitoring data by basin: http://www.h-gac.com/community/water/rivers/data/surface_water_monitoring_data.aspx

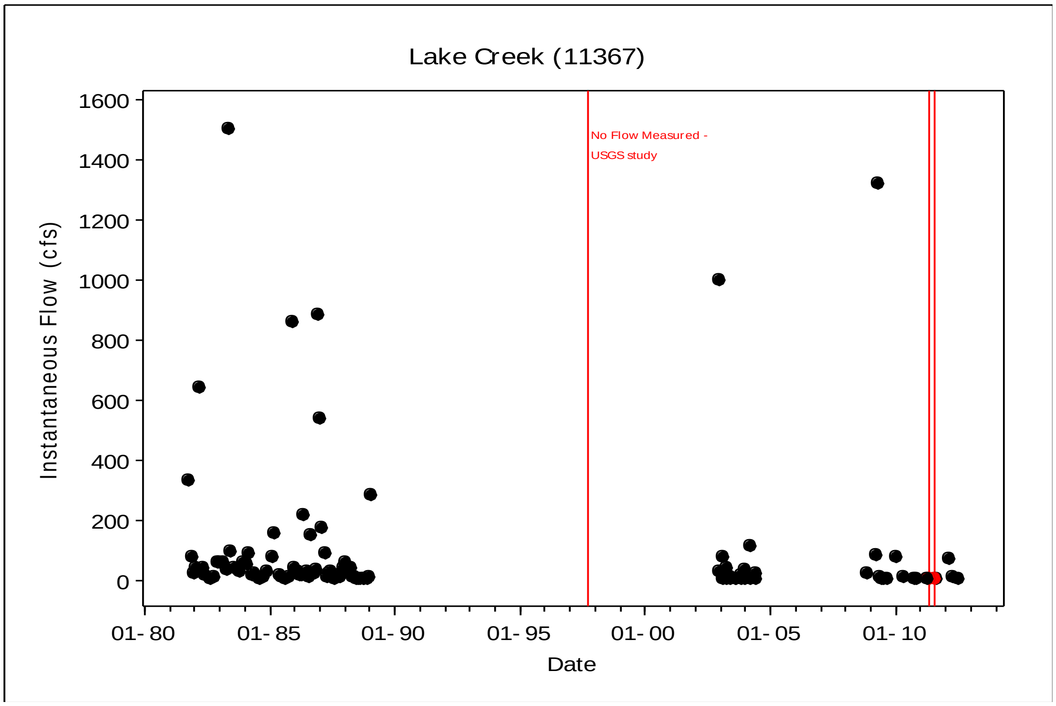

Figure 11. Historical instantaneous flow (cfs=cubic feet per second) measurements collected at the Lake Creek (11367) site. The vertical red lines show the sample dates reported during the USGS and current study. Note: there are periods of time where no flow data was recorded. Data source: H-GAC surface water monitoring data by basin: http://www.h-gac.com/community/water/rivers/data/surface_water_monitoring_data.aspx

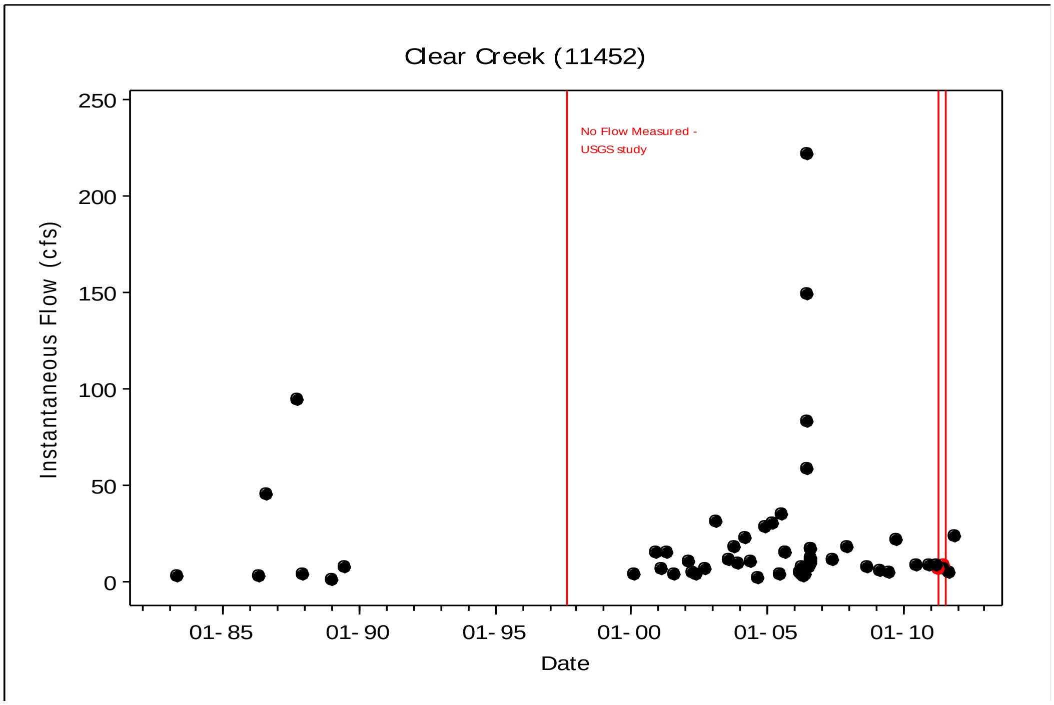

Figure 12. Historical instantaneous flow (cfs=cubic feet per second) measurements collected at the Clear Creek (11452) site. The vertical red lines show the sample dates reported during the USGS and current study. Note: there are periods of time where no flow data was recorded. Data source: H-GAC surface water monitoring data by basin: http://www.h-gac.com/community/water/rivers/data/surface_water_monitoring_data.aspx

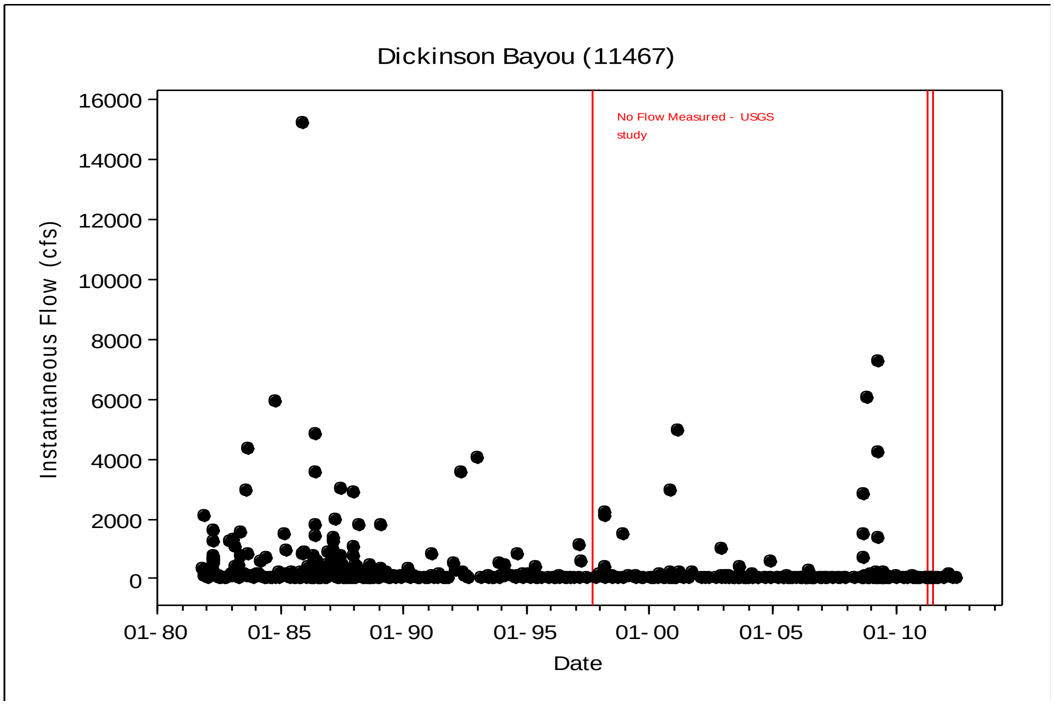

Figure 13. Historical instantaneous flow (cfs=cubic feet per second) measurements collected at the Dickinson Bayou (11467) site. The vertical red lines show the sample dates reported during the USGS and current study. Note: there are periods of time where no flow data was recorded. Data source: H-GAC surface water monitoring data by basin: http://www.h-gac.com/community/water/rivers/data/surface_water_monitoring_data.aspx

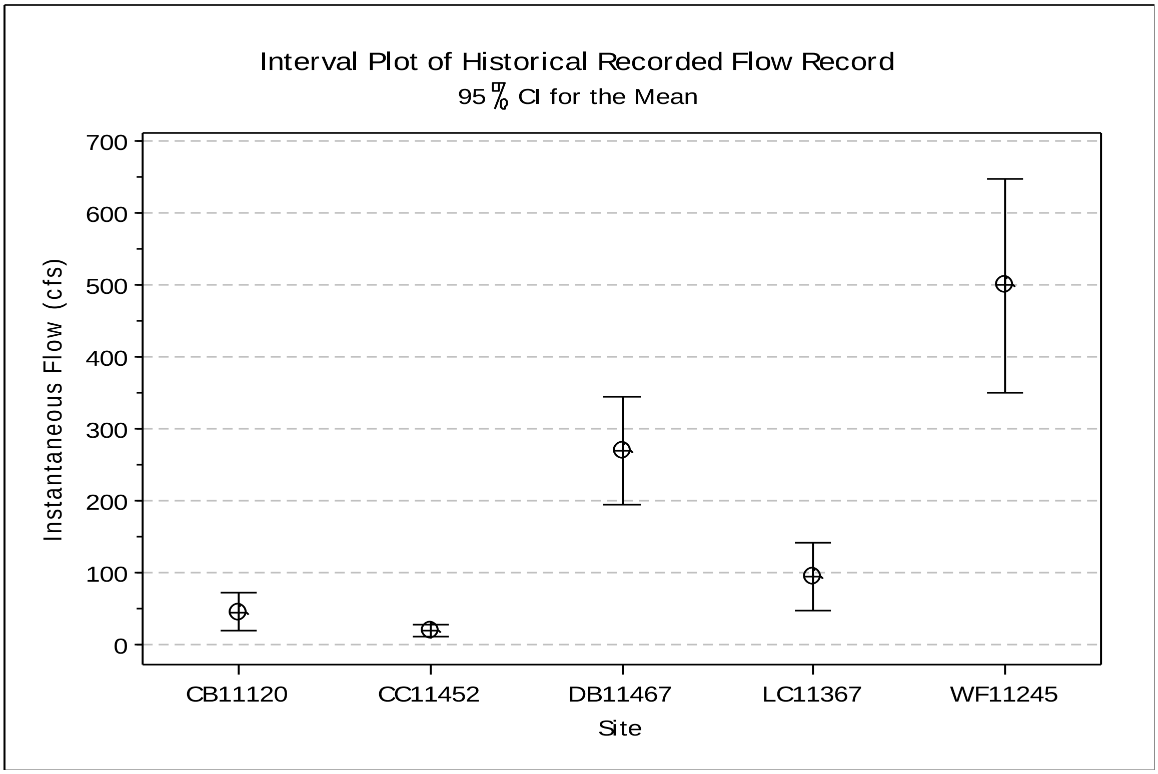

Figure 14. Comparison of historical average flows at each site based on instantaneous flows recorded. Average flows at site 11245 were statistically higher than the other sites and the flows at site 11467 were statistically higher than sites 11120 and 11452 (ANOVA *p* = 0.05; Fishers multiple range test). CB – Cedar Bayou 11120, CC – Clear Creek 11452, DB – Dickinson Bayou 11457, LC – Lake Creek 11367, WF – West Fork San Jacinto River 11245.

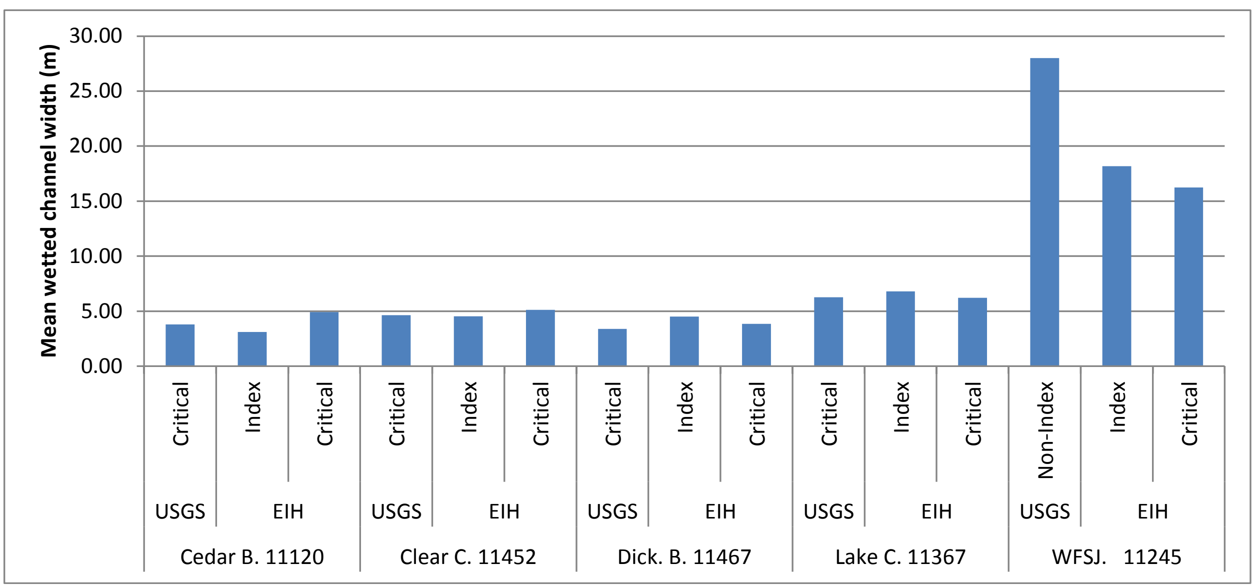

Figure 15. Mean wetted channel width (m) recorded at five field survey sites by EIH and USGS. Corresponds to data in Table 4.

Table 5 Additional selected physical habitat data collected by EIH in 2011. Complete dataset available in Appendix 7.

Site Name	HGAC ID	TCEQ ID	Sample Period	Sample Date	Approximate drainage area above the most downstream transect (km^2)	Number of Lateral Transects Made	Dominant Substrate Type	Number of Riffles	Well-defined Stream Bends	Average % Instream Cover	Average % Stream Bank Erosion Potential	Average % Tree Canopy Coverage	Habitat Flow Status	Land Development Impact	Aesthetics
Cedar Bayou	cedr7500	11120	Index	05/03/2011	167.999	5	Clay	2	0	32.50	49.00	61.47	Low	Low	Common
			Critical	07/21/2011		5	Clay	3	1	29.00	29.00	79.12	Moderate	Low	Natural
Clear Creek	cler7000	11452	Index	04/28/2011	103.896	5	Clay	1	3	35.00	64.00	77.06	Low	Moderate	Common
			Critical	07/15/2011		5	Clay	0	1	29.00	39.50	63.24	Moderate	Moderate	Common
Dickinson Bayou	dick0050	11467	Index	04/26/2011	44.510	5	Clay	0	2	31.00	63.00	92.94	Low	Low	Natural
			Critical	07/14/2011		5	Clay	0	2	13.80	37.00	96.18	Moderate	Low	Common
Lake Creek	lake1367	11367	Index	05/10/2011	754.790	5	Sand	2	2	36.00	38.00	78.82	Low	Uninpacted	Natural
			Critical	07/22/2011		5	Sand	4	3	31.00	21.50	95.59	Moderate	Uninpacted	Natural
West Fork San Jacinto	wfsj8000	11245	Index	05/06/2011	1329.971	6	Sand	3	2	25.00	49.17	7.35	Moderate	Uninpacted	Natural
			Critical	07/27/2011		6	Sand	3	1	13.33	27.50	12.25	Low	Uninpacted	Natural

Water Quality Parameters

Water Chemistry

As previously described, field measurements of basic water chemistry variables were measured on each sample date at each site (Table 2). This included water temperature, dissolved oxygen, pH, specific conductance, and secchi depth. Most of the historical USGS samples were collected during the critical period. Therefore, we compared these historical data with new data collected during the critical period. An exception to this pattern was the West Fork of the San Jacinto site 11245 which was monitored in 1997 by the USGS during the non-index period. Therefore it was difficult to compare data collected by the USGS at this site with current data. While comparisons of single data points cannot be statistically analyzed for significance, in every case the instantaneous D.O. measurements from the 1997-98 USGS data were greater than those of the EIH study from the same sample period nearly 14 years later (Figure 16). Most of the other water quality variables did not vary considerably between historical and recent collections (Table 6). However, recently observed specific conductance levels at the West Fork San Jacinto were elevated (>1000 µS) when compared to historical levels (128 µS) measured by the USGS.

In addition to the field measurements of basic water chemistry, EIH collected water samples for laboratory analysis of additional variables (Table 7). These variables were not monitored as part of the USGS study. *E. coli* bacteria exceeded the standard of 126 (MPN/100 ml) on four occasions including: 1) Dickinson Bayou during the critical period with 135 MPN/100 ml, 2) Lake Creek during the index with 410 MPN/100 ml, and 3) West Fork San Jacinto during both sampling periods with 146 and 161 MPN/100 ml (index and critical respectively). Nutrient levels observed at the field survey sites in 2011 were generally low with the exception of West Fork at San Jacinto site (11245) which exhibited relatively high nitrate + nitrite nitrogen levels during the index and critical periods (10.90 and 9.66 mg/L respectively) (Figure 17).

Diel Dissolved Oxygen Monitoring

EIH conducted 24-hr dissolved oxygen (D.O.) monitoring at all 5 sites in 2011 during both the index and critical periods (Table 8). In general, with the exception of Cedar Bayou site 11120, the daily average D.O. was higher in the index period than the critical period. The difference between minimum daily D.O. was even more extreme and lower in the critical versus index period. Typically, based on TCEQ guidance, in order to make an aquatic life use standard compliance assessment more than one event in the critical and index periods are needed. However, based on our monitoring results the sites with the most limiting D.O. levels were Clear Creek site 11452 and West Fork of the San Jacinto site 11245, both with values below 4.0 mg/L as the daily average. EIH attempted to acquire 24-hr dissolved oxygen (D.O.) monitoring data for the USGS study. However, examination of the SWMIS database failed to locate any archived data. Furthermore, discussions with USGS representative Bruce Moring indicated any historical data maintained by their agency was unavailable or lost. Therefore we were unable to compare the 1987 study period with our recent 24-hr data.

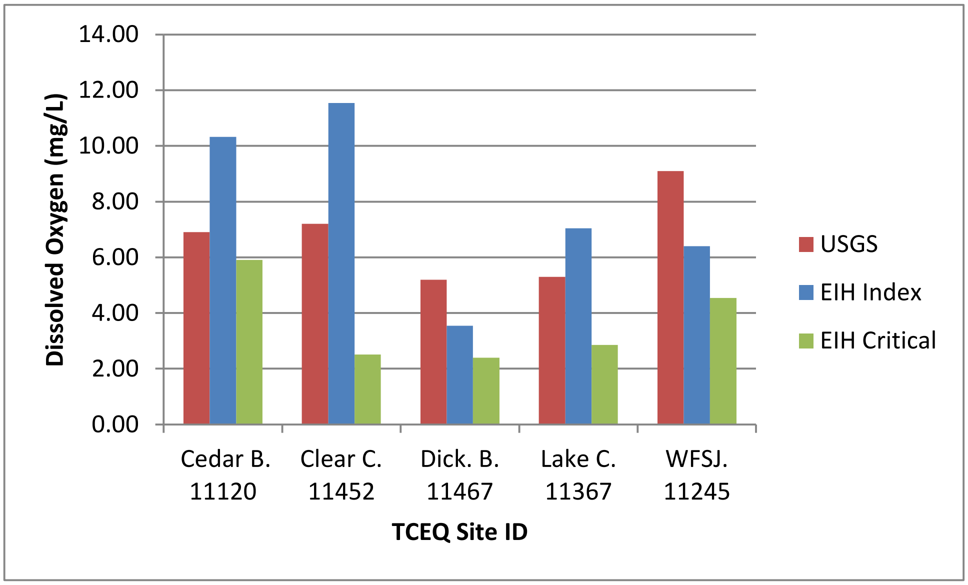

Figure 16. Instantaneous dissolved oxygen (mg/L) values observed during the 1997-98 USGS study and the 2011 EIH study. Note that measurements obtained during the USGS study occurred during the critical period with the exception of data collected at site 11245 which was sampled in the non-index period.

Table 6. Water chemistry data collected at the study sites by USGS and EIH.

Site Name	HGAC ID	TCEQ ID	Reporting Agency	Sample Period	Sample Date	Dissolved oxygen (mg/L)	pH (psu)	Conductance (µS)	Secchi-disk depth (m)	Water temperature (°C)
Cedar Bayou	cedr7500	11120	USGS	Critical	08/25/1997	6.90	7.50	636	*	32.80
			EIH	Index	05/03/2011	10.32	7.92	1005	> 1.2	18.92
				Critical	07/21/2011	5.91	7.41	500	1.15	28.64
Clear Creek	cler7000	11452	USGS	Critical	08/25/1997	7.20	7.90	688	*	32.00
			EIH	Index	04/28/2011	11.54	7.99	1094	0.50	25.13
				Critical	07/15/2011	2.51	7.50	1092	1.10	30.08
Dickinson Bayou	dick0050	11467	USGS	Critical	09/04/1997	5.20	7.80	691	*	26.80
			EIH	Index	04/26/2011	3.54	7.71	887	0.28	25.62
				Critical	07/14/2011	2.40	7.69	897	0.82	28.90
Lake Creek	lake1367	11367	USGS	Critical	09/19/1997	5.30	6.68	195	0.42	26.00
			EIH	Index	05/10/2011	7.04	7.61	186	0.68	26.31
				Critical	07/22/2011	2.85	7.32	177	0.69	28.65
West Fork San Jacinto	wfsj8000	11245	USGS	Non-Index	03/05/1998	9.10	6.90	128	*	17.00
			EIH	Index	05/06/2011	6.40	7.42	1109	> 1.2	20.85
				Critical	07/27/2011	4.54	7.53	1120	0.32	28.44

* Value not reported by USGS

Table 7. Additional water quality data collected by EIH. TSS = total suspended solids, VSS = volatile suspended solids, TOC = total organic carbon, TDS = total dissolved solids.

Site Name	HGAC ID	TCEQ ID	Sample Period	Sample Date	Days Since Last Significant Rainfall	E. coli (MPN/100 ml)	TSS (mg/l)	VSS (mg/l)	NH_3-N, Total (mg/l)	NO_2+NO_3-N, Total (mg/l)	Total PO_4-P (mg/l)	Ortho PO^{4}-P, field filtered (mg/l)	TOC (mg/l)	Cl- (mg/l)	SO_4 (mg/l)	TDS, dried @ 180°C (mg/l)
Cedar Bayou	cedr7500	11120	Index	05/03/2011	34	10	7.0	4.0	< 0.1	< 0.04	0.08	0.06	9.4	490	69.0	1504
			Critical	07/21/2011	19	91	2.0	1.5	0.1	2.04	0.30	0.27	9.4	100	7.6	280
Clear Creek	cler7000	11452	Index	04/28/2011	23	10	14.0	6.0	< 0.1	1.02	2.66	1.74	5.7	170	37.2	612
			Critical	07/15/2011	14	74	9.3	4.5	0.1	0.83	1.46	1.06	5.7	1800	42.6	572
Dickinson Bayou	dick0050	11467	Index	04/26/2011	43	41	52.5	7.5	< 0.1	< 0.04	0.10	0.05	4.0	130	55.2	496
			Critical	07/14/2011	> 60	135	5.6	< 1.0	< 0.1	0.09	< 0.06	< 0.04	3.5	3200	75.0	508
Lake Creek	lake1367	11367	Index	05/10/2011	14	410	7.8	2.8	< 0.1	0.12	0.09	0.06	3.4	30	5.4	108
			Critical	07/22/2011	3	26	21.5	11.5	0.1	0.21	0.18	0.10	4.3	30	13.8	116
West Fork San Jacinto	wfsj8000	11245	Index	05/06/2011	> 60	146	6.0	3.3	< 0.1	10.90	2.11	2.08	5.3	170	90.6	640
			Critical	07/27/2011	8	161	34.0	11.0	0.2	9.79	3.30	1.32	5.2	170	107.0	672

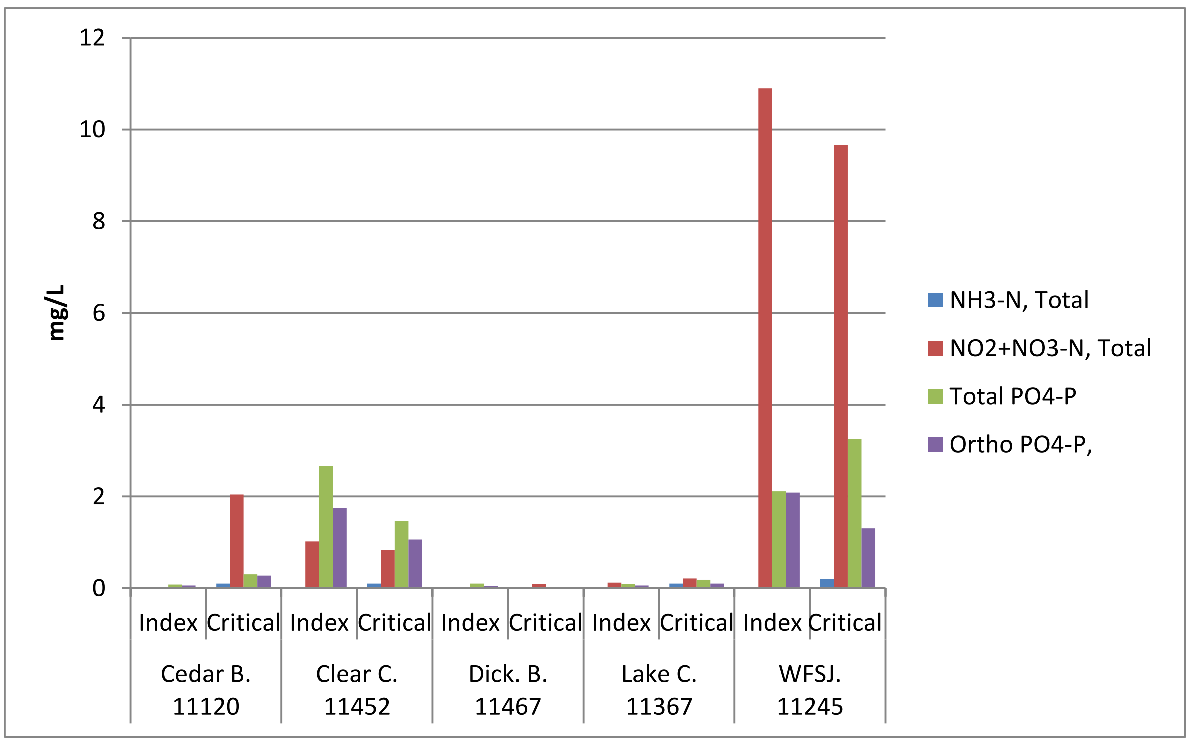

Figure 17. Nutrient data for the sites surveyed by EIH in 2011.

Table 8. Twenty-four hour dissolved oxygen monitoring by EIH. Note that a reading was taken every 15 minutes for 24 hours totaling 96 measurements used for this summary table. The data from the CAMS site was collected every hour totaling 24 measurements during the sample period. CAMS data was collected from the USGS 08068000 site which can be accessed from : http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=08068000 . Spec. Cond. = Specific Conductance.

Site Name	HGAC ID	TCEQ ID	Reporting Agency	Sample Period	Date	Depth (m)	24-Hr D.O. Avg. (mg/L)	Max Daily D.O. (mg/L)	Min Daily D.O. (mg/L)	24 Hr Avg Water Temp (C)	Max Daily Water Tamp (C)	Min Daily Water Temp (C)	24-Hr Avg Spec. Cond. (µS)	24-Hr Max Spec. Cond. (uS)	24-Hr Min Spec. Cond. (uS)	Max Daily pH	Min Daily pH
Cedar Bayou	cedr7500	11120	EIH	Index	05/07/2011	0.290	4.24	5.21	3.45	18.29	19.62	17.20	2049.74	2063.0	2038.0	7.46	8.14
			EIH	Critical	08/04/2011	0.377	5.25	6.50	3.85	28.70	29.40	28.00	1102.71	1110.8	1092.8	7.85	7.49
Clear Creek	cler7000	11452	EIH	Index	5/4-5/2011	0.425	5.96	8.47	4.00	20.38	23.43	17.87	1026.55	1048.0	1004.0	8.45	7.29
			EIH	Critical	07/27/2011	0.280	3.23	5.80	1.45	31.09	32.33	29.85	1003.77	1044.4	895.9	7.78	7.51
Dickinson Bayou	dick0050	11467	EIH	Index	05/07/2011	0.350	5.49	7.91	3.28	23.94	26.13	22.54	915.94	939.0	895.0	8.09	7.75
			EIH	Critical	07/27/2011	0.339	4.47	7.06	2.06	30.04	30.92	29.39	894.23	918.8	867.2	8.12	7.63
Lake Creek	lake1367	11367	EIH	Index	05/11/2011	0.490	8.50	8.96	8.28	26.35	26.93	26.06	189.14	191.0	186.0	7.17	6.71
			EIH	Critical	07/30/2011	0.453	4.02	5.55	2.69	29.43	30.25	28.75	151.52	152.8	150.6	6.55	6.29
West Fork San Jacinto	wfsj8000	11245	EIH *	Index	05/07/2011	0.673	*	*	*	25.71	29.88	21.95	1154.78	1247.0	947.0	8.50	7.22
			TCEQ CAMS *	Index	05/07/2011	NA	8.09	13.20	4.50	25.83	30.10	21.80	1156.04	1260.0	948.0	8.80	7.50
			EIH	Critical	08/04/2011	1.947	3.83	4.68	3.02	30.13	31.81	28.88	1585.55	1617.8	1510.7	7.94	7.30

* EIH Dissolved Oxygen did not pass post-calibration, TCEQ CAMS data from the same site and date were reported as a result.

Comparison of Physico-chemical Variable Patterns between Collections

We analyzed the overall pattern in physico-chemical variables between collections and sites using multivariate cluster analysis. Qualitative variables, such as aesthetics, were not included in the analysis. Since the historical USGS collections did not monitor many of the key environmental variables, these collections were not included in this analysis. Cluster analysis identified 3 collection groups based on the similarity of the levels of physico-chemical variables (**Error! Reference source not found.**). The three groups include the West Fork San Jacinto River collections, Lake Creek collections, and the remaining three sites which grouped together. This indicates that the Cedar Bayou, Clear Creek and Dickinson Bayou sites exhibited similar overall patterns in physico-chemical variables. These three sites are all coastal streams occurring along the Galveston Bay watershed. In contrast, Lake Creek and the West Fork of San Jacinto River are inland water bodies located above the Lake Houston dam in the San Jacinto River watershed.

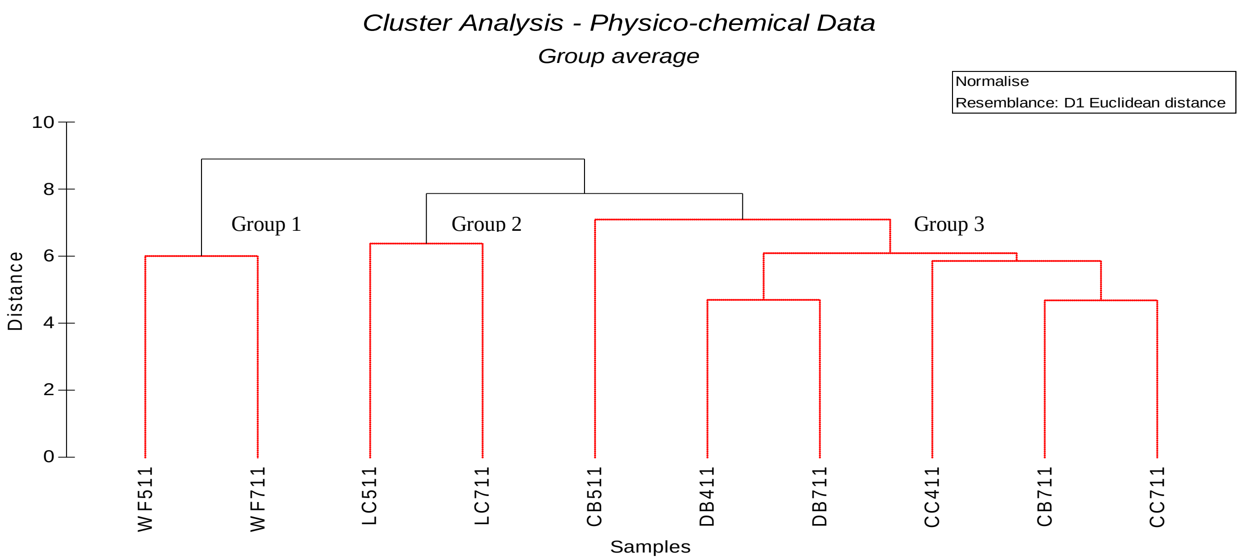

Figure 18. Results of cluster analysis of collections using normalized physico-chemical variables and Euclidean distance measure and group average clustering method. Similar groups were identified by the SIMPROF method and are denoted by same colored branches of the dendrogram (Clarke and Gorley 2006). Samples denoted by the following code sequence: XXMYY, where XX = stream, MYY = month & year.

Fish

All sites sampled in 2011 met the criteria for an aquatic life use designation of high or exceptional using the regional fish index of biotic integrity (IBI) (Table 9). In addition all sites exhibited some improvement in fish community scores since the original USGS study was conducted in 1997-98. While caution must be used when comparing single survey points nearly 14 years apart, these data suggest that all sites are currently supporting a healthy fish community. There were two instances where the regional IBI score for the aquatic life use designation could not be calculated for the historical USGS data due to lack of electrofishing data. This included historical USGS collections at the Clear Creek and the West Fork of the San Jacinto River. In each of these instances, electrofishing effort data was lacking. As a result, the old statewide IBI scoring and evaluation criteria were calculated for all datasets (Table 11) (TNRCC, 1999). The older statewide method does not require electrofishing data to compute an IBI score. As represented in Table 12, the parameters for calculating the statewide IBI include metrics such as number of darter species and number of sucker species. The *Surface Water Quality Monitoring Procedures, Volume 2: Methods for Collecting and Analyzing Biological Assemblage and Habitat Data*, published in 2007 replaced the *Receiving WaterAssessment Procedures Manual*, GI-253. This update in procedures changed the statewide fish IBI method to a regionalized approach and replaced the metrics of number of darter and sucker species with more general metrics such as number of species within certain feeding guilds. It also introduced the use of effort metrics based on specific gear (electrofishing versus seining) to the IBI calculations. Overall, the regional IBI metrics employ more scientifically sound parameters and supersede the statewide IBI evaluation criteria. It accounts for regional expectations of fish community composition in least disturbed streams and rivers based on ecoregions. Statewide IBI metrics were calculated for this dataset due to the fact that effort data was not collected for two of the USGS sampling events, thus the regional IBI could not be calculated. In general when the IBI scores are compared for the same dataset between the statewide and regional scoring metrics, the statewide IBI results in a lower aquatic life use designation than the regional IBI (Table 11 through Table 12).

Species richness for fish collections was greatest for the Lake Creek and the West Fork of the San Jacinto River sites and lowest for the Dickinson Bayou site (Table 10 and Figure 19). Species richness for each event show a general trend of increasing number of species collected during the EIH sample events as compared to the USGS events (Figure 19). The exception to this trend would be for the Cedar Bayou site 11120, which exhibited higher species richness (n = 15) during the initial USGS study in 1997 as compared to a decreased richness (n = 10) observed during the critical period of the EIH study in 2011. This decrease in species richness at Cedar Bayou was not due to sample number, since the number of fish collected during the 2011 EIH study was notably greater than that of the USGS sampling (Figure 20). In fact the total number of individuals collected per sample event was greater during the EIH study than that of the USGS study for all five study sites. The USGS study used electrofishing as their only method for fish collection, while EIH used both seines and electrofishing. Therefore, the increased number of fish taxa at most sites may reflect the influence of using two collection methods.

The percent of individuals collected that were considered tolerant (excluding *Gambusia affinis*) has decreased over time from the USGS fish collection in 1997-98 to the more recent EIH fish collection in 2011 at all five survey sites (

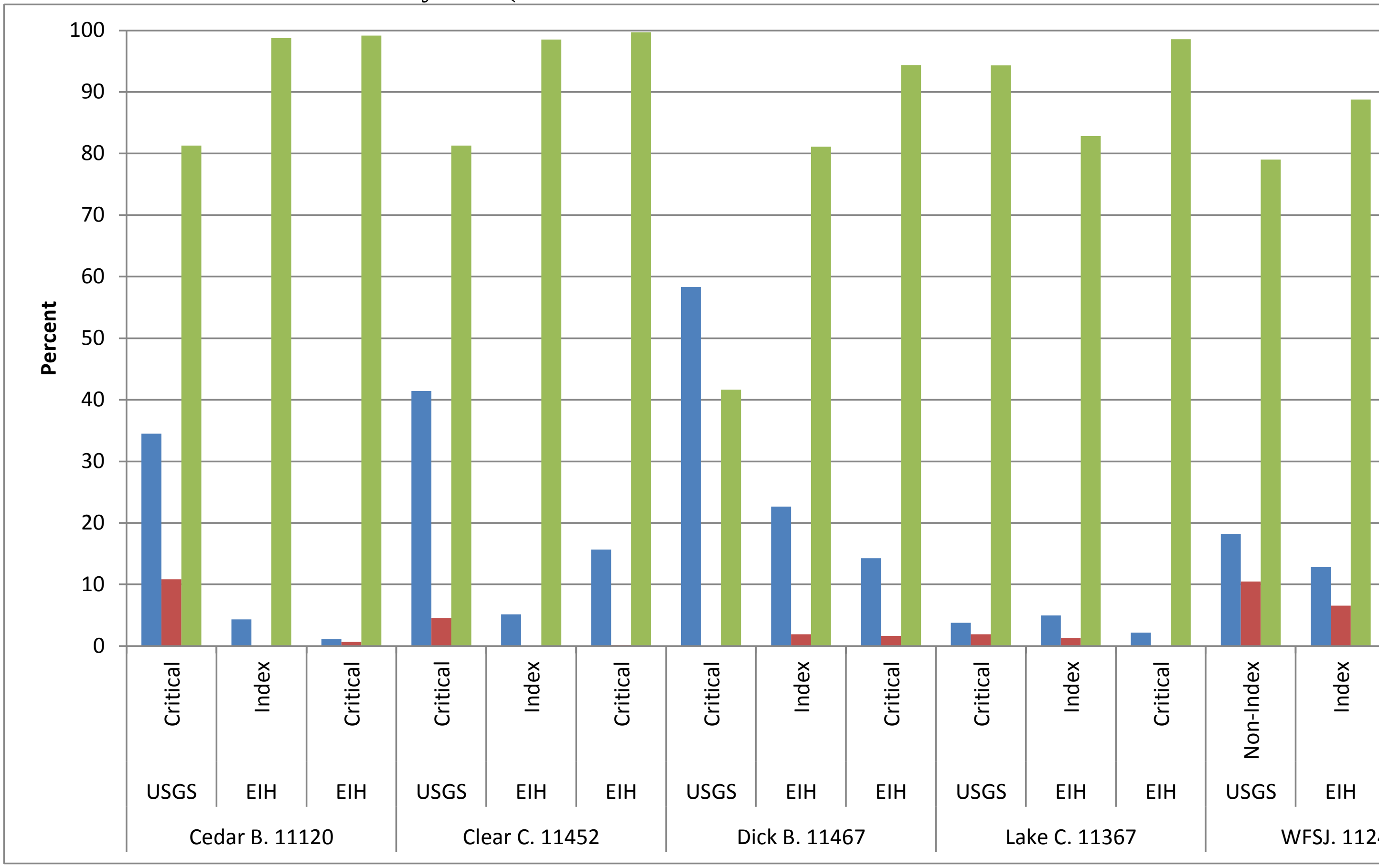

Figure 21). The percent of individuals collected that were classified as invertivores increased between the USGS collection to the EIH collection at every site surveyed.

Table 9. Regional Fish Index of Biotic Integrity (IBI) values for the study sites comparing USGS historical data and current EIH data.

Site Name	HGAC ID	TCEQ ID	Reporting Agency	Sample Period	Sample Date	Total Score	Aquatic Life Use Designation
Cedar Bayou	cedr7500	11120	USGS	Critical	08/25/1997	41	High
			EIH	Index	05/03/2011	48	High
				Critical	07/21/2011	41	High
Clear Creek	cler7000	11452	USGS	Critical	08/25/1997	*	*
			EIH	Index	04/28/2011	52	Exceptional
				Critical	07/15/2011	48	High
Dickinson Bayou	dick0050	11467	USGS	Critical	09/04/1997	29	Limited
			EIH	Index	04/26/2011	39	High
				Critical	07/14/2011	45	High
Lake Creek	lake1367	11367	USGS	Critical	09/19/1997	44	High
			EIH	Index	05/10/2011	54	Exceptional
				Critical	07/22/2011	47	High
West Fork San Jacinto	wfsj8000	11245	USGS	Non-Index	03/05/1998	*	*
			EIH	Index	05/06/2011	49	High
				Critical	07/27/2011	47	High

*These values could not be calculated due to missing or unavailable data pertinent to metric calculations.

Table 10. Regional Fish Index of Biotic integrity sample composition for USGS and EIH data. Note that there was no electrofishing data provided for the USGS study for sites: Clear Creek and West Fork of the San Jacinto.

Site Name	HGAC ID	TCEQ ID	Reporting Agency	Sample Period	Sample Date		Total number fish species	Number native cyprinid species	Number benthic invertivore species	Number sunfish species	Number intolerant species	Percent individuals as tolerant **	Percent individuals as omnivores	Percent individuals as invertivores	Percent individuals as piscivores	Number individuals in sample	Individuals per seine haul	Individuals per min electrofishing	Percent individuals as non-natives	Total Score
Cedar Bayou	cedr7500	11120	USGS	Critical	08/25/1997	Raw Value	15	3	1	6	0	34.48	10.84	81.28	***	203	0.00	0.16	0	41
						IBI Score	5	5	3	5	1	3	3	5	***	1	1	1	5	
			EIH	Index	05/03/2011	Raw Value	14	1	3	5	2	4.30	0	98.73	***	395	26.67	7.73	0	48
						IBI Score	5	1	5	5	5	5	5	5	***	2	1	3	5	
			EIH	Critical	07/21/2011	Raw Value	10	2	0	4	0	1.11	0.70	99.17	***	719	70.89	3.67	0	41
						IBI Score	5	3	1	5	1	5	5	5	***	1	1	1	5	
Clear Creek	cler7000	11452	USGS	Critical	08/25/1997	Raw Value	11	3	0	3	0	41.41	4.55	81.31	***	198	0.00	****	0	*
						IBI Score	5	5	1	3	1	3	5	5	***	*	1	*	5	
			EIH	Index	04/28/2011	Raw Value	15	3	1	5	1	5.13	0	98.53	***	819	97.86	8.92	0	52
						IBI Score	5	5	3	5	5	5	5	5	***	4	3	5	5	
			EIH	Critical	07/15/2011	Raw Value	13	3	1	3	1	15.69	0.14	99.73	***	733	98.57	1.82	0.27	48
						IBI Score	5	5	3	3	5	5	5	5	***	2	3	1	5	
Dickinson Bayou	dick0050	11467	USGS	Critical	09/04/1997	Raw Value	5	0	0	3	0	58.33	0	41.67	***	12	0	0.01	0	29
						IBI Score	3	1	1	3	1	1	5	3	***	1	1	1	5	
			EIH	Index	04/26/2011	Raw Value	10	1	0	5	0	22.64	1.89	81.13	***	53	4	2.05	0	39
						IBI Score	5	1	1	5	1	5	5	5	***	1	1	1	5	
			EIH	Critical	07/14/2011	Raw Value	11	1	1	5	1	14.24	1.66	94.37	***	302	32.25	2.02	0	45
						IBI Score	5	1	3	5	5	5	5	5	***	1	1	1	5	
Lake Creek	lake1367	11367	USGS	Critical	09/19/1997	Raw Value	18	3	4	4	3	3.79	1.89	94.32	3.79	264	0	0.23	0	44
						IBI Score	5	3	3	3	3	5	5	5	1	1	1	1	5	
			EIH	Index	05/10/2011	Raw Value	24	5	4	6	3	4.95	1.32	82.84	15.84	303	39.83	2.96	0.66	54
						IBI Score	5	5	3	5	3	5	5	5	5	3	5	1	5	
			EIH	Critical	07/22/2011	Raw Value	19	5	1	5	0	2.20	0	98.59	1.41	637	81	4.21	0	47
						IBI Score	5	5	1	5	1	5	5	5	1	4	5	3	5	
West Fork San Jacinto	wfsj8000	11245	USGS	Non-Index	03/05/1998	Raw Value	18	3	0	5	0	18.18	10.49	79.02	9.79	143	0	****	2.80	*
						IBI Score	3	3	1	5	1	5	3	5	5	*	1	*	1	
			EIH	Index	05/06/2011	Raw Value	23	2	3	7	3	12.81	6.56	88.75	4.38	320	26.17	8.13	0.94	49
						IBI Score	5	3	3	5	3	5	5	5	1	4	3	5	5	
			EIH	Critical	07/27/2011	Raw Value	22	3	1	6	2	4.01	1.49	97.17	1.34	1273	166.43	5.92	0.08	47
						IBI Score	5	3	1	5	3	5	5	5	1	4	5	3	5	

*These values could not be calculated due to missing or unavailable data pertinant to metric calculations.
** Not including *G. affinis*
*** Parameter only applicable for Ecoregion 35
**** No reported electrofishing effort data for this site

Table 11. Statewide Fish Index of Biotic Integrity (IBI) values for the study sites comparing USGS historical data and current EIH data (TNRCC, 1999).

Site Name	HGAC ID	TCEQ ID	Reporting Agency	Sample Period	Sample Date	Total Score	Statewide Aquatic Life Use Designation
Cedar Bayou	cedr7500	11120	USGS	Critical	08/25/1997	46	Intermediate/High
			EIH	Index	05/03/2011	50	High
				Critical	07/21/2011	44	Intermediate
Clear Creek	cler7000	11452	USGS	Critical	08/25/1997	42	Intermediate
			EIH	Index	04/28/2011	46	Intermediate/High
				Critical	07/15/2011	44	Intermediate
Dickinson Bayou	dick0050	11467	USGS	Critical	09/04/1997	36	Limited/Intermediate
			EIH	Index	04/26/2011	40	Intermediate
				Critical	07/14/2011	46	Intermediate/High
Lake Creek	lake1367	11367	USGS	Critical	09/19/1997	52	High
			EIH	Index	05/10/2011	56	High/Exceptional
				Critical	07/22/2011	46	Intermediate/High
West Fork San Jacinto	wfsj8000	11245	USGS	Non-Index	03/05/1998	44	Intermediate
			EIH	Index	05/06/2011	54	High/Exceptional
				Critical	07/27/2011	52	High

Table 12. Statewide Fish Index of Biotic integrity sample composition for USGS and EIH data (TNRCC, 1999).

Site Name	HGAC ID	TCEQ ID	Reporting Agency	Sample Period	Sample Date	Number of Fish Species	Number of Darter Species	Number of Sunfish Species *	Number of sucker species	Number of Intolerant Species	% of Individuals as Tolerants	% of Individuals as Omnivores	% of Individuals as Invertivores	% of Individuals as Piscivores	Number of Individuals in Sample	% of individuals as hybrids	% of Individuals With Disease/ Anomaly
Cedar Bayou	cedr7500	11120	USGS	Critical	08/25/1997	15	1	6	0	0	34.48	10.84	81.28	7.9	203	0.00	0.00
			EIH	Index	05/03/2011	14	1	5	0	2	4.30	0.00	98.73	1.3	395	0.00	0.00
			EIH	Critical	07/21/2011	10	0	4	0	0	1.11	0.70	99.17	0.1	719	0.00	0.00
Clear Creek	cler7000	11452	USGS	Critical	08/25/1997	11	0	3	0	0	41.41	4.55	81.31	14.1	198	0.00	0.00
			EIH	Index	04/28/2011	15	0	5	0	1	5.13	0.00	98.53	1.5	819	0.00	0.00
			EIH	Critical	07/15/2011	13	0	3	0	1	15.69	0.14	99.73	0.1	733	0.00	0.00
Dickinson Bayou	dick0050	11467	USGS	Critical	09/04/1997	5	0	3	0	0	58.33	0.00	41.67	58.3	12	0.00	0.00
			EIH	Index	04/26/2011	10	0	5	0	0	22.64	1.89	81.13	17.0	53	0.00	0.00
			EIH	Critical	07/14/2011	11	0	5	0	1	14.24	1.66	94.37	4.0	302	0.00	0.00
Lake Creek	lake1367	11367	USGS	Critical	09/19/1997	18	1	4	0	3	3.79	1.89	94.32	3.8	264	0.00	0.00
			EIH	Index	05/10/2011	24	2	6	1	3	4.95	1.32	82.84	15.8	303	0.00	0.00
			EIH	Critical	07/22/2011	19	0	5	0	0	2.20	0.00	98.59	1.4	637	0.00	0.00
West Fork San Jacinto	wfsj8000	11245	USGS	Non-Index	03/05/1998	18	0	5	1	0	18.18	10.49	79.02	9.8	143	0.00	0.00
			EIH	Index	05/06/2011	23	2	7	1	3	12.81	6.56	88.75	4.4	320	0.00	0.00
			EIH	Critical	07/27/2011	22	1	6	1	2	4.01	1.49	97.17	1.3	1273	0.00	0.00

* excludes bass.

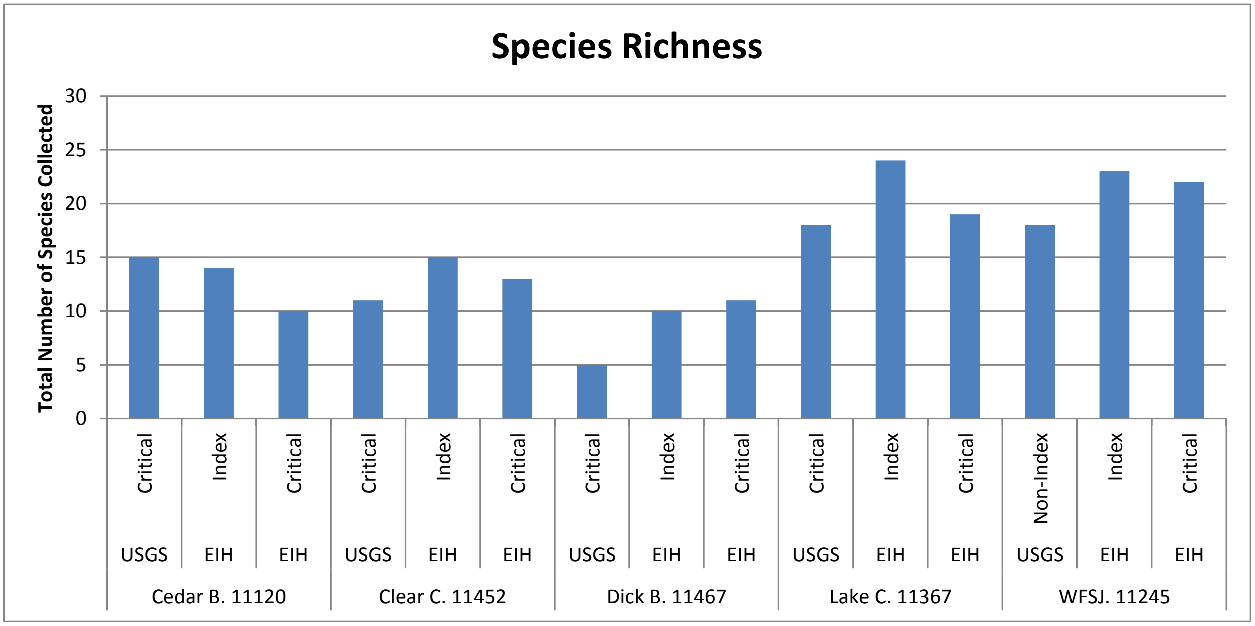

Figure 19. Fish species richness per sampling event for each of the 5 study sites sampled by USGS (1997-1998) and EIH (2011).

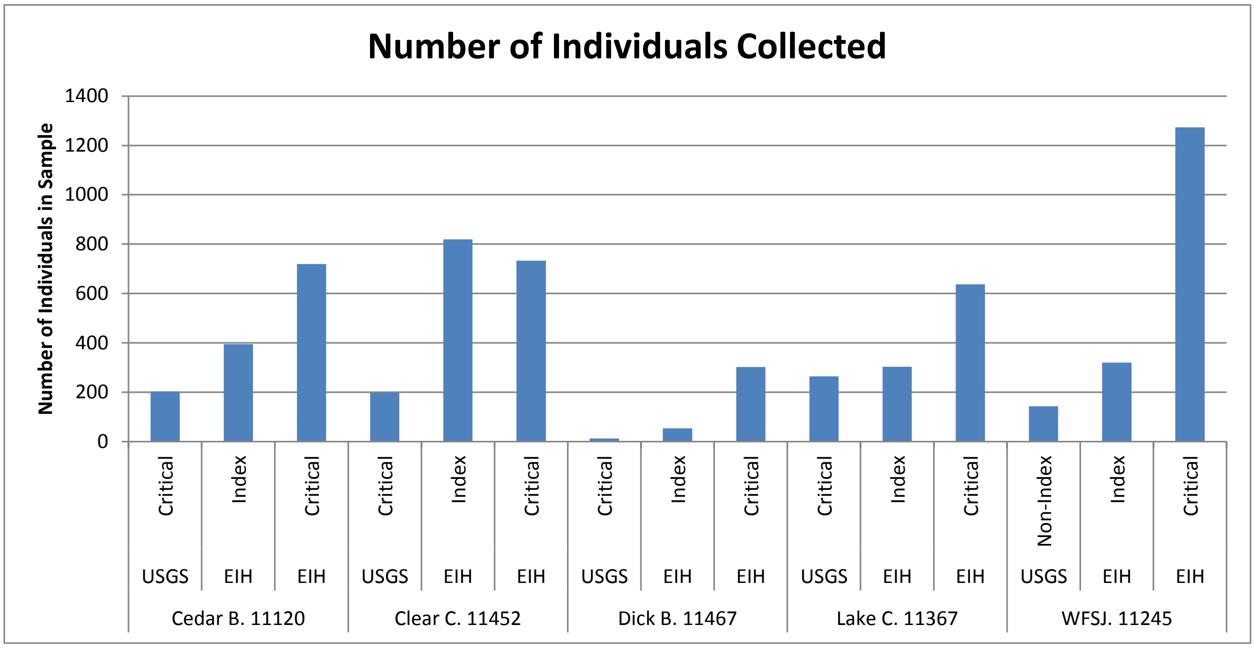

Figure 20. Total number of fish collected per sampling event for each of the 5 study sites sampled by USGS (1997-1998) and EIH (2011).

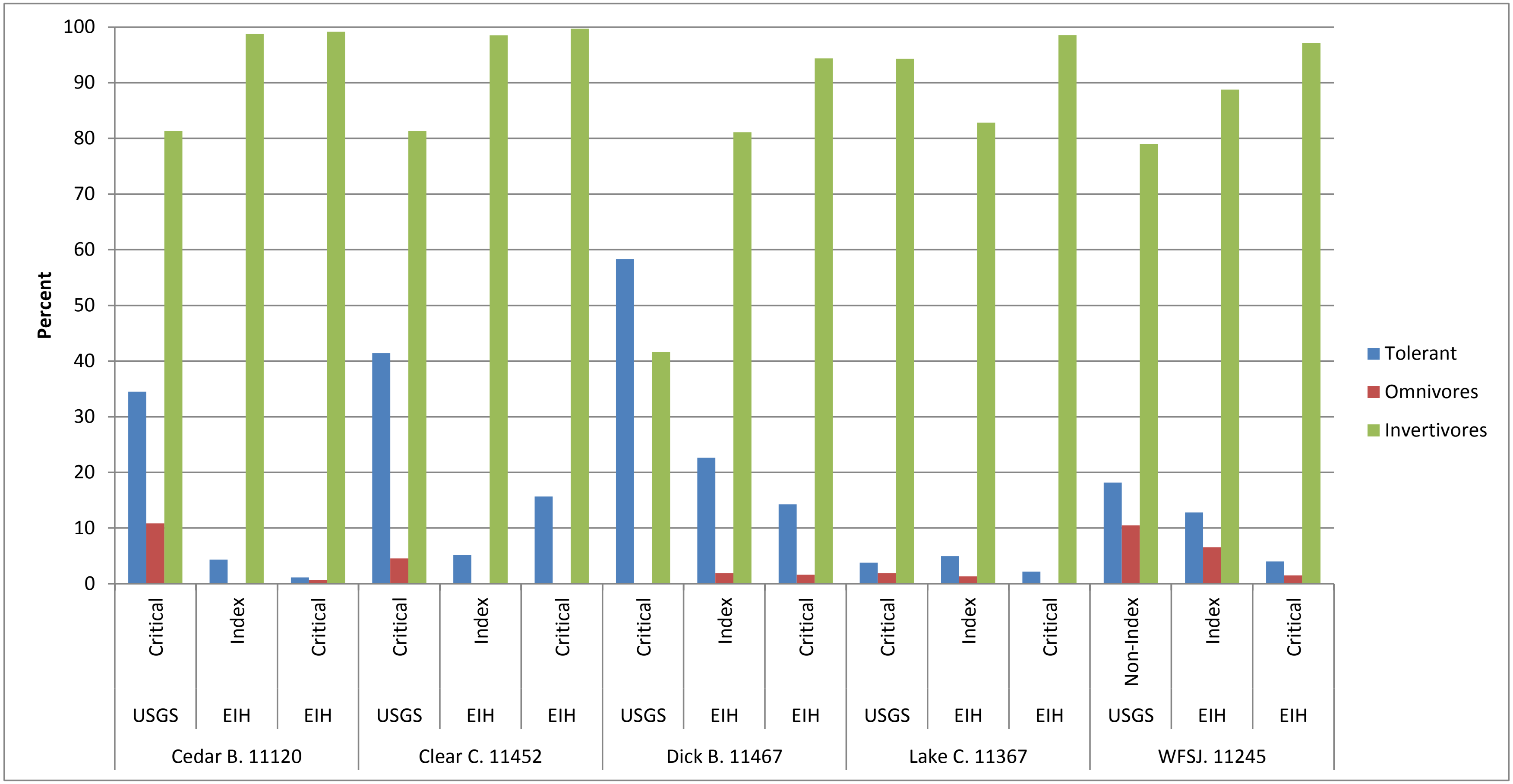

Figure 21. Percent of the total catch of tolerant fish individuals, omnivores, and invertivores collected by USGS (1997-1998) and EIH (2011) at all 5 survey sites.

Species composition varied between sites and between study years (Table 13). One interesting shift observed was the presence of the invasive fish species: *Herichthys cyanoguttatum*, the Rio Grande Cichlid, at Clear Creek site 11452 in the 2011 EIH sampling. This fish was not found at any other site surveyed, and was not found at the Clear Creek site during the 1997 USGS sampling. Past studies by Ramirez (unpublished UHCL report) have reported this species within the watershed the early 2000's. Cluster analysis results based on classification of collections using the most common frequently encountered (> 20% of all collections) fish species indicated that little change in the community had occurred at most sites. The only exception was the Dickinson Bayou 1997 collection (site 11467) which was significantly different in species composition from the other sites (Figure 22). This collection was also unique in possessing extremely low numbers of fish (12), the lowest number (5) of species, and containing the only reports of spotted gar (Figure 19 and Table 13). It is possible that this site was not sampled intensely enough to characterize the fish assemblage.

Benthics

All but one site sampled in 2011 exhibited a benthic aquatic life use index of biotic integrity (IBI) designation greater than the IBI score from the same site in 1997-98 (Table 9 & Figure 23). The exception is Lake Creek site 11367 where the IBI score decreased from intermediate (score 26) to limited (score 21) during the critical period. No benthic data was collected during the USGS study for the West Fork of the San Jacinto River (site 11245) so a comparison of IBI scores over time could not be examined. It should be noted that during the 1997-98 USGS study two separate benthic samples were reported for 09/04/1997 at Dickinson Bayou site 11467. These two samples were analyzed and reported separately. Taxa richness for benthic macroinvertebrate collections is shown in Figure 24. Taxa richness for each event show a general trend of increasing number of species collected during the EIH sample events as compared to the USGS events (Table 10 & Figure 24). The exception to this trend was Lake Creek site 11367, which exhibited higher taxa richness (23) during the initial USGS study in 1997 as compared to a decreased richness (19) observed during the critical period of the EIH study in 2011.

The percent dominant functional feeding group (FFG) is the ratio of the number of individuals in the numerically dominant functional group to the total number of individuals in the sample. This metric is based on the premise that physicochemical disturbance can result in an imbalanced trophic structure. Percent dominant FFG is illustrated in Figure 25. In addition the percent predators and percent collector-gatherers are included in this figure, and are two of the five FFG categories used to calculate the dominant FFG.

Taxa composition varied greatly between sites and between study years (Table 16). Results of cluster analysis of common benthic species identified 4 collection groups (Figure 26). Group 1 consisted of 1997 Dickinson Bayou collections. Group 2 consisted of 2011 collections at the West Fork San Jacinto River, Clear Creek and the Cedar Bayou July 2011 collections. Group 3 consisted of the 2011 collections at Lake Creek, Dickinson Bayou and the May 2011 Cedar Bayou collection. The last cluster, group 4, consisted of 1997 collections at Cedar Bayou, Lake Creek and Clear Creek. Based on this analysis alone it appears the community composition had shifted considerably between 1997 and 2011 at the study sites.

Table 13. Species composition of fish collection by both USGS and EIH at all 5 study site locations. Raw data provided in Appendices.

					11120			11452			11467			11367			11245	
				USGS	EIH	EIH	USGS	EIH	EIH	USGS	EIH	EIH	USGS	EIH	EIH	USGS	EIH	EIH
				Critical	Index	Critical	Critical	Index	Critical	Critical	Index	Critical	Critical	Index	Critical	Non-Index	Index	Critical
Group	Family	Scientific Name	Common Name	8/25/1997	5/3/2011	7/21/2011	8/25/1997	4/28/2011	7/15/2011	9/4/1997	4/26/2011	7/14/2011	9/19/1997	5/10/2011	7/22/2011	3/5/1998	5/6/2011	7/27/2011
Gars	Lepisosteidae	*Lepisosteus oculatus*	Spotted Gar	0	0	0	0	2	0	2	0	0	0	0	1	3	0	0
		Atractosteus spatula	Alligator gar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Herrings	Clupeidae	*Dorosoma cepedianum*	Gizzard Shad	0	0	0	0	0	0	0	0	0	4	0	0	4	5	5
		Dorosoma petenense	Threadfin Shad	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0
Minnows	Cyprinidae	*Ctenopharyngodon idella*	Grass Carp	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
		Cyprinella lutrensis	Red Shiner	9	0	0	31	30	110	0	0	0	0	0	1	1	0	0
		Cyprinella venusta	Blacktail Shiner	0	102	19	0	4	0	0	1	0	48	55	199	37	147	801
		Cyprinus carpio	Common carp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
		Lythrurus fumeus	Ribbon shiner	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
		Notemigonus crysoleucas	Golden shiner	0	0	1	0	0	0	0	0	0	0	1	0	0	1	0
		Hybopsis amnis	Pallid Shiner	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0
		Notropis atrocaudalis	Black Spot Shiner	0	0	0	0	0	1	0	0	0	0	57	4	0	0	0
		Notropis stramineus	Sand Shiner	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0
		Notropis texanus	Weed shiner	0	0	0	0	0	0	0	0	0	0	5	7	0	0	0
		Notropis volucellus	Mimic shiner	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30
		Pimephales promelas	Fathead Minnow	3	0	0	2	0	0	0	0	0	0	0	0	0	0	0
		Pimephales vigilax	Bullhead Minnow	16	0	0	51	61	32	0	0	1	81	11	0	17	0	0
Suckers	Catastomidae	*Carpiodes carpio*	River Carpsucker	0	0	0	0	0	0	0	0	0	0	1	0	2	10	7
		Moxostoma poecilurum	Blacktail Redhorse	0	0	0	0	0	0	0	0	0	7	8	2	0	0	0
Catfish	Ictaluridae	*Ameiurus natalis*	Yellow Bullhead	4	0	0	0	0	1	0	0	5	0	3	0	0	0	0
		Ictalurus furcatus	Blue Catfish	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
		Ictalurus punctatus	Chanel Catfish	15	0	0	4	0	0	0	0	0	1	0	0	1	6	6
		Noturus gyrinus	Tadpole Madtom	0	1	0	0	1	1	0	0	1	2	0	0	0	0	0
		Noturus nocturnus	Freckled Madtom	0	2	0	0	0	0	0	0	0	1	1	0	0	1	0
Pikes	Esocidae	*Esox americanus*	Grass Pickerel	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Pirate Perches	Aphredoderidae	*Aphredoderus sayanus*	Pirate Perch	0	2	0	0	0	0	0	0	0	1	1	1	0	0	1
Killifishes	Fundulidae	*Fundulus chrysotus*	Golden Topminnow	0	2	15	0	0	0	0	0	0	0	0	0	0	1	3
		Fundulus notatus	Blackstripe Topminnow	1	122	144	0	111	258	0	17	113	1	27	245	1	27	309
Livebearers	Poeciliidae	*Gambusia affinis*	Western Mosquitofish	31	38	531	30	534	188	3	1	114	1	1	21	0	6	10
		Poecilia latipinna	Sailfin Molly	0	0	5	2	0	0	0	0	0	0	0	0	0	0	0
Silversides	Atherinopsidae	*Labidesthes sicculus*	Brook Silverside	0	0	0	0	0	0	0	0	0	0	33	0	0	5	0
		Menidia beryllina	Inland silverside	0	0	0	0	14	106	0	0	0	0	0	83	0	0	8
Temperate Basses	Moronidae	*Morone saxatilis*	Striped Bass	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
Pygmy Sunfishes	Elassomatidae	*Elassoma zonatum*	Banded Pygmy Sunfish	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Sunfishes	Centrarchidae	*Chaenobryttus gulosus*	Warmouth	10	0	0	0	2	0	1	1	0	0	1	0	0	0	2
		Lepomis auritus	Redbreast Sunfish	0	0	0	0	0	2	0	0	0	0	2	0	0	2	0
		Lepomis cyanellus	Green Sunfish	2	3	1	27	7	0	4	7	10	1	8	3	0	3	6
		Lepomis humilis	Orange-spotted Sunfish	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0
		Lepomis macrochirus	Bluegill	31	14	1	16	1	5	0	4	33	3	3	9	13	15	22
		Lepomis megalotis	Longear Sunfish	72	65	1	33	49	19	2	17	18	80	35	46	38	55	34
		Lepomis microlophus	Redear Sunfish	0	0	1	0	0	0	0	0	2	3	0	2	3	16	4
		Lepomis miniatus	Redspotted sunfish	0	39	0	0	1	0	0	3	3	0	2	2	0	5	5
		Lepomis punctatus	Spotted Sunfish	2	0	0	0	0	0	0	0	0	0	0	0	2	0	0
		Micropterus punctulatus	Spotted bass	0	0	0	0	0	0	0	0	0	0	27	3	0	7	1
		Micropterus salmoides	Largemouth Bass	4	2	0	1	1	1	0	1	2	9	12	1	7	3	6
		Pomoxis annularis	White Crappie	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Perches	Percidae	*Etheostoma chlorosomum*	Bluntnose darter	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0
		Etheostoma gracile	Slough Darter	2	1	0	0	0	0	0	0	0	0	0	0	0	1	0
		Percina sciera	Dusky Darter	0	0	0	0	0	0	0	0	0	17	2	0	0	1	1
Drums	Sciaenidae	*Aplodinotus grunniens*	Freshwater Drum	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0
Cichlids	Cichlidae	*Herichthys cyanoguttatum*	Rio Grande Cichlid	0	0	0	0	1	9	0	0	0	0	0	0	0	0	0
Mullets	Mugilidae	*Mugil cephalus*	Striped Mullet	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0
			Total Number	203	395	719	198	819	733	12	53	302	264	303	637	143	320	1273

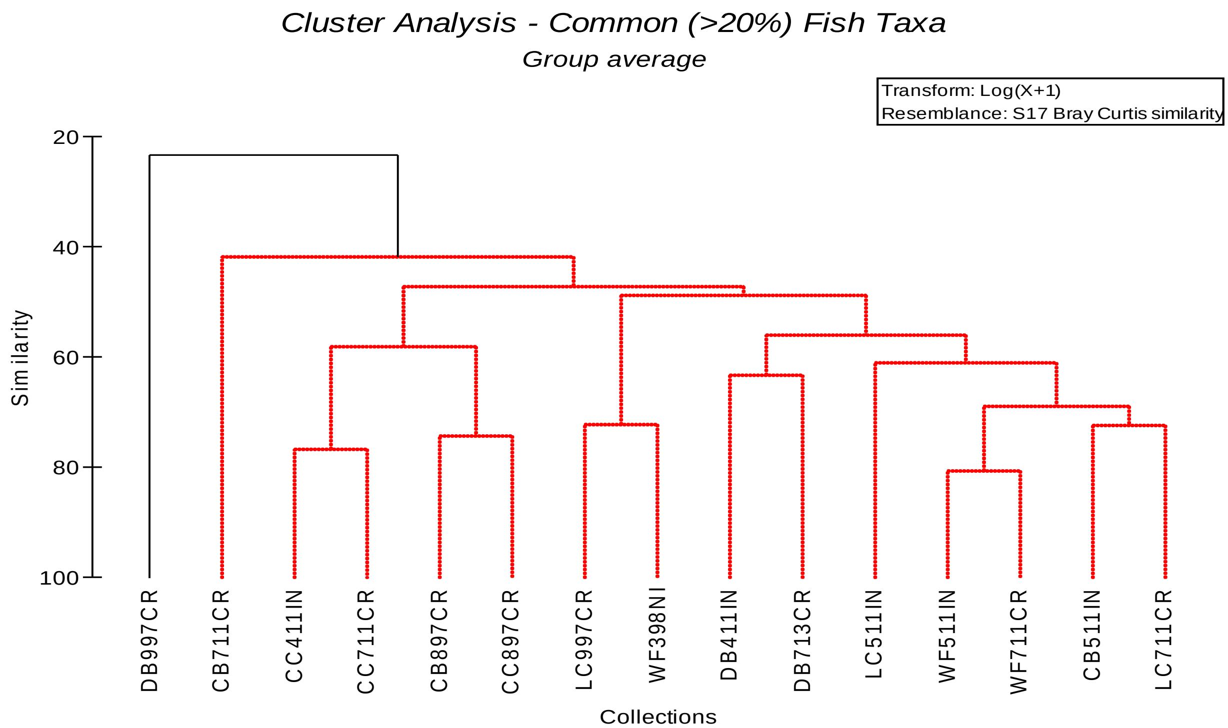

Figure 22. Results of cluster analysis of fish collections using common (>20% sites) species transformed (log + 1) abundance data and the Bray Curtis similarity distance measure and group average clustering method. Similar groups were identified by the SIMPROF method and are denoted by same colored branches of the dendrogram ((Clarke and Gorley 2006)). Samples denoted by the following code: XXMYYZZ, where XX = stream, MYY = month & year, ZZ = critical or index period.

Table 14 Benthic aquatic life use index of biotic integrity scores for all five study sites surveyed by USGS and EIH.

Site Name	HGAC ID	TCEQ ID	Reporting Agency	Sample Period	Sample Date	AQUATIC LIFE USE SCORE	AQUATIC LIFE USE RATING
Cedar Bayou	cedr7500	11120	USGS	Critical	08/25/1997	27	Intermediate
			EIH	Index	05/03/2011	29	High
				Critical	07/21/2011	31	High
Clear Creek	cler7000	11452	USGS	Critical	08/25/1997	22	Intermediate
			EIH	Index	04/28/2011	32	High
				Critical	07/15/2011	28	Intermediate
Dickinson Bayou	dick0050	11467	USGS *	Critical	09/04/1997	23	Intermediate
				Critical	09/04/1997	24	Intermediate
			EIH	Index	04/26/2011	30	High
				Critical	07/14/2011	29	High
Lake Creek	lake1367	11367	USGS	Critical	09/19/1997	26	Intermediate
			EIH	Index	05/10/2011	27	Intermediate
				Critical	07/22/2011	21	Limited
West Fork San Jacinto	wfsj8000 **	11245	EIH	Index	05/06/2011	29	High
				Critical	07/27/2011	20	Limited

* USGS reported two separate benthic samples for Dickinson Bayou site

** No benthic data collected at the West Fork San Jacinto by USGS study.

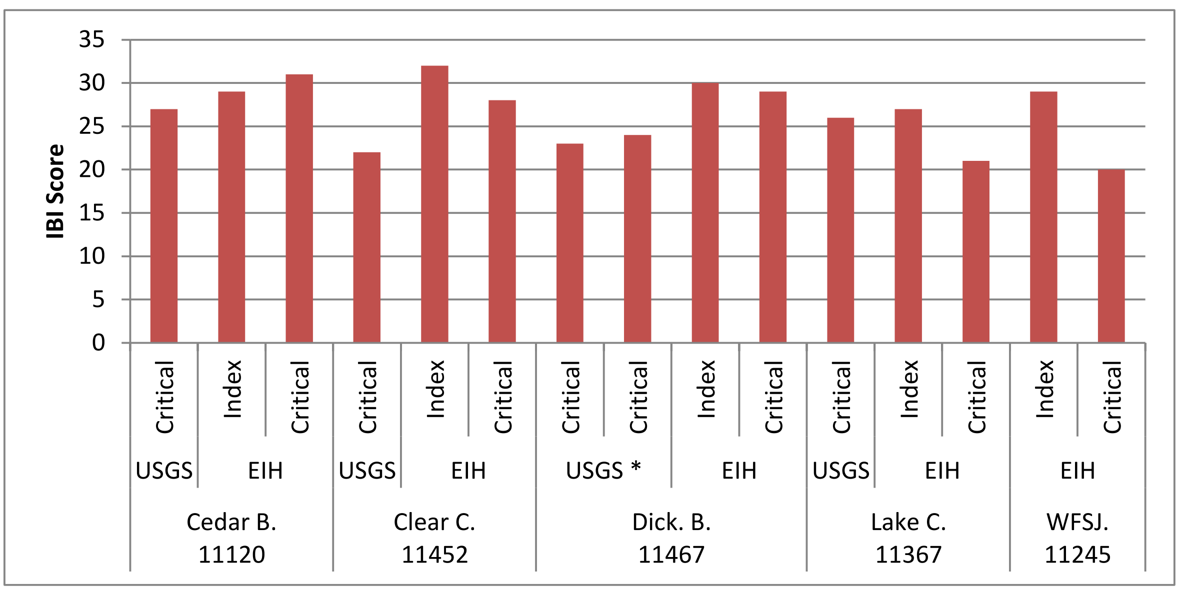

Figure 23. Benthic macroinvertebrate index of biotic integrity (IBI) scores for the aquatic life use criteria for all 5 study sites surveyed by USGS and EIH. *USGS collected two separate benthic samples at Dickinson Bayou site 11467. Note benthic sample not collected at West Fork of the San Jacinto River site 11245 by USGS. Data corresponds to Table 14.

Table 15. Benthic index of biotic integrity sample composition for USGS and EIH data. EPT = total number of distinct taxa within the orders of Ephemeroptera, Plecoptera, and Trichoptera, HBI = Hilsenhoff Biotic Index, FFG = Functional Feeding Groups, CG = Collector-Gatherers.

Site Name	HGAC ID	TCEQ ID	Reporting Agency	Sample Period	Sample Date	Taxa Richness	EPT Index	HBI	% Chironomidae	% Dominant Taxon	Dominant FFG	Predators	Intolerant : Tolerant	% Total Trichoptera as Hydropsychidae	Number of Non-Insect Taxa	Collect or-gatherers	% n as Elmidae
Cedar Bayou	cedr7500	11120	USGS	Critical	08/25/1997	15	7	5.22	28.57	28.57	45.79	15.02	0.88	75	1	45.79	6.59
			EIH	Index	05/03/2011	16	4	6.99	9.15	40.52	45.53	7.63	0.07	0	5	45.53	1.96
			EIH	Critical	07/21/2011	21	2	7.52	6.29	18.86	44.29	10.95	0.03	NA	8	33.52	3.43
Clear Creek	cler7000	11452	USGS	Critical	08/25/1997	14	5	6.24	63.86	63.86	34.78	25.74	0.02	77.78	3	34.78	19.52
			EIH	Index	04/28/2011	20	5	6.39	7.73	20.99	60.87	6.72	0.40	0	9	60.87	4.42
			EIH	Critical	07/15/2011	17	4	7.08	2.99	40.12	50.70	4.89	0.09	NA	7	50.70	1.8
Dickinson Bayou	dick0050	11467	USGS *	Critical	09/04/1997	5	2	5.83	89.33	89.33	34.44	34.44	0.07	0	0	32.44	1.33
			USGS *	Critical	09/04/1997	9	3	5.81	88.76	88.76	32.84	31.36	0.08	0	0	32.84	4.73
			EIH	Index	04/26/2011	14	1	7.35	3.76	33.87	34.77	7.21	0.02	NA	9	34.77	1.61
			EIH	Critical	07/14/2011	19	3	5.76	8.67	34.1	65.80	5.97	0.92	0	10	65.80	1.73
Lake Creek	lake1367	11367	USGS	Critical	09/19/1997	27	12	5.75	20.36	27.84	57.73	10.78	0.74	58.33	3	57.73	21.61
			EIH	Index	05/10/2011	19	2	6.72	15.98	23.08	47.63	13.61	0.17	NA	11	47.63	3.55
			EIH	Critical	07/22/2011	19	2	6.91	27.16	31.48	52.57	14.61	0.04	NA	11	52.57	0.62
West Fork San Jacinto	wfsj8000 **	11245	EIH	Index	05/06/2011	18	7	6.04	10.45	20.40	66.75	6.50	0.80	15.38	6	66.75	0.5
			EIH	Critical	07/27/2011	14	6	5.98	20.32	32.09	61.32	11.59	0.88	100	4	61.32	0.53

* USGS reported two separate benthic samples for Dickinson Bayou site

** No benthic data collected at the West Fork San Jacinto by USGS study.

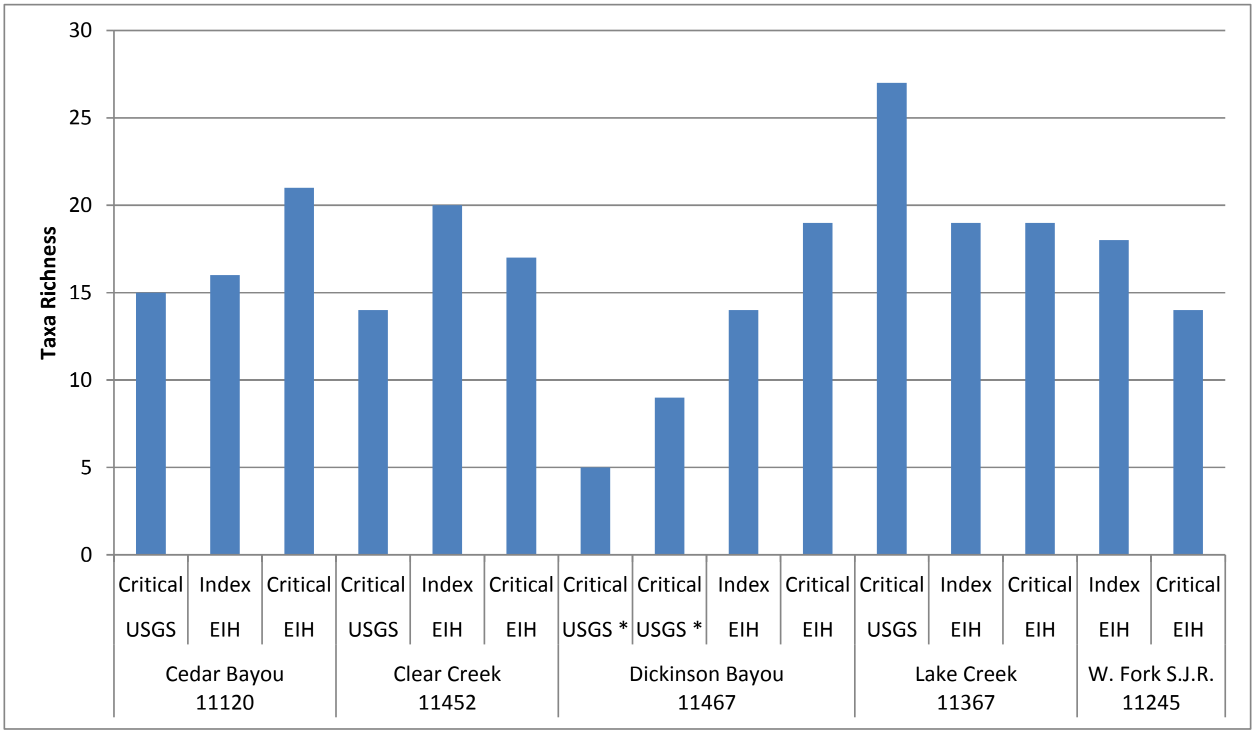

Figure 24. Benthic macroinvertebrate taxa richness for the 5 survey sites sampled by USGS and EIH. * USGS reported two separate benthic samples for site 11467, taken on the same day. W. Fork S.J.R = West Fork of the San Jacinto River.

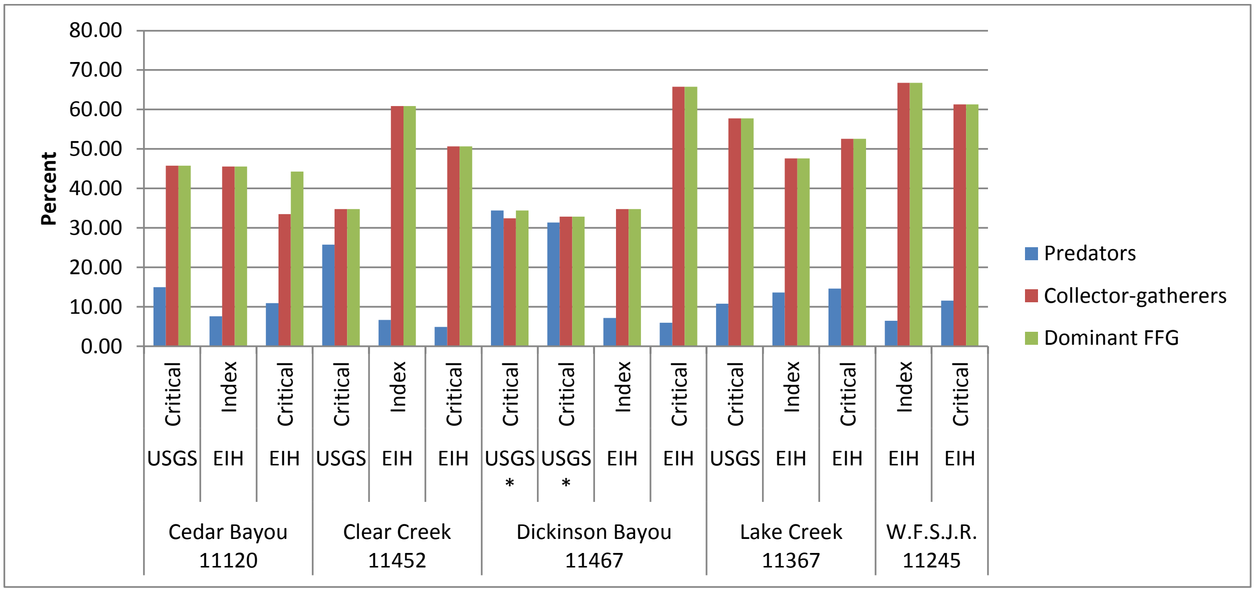

Figure 25. Percent dominant functional feeding group (FFG) for benthic macroinvertebrate samples collected at the survey sites by USGS and EIH. The percent predators and percent collector-gatherers are displayed as well, and are used in the calculation for the percent dominant FFG. W.F.S.J.R = West Fork of the San Jacinto River.

Table 16. Taxa composition of benthic macroinvertebrate collection by both USGS and EIH at all 5 study site locations. Raw data provided in Appendices.

					Cedar Bayou			Clear Creek			Dickinson Bayou				Lake Creek			West Fork San Jacinto	
					cedr7500			cler7000			dick0050				lake1367			wfsj8000	
					11120			11452			11467				11367			11245	
					USGS	EIH		USGS	EIH		USGS *	USGS *	EIH		USGS	EIH		EIH	
Phylum	**Class**	**Order**	**Family**	**Genus**	Critical	Index	Critical	Critical	Index	Critical	Critical	Critical	Index	Critical	Critical	Index	Critical	Index	Critical
Annelida	Hirudinea				0	0	0	0	3	2	0	0	0	0	1	1	0	3	0
	Oligochaeta				1	3	22	4	14	14	0	0	0	2	0	15	51	41	4
	Clitellata	Branchiobdellida			0	0	0	0	0	0	0	0	1	0	0	0	0	1	0
Arthropoda	Hydracarina				0	6	1	0	0	0	0	0	3	2	0	6	2	0	0
	Crustacea	Amphipoda	Gammaridae	*Gammarus*	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0
			Hyalellidae	*Hyalella*	0	39	25	0	14	23	0	0	63	42	0	30	1	32	11
		Cladocera			0	0	0	0	0	0	0	0	35	8	0	7	1	0	0
		Decapoda	Palaemonidae	*Palaemonetes*	0	0	0	0	3	0	0	0	1	4	0	0	0	0	0
		Ostracoda			0	0	0	0	38	14	0	0	0	10	0	6	3	1	0
		Copepoda			0	3	0	0	0	0	0	0	0	7	0	1	7	0	0
Mollusca	Gastropoda	Basommatophora	Physidae		0	0	0	6	0	0	0	0	0	0	0	0	0	0	0
			Ancylidae	*Ferrissia*	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0
			Physidae	*Physella*	0	0	14	0	0	0	0	0	0	0	0	0	1	0	1
			Planorbidae	*Gyraulus*	0	0	7	0	0	0	0	0	1	0	0	2	0	0	0
				Helisoma	0	0	8	0	0	0	0	0	0	1	0	0	0	0	0
		Mesogastropoda	Hydrobiidae		0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
				Cincinnatia	0	0	0	0	9	3	0	0	0	0	0	0	0	0	0
				Pyrgophorus	0	13	33	0	8	19	0	0	5	7	0	5	16	4	0
	Bivalvia	Heterodonta	Pisidiidae	*Eupera*	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
				Pisidium	0	0	1	0	2	1	0	0	0	1	0	2	0	0	0
				Sphaerium	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
			Corbiculidae	*Corbicula*	0	0	0	0	6	0	0	0	0	0	1	2	9	0	0
Platyhelminthes	Turbellaria	Tricladida	Planariidae	*Dugesia*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Arthropoda	Insecta	Coleoptera	Dryopidae	*Helichus*	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0
			Elateridae		1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Elmidae	*Dubiraphia*	0	2	0	3	0	0	0	0	2	2	9	5	0	1	0
				Heterelmis	0	0	0	0	0	0	1	4	0	0	0	0	0	0	0
				Macronychus	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0
				Microcylloepus	1	0	0	0	0	0	0	4	0	0	0	0	0	0	0
				Stenelmis	5	1	6	78	8	3	0	0	1	1	143	1	1	0	1
			Gyrinidae	*Gyretes*	0	0	0	2	0	0	3	1	0	0	1	0	0	0	0
			Haliplidae	*Peltodytes*	0	0	1	0	0	3	0	0	0	0	0	2	0	0	0
			Hydraenidae		0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
			Hydrophilidae	*Berosus*	0	0	4	1	0	0	0	0	0	0	0	0	0	0	0
			Staphylinidae		1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Diptera	Ceratopogonidae		0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
				Bezzia	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0
				Dasyhelea	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
				Probezzia	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0
				Stilobezzia	0	0	1	0	0	0	0	0	0	0	0	0	3	0	0
			Chironomidae		26	14	11	265	14	5	67	150	7	15	147	27	44	21	38
			Psychodidae	*Pericoma*	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
			Stratiomyidae	*Nemotelus*	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
				Stratiomys	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0

Table 166. cont. Taxa composition of benthic macroinvertebrate collection by both USGS and EIH at all 5 study site locations. Raw data provided in Appendices.

					Cedar Bayou			Clear Creek			Dickinson Bayou				Lake Creek			San Jacinto	
					cedr7500			cler7000			dick0050				lake1367			wfsj8000	
					11120			11452			11467				11367			11245	
					USGS	EIH		USGS	EIH		USGS *	USGS *	EIH		USGS	EIH		EIH	
Phylum	Class	Order	Family	Genus	Critical	Index	Critical	Critical	Index	Critical	Critical	Critical	Index	Critical	Critical	Index	Critical	Index	Critical
Arthropoda	Insecta	Ephemeroptera	Baetidae		0	0	0	0	0	0	0	3	0	0	3	0	0	0	0
				Baetis	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0
				Callibaetis	0	4	2	0	1	4	0	0	0	59	0	12	1	6	2
				Fallceon	13	1	0	0	8	3	0	0	0	0	0	0	0	27	21
				Labiobaetis	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
				Paracloeodes	0	0	0	0	0	0	0	0	0	0	8	0	0	0	16
			Caenidae	*Caenis*	0	62	24	16	27	67	0	0	56	8	85	39	15	7	23
			Heptageniidae	*Stenacron*	1	0	0	0	0	0	3	0	0	0	23	0	0	0	0
				Stenonema	0	0	0	0	0	0	0	0	0	0	18	0	0	0	0
			Isonychiidae	*Isonychia*	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0
			Leptophlebiidae		2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Leptohyphidae	*Tricorythodes*	21	0	0	2	21	3	0	0	0	0	201	0	0	41	60
		Hemiptera	Gerridae	*Rheumatobates*	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
			Veliidae		0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
				Rhagovelia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
		Lepidoptera	Pyralidae		0	0	1	0	0	0	0	0	0	0	0	0	1	0	0
		Megaloptera	Corydalidae	*Corydalus*	1	0	0	0	0	0	0	0	0	0	18	0	0	0	0
		Odonata	Calopterygidae	*Hetaerina*	2	0	0	0	1	0	0	0	0	0	0	0	0	1	0
			Coenagrionidae	*Argia*	1	0	1	16	1	1	0	0	0	1	4	0	0	1	0
				Enallagma	0	0	1	0	1	0	0	0	0	1	0	0	0	0	0
			Corduliidae	*Macromia*	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
			Gomphidae	*Dromogomphus*	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
				Erpetogomphus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
				Progomphus	0	0	0	0	0	0	0	0	0	0	1	0	3	0	0
			Libellulidae		0	1	0	0	0	0	0	0	8	1	0	4	0	1	0
				Pachydiplax	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
		Trichoptera	Hydropsychidae	*Cheumatopsyche*	12	0	0	14	0	0	0	0	0	0	7	0	0	2	1
			Hydroptilidae		0	0	0	4	0	0	0	0	0	0	1	0	0	0	0
				Hydroptila	2	0	0	0	0	0	0	0	0	0	0	0	0	3	0
				Ithytrichia	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
				Mayatrichia	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
				Oxyethira	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0
			Leptoceridae	*Nectopsyche*	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
				Oecetis	0	0	0	0	1	0	0	0	0	0	3	0	0	0	0
			Philopotamidae	*Chimarra*	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Polycentropodidae	*Cyrnellus*	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0
				Nyctiophylax	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
				total	92	153	175	415	181	167	75	169	186	173	722	169	162	201	187

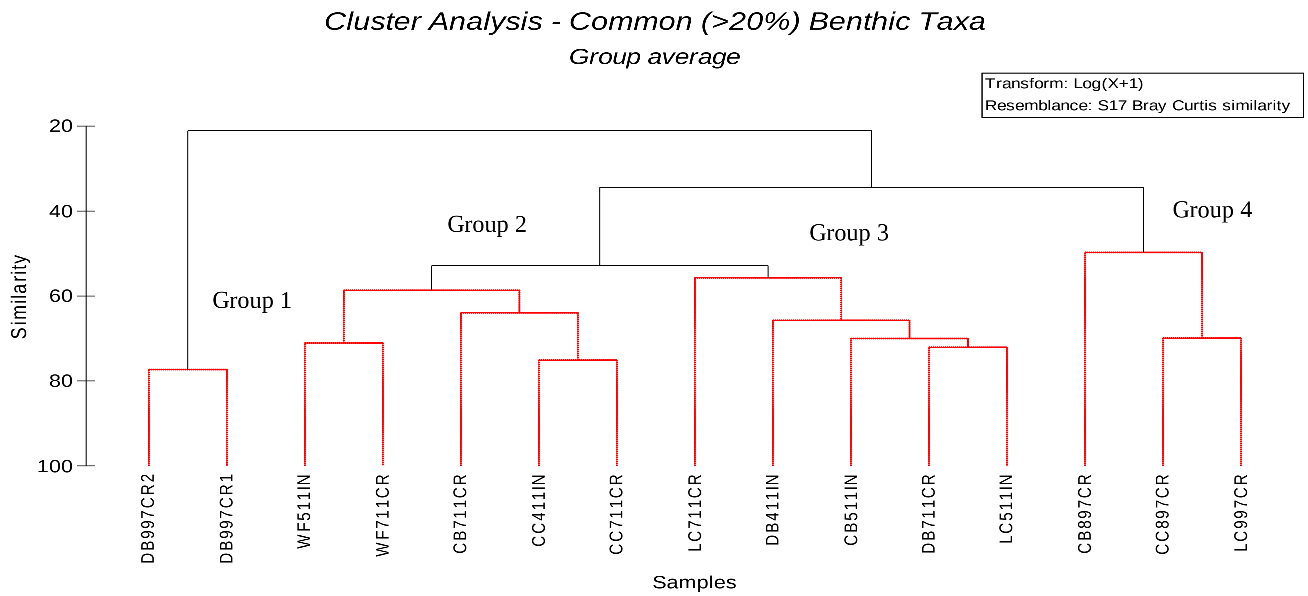

Figure 26. Results of cluster analysis of benthic collections using common (>20% sites) species transformed (log + 1) abundance data and the Bray Curtis similarity distance measure and group average clustering method. Similar groups were identified by the SIMPROF method and are denoted by same colored branches of the dendrogram ((Clarke and Gorley 2006)). Samples denoted by the following code: XXMYYZZ, where XX = stream, MYY = month & year, ZZ = critical or index period.

The differences in species composition is most likely linked to the increased number of taxa and number of individuals as collector-gathers, and reduced number of predator taxa in 2011 when compared to most 1997 critical period collections at the same site (Figure 24 and 25).

While caution must be used when comparing single survey points nearly 14 years apart, these data suggest that Cedar Bayou site 11120 and Dickinson Bayou site 11467 are currently exhibiting a benthic community with a high aquatic life use rating. The remaining three sites (11452, 11367, & 11245) possessed an ALU rating ranging from limited to high. Additional monitoring events would be necessary to confirm the appropriate ALU rating for these sites.

Comparison of Historical and Current Data with Designated Aquatic life Uses and Water Quality Standards

The overall goal of this study was to collect environmental data describing physical, chemical, and biological characteristics of each selected water body and compare this data against the assigned water quality standards for each stream segment, Aquatic Life Use (ALU) designations and associated dissolved oxygen (DO) criteria (using regional metrics). The second major goal was to compare data from the previous USGS data with the recent 2011 data using current biological integrity scores to identify which waterways may have exhibited a change in water quality and associated aquatic life use over time.

Water Quality Parameters

The Aquatic Life Use designation of a water body determines the applicable dissolved oxygen standard required for that water body to meet the ALU designation. For example, a water body with an ALU designation of “high” requires stringent dissolved oxygen conditions. Table 17 describes the current dissolved oxygen standards for each water body studied and the corresponding observed values from the 2011 EIH study. Using the two sampling events surveyed in this study, only one site (Dickinson Bayou) met the standard for 24-hr average D.O. mg/L, however it did not meet absolute minima D.O. mg/L standard during the critical event. Only two sites, Cedar Bayou and the West Fork of the San Jacinto River, met the standard for the absolute minima D.O. mg/L standard during both sampling events (Table 8). Due to the lack of 24-hr dissolved oxygen collected in 1997-98 we could not conduct a comparison of current and historical diel dissolved oxygen data. Dissolved oxygen is certainly a limiting factor for fish and benthic macroinvertebrate communities. However, in slow moving coastal water bodies which may possess physical conditions (low velocity, salt wedge, turbid water, and high temperatures) that limit reaereation, organisms may be more adapted to chronic low D.O. conditions.

Additional water chemistry parameters with listed standards for each water body, and their corresponding observed values from the 2011 EIH study are presented in Table 18. The Lake Creek site, which was determined to be the least impacted watershed studied, most closely met the standards for the water chemistry parameters with the exception of the single grab *E. coli* sample collected during the index event.

Because of the limited water quality data collected by the USGS study, no direct inferences could be made about the could be made about the changes of water quality over time using the data from this study. As a result, water quality result, water quality data for the five survey sites was obtained from H-GAC surface water quality data by basin (HGAC quality data by basin (HGAC 2013). *E. coli* data is available for the Lake Creek (site 11367) from 2007 to present and from 2007 to present and shows that grab samples which exceed the standard are rare, and there is a slight decreasing is a slight decreasing general trend over time (Figure 27). Chloride (mg/L as Cl-) exceeded the standard during one or both sampling events at four of the five survey sites during this study (Table 18 and

Figure 28). Sulfate grab samples exceeded the standard of 50 mg/L during both sampling events at the West Fork of the San Jacinto site during this study (Table 18 & Figure 29). Additional information on water quality trends for the associated water quality segments are in H-GAC’s Basin Summary Report (HGAC 2011).

Table 17. Summary of 24-hr dissolved oxygen standards and observed values collected by EIH during 2011. Shaded cells are values that did not meet the standard.

Site Name	HGAC ID	TCEQ ID	Period	Sample Date	24-hr Average D.O. (mg/L) Standard	24-hr Average D.O. (mg/L) Observed	Absolute Minima D.O. (mg/L) Standard	Absolute Minima D.O. (mg/L) Observed
Cedar Bayou	cedr7500	11120	Index	05/03/2011	5.00	4.24	3.00	3.45
			Critical	07/21/2011		5.25		3.85
Clear Creek	cler7000	11452	Index	04/28/2011	5.00	5.96	3.00	4.00
			Critical	07/15/2011		3.23		1.45
Dickinson Bayou	dick0050	11467	Index	04/26/2011	4.00	5.49	3.00	3.28
			Critical	07/14/2011		4.47		2.06
Lake Creek	lake1367	11367	Index	05/10/2011	5.00	8.50	3.00	8.28
			Critical	07/22/2011		4.02		2.69
West Fork San Jacinto	wfsj8000	11245	Index	05/06/2011	5.00	8.09	3.00	4.50
			Critical	07/27/2011		3.83		3.02

Table 18. Summary of the water quality standards and the observed values from the 2011 sampling by EIH. Note the shaded cells are values that did not meet the standard.

					Temperature (°C)		pH (standard units)		*E. coli* (MPN/100mL) (grab)		Chloride (mg/L as Cl)		Sulfate (mg/L as SO_4)		Total Dissolved Solids (mg/L)	
Site Name	HGAC ID	TCEQ ID	Period	Sample Date	Standard	Observed	Standard	Observed	Standard	Observed	Standard	Observed	Standard	Observed	Standard	Observed
Cedar Bayou	cedr7500	11120	Index	05/03/2011	32	18.92	6.5-9.0	7.92	394	10	200	490	150	69.0	700	1504
			Critical	07/21/2011		28.64		7.41		91		100		7.6		280
Clear Creek	cler7000	11452	Index	04/28/2011	35	25.13	6.5-9.0	7.99	394	10	200	170	100	37.2	600	612
			Critical	07/15/2011		30.08		7.50		74		1800		42.6		572
Dickinson Bayou	dick0050	11467	Index	04/26/2011	35	25.62	6.5-9.0	7.71	394	41	200	130	100	55.2	600	496
			Critical	07/14/2011		28.90		7.69		135		3200		75.0		508
Lake Creek	lake1367	11367	Index	05/10/2011	32	26.31	6.5-9.0	7.61	394	410	80	30	50	5.4	300	108
			Critical	07/22/2011		28.65		7.32		26		30		13.8		116
West Fork San Jacinto	wfsj8000	11245	Index	05/06/2011	35	20.85	6.5-9.0	7.42	394	146	80	170	50	90.6	400	640
			Critical	07/27/2011		28.44		7.53		161		170		107.5		680

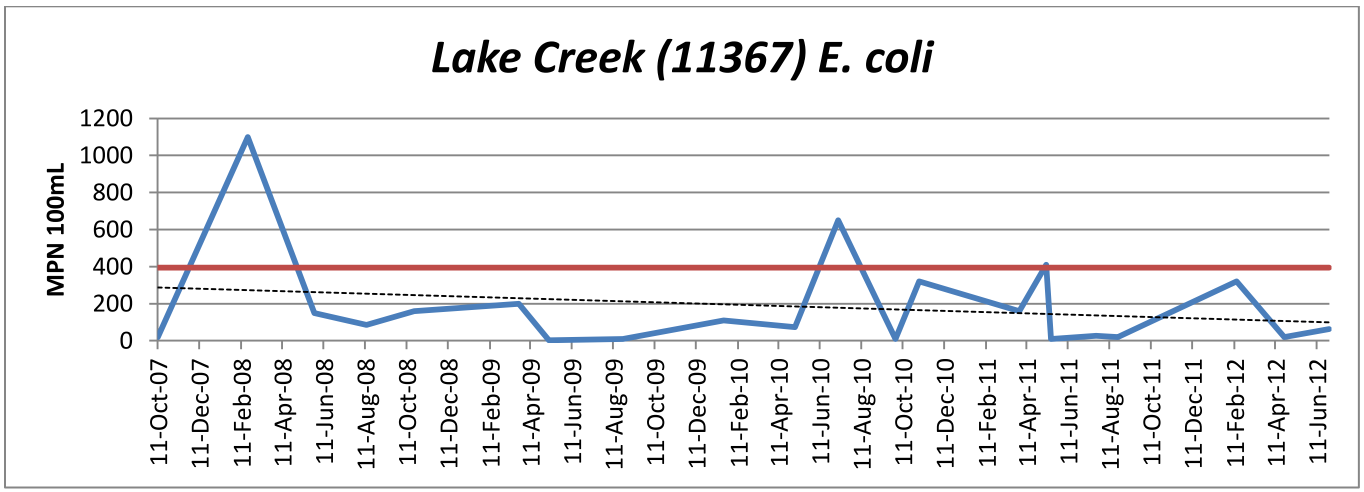

Figure 27. *E. coli* grab samples data from October 2007 through June 2012 at site 11367, Lake Creek. The red line shows the current grab standard of 394 (MPN/100mL), the dashed line is a trendline showing the general trend over the four and a half years of data. N=21. Data source: H-GAC surface water monitoring data by basin: http://www.h-gac.com/community/water/rivers/data/surface_water_monitoring_data.aspx

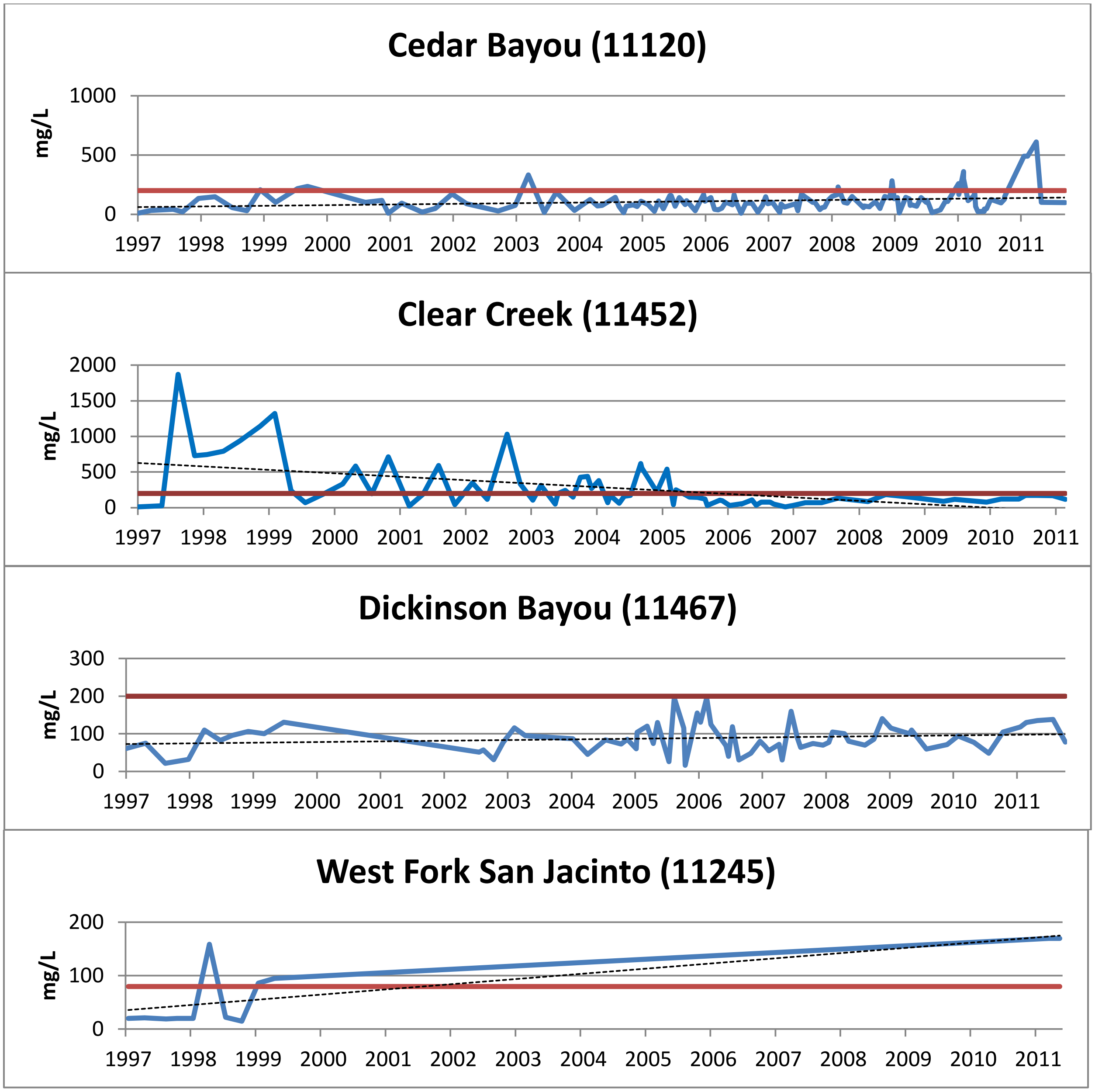

Figure 28. Chloride (mg/L as Cl-) data from 1997 through 2011 for the four survey sites that exhibited grab values above the standard for that site. The red line shows the current grab standard for chloride in mg/L for each site and the dashed line is a trendline showing the general trend over the fourteen years of data. Note: the value of 3,200mg/L Cl- collected at Dickinson Bayou site on 7/14/2011 has been removed from this dataset as it is considered an outlier. Also note that there was no chloride data available for site 11245 between 2000 and 2010. Data source: H-GAC surface water monitoring data by basin: http://www.h-gac.com/community/water/rivers/data/surface_water_monitoring_data.aspx

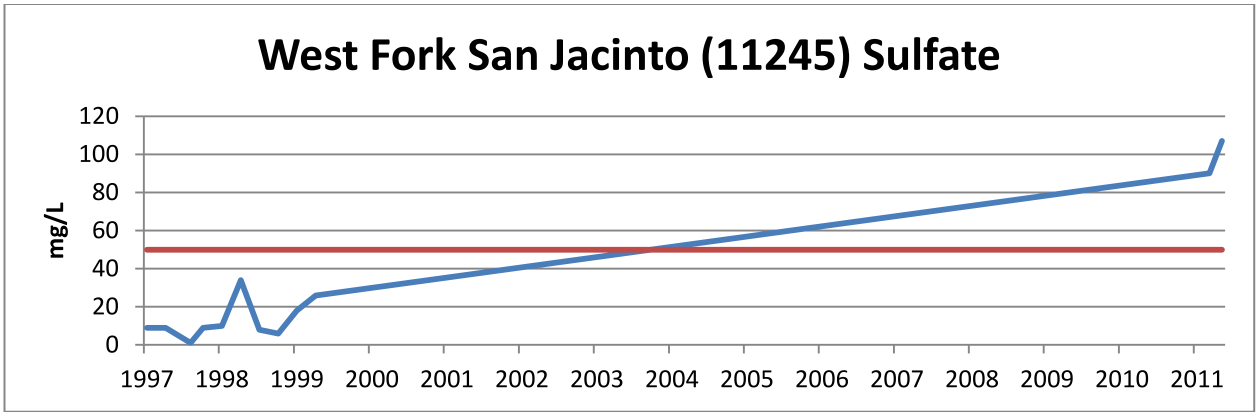

Figure 29. Sulfate (mg/L as SO4) data from 1997 through 2011 for the West Fork of the San Jacinto site 11245/ The red line shows the Sulfate standard of 50mg/L. Note that there is no data available between 2000 and 2010 for this site. Data source: H-GAC surface water monitoring data by basin: http://www.h-gac.com/community/water/rivers/data/surface_water_monitoring_data.aspx

Fish

The ALU designation of a waterbody dictates the appropriate Fish IBI score requirement for that water body to meet the ALU designation. Table 19 illustrates the current Fish IBI standards for each water body studied and the corresponding observed statewide and regional IBI values from the 2011 EIH as well as the USGS study. Using the two sampling events surveyed in 2011, all regional fish IBI scores met the current minimum ALU designation for each water body. Unfortunately, a regional IBI could not be calculated for Clear Creek and West Fork of the San Jacinto River sites using the 1997-98 USGS data due to unavailable data pertinent to IBI metric calculations (missing electrofishing effort data). The calculated regional fish IBI using the 1997 USGS data for the Dickinson Bayou Site resulted in a “Limited” IBI designation. This IBI designation should be cautiously evaluated, because only twelve individuals were captured during that sampling event, suggesting perhaps insufficient sampling effort was used during the 1997-98 study.

Using the statewide IBI metrics, ALU scores could be calculated for all sites and all events (Table 19). The ALU values in Table 19 highlighted in light grey represent ALU values that are below the current standard designation, but near the cutoff. The ALU values highlighted in the darker grey represent the ALU values that fall well below the cutoff of the current standard designation. As stated before, the regional IBI metrics employ more scientifically sound parameters and supersede the previous statewide IBI evaluation criteria. This is because the regionalized fish IBI takes into account the maximum community integrity possible for a specific ecoregions due to the natural distribution of fish species. Generally speaking, the statewide IBI calculations tend to result in lower ALU values compared to the regional IBI calculations. Using the statewide ALU values only, it appears that for sites Dickinson Bayou (11467) and the West Fork of the San Jacinto River (11245) there has been an increase in the ALU ranking for fish communities. Again, we caution the reader when comparing single sampling events spaced ~14 years apart.

Table 19. Summary of the statewide and regional aquatic life use standards and the observed fish derived use values from the 2011 sampling by EIH. ALU values highlighted in light grey represent ALU values that are below the current standard designation, but near the cutoff, the ALU values highlighted in the darker grey represent the ALU values that fall well below the cutoff of the current standard designation.

						Aquatic Life Use		
Site Name	HGAC ID	TCEQ ID	Reporting Agency	Sample Period	Sample Date	Current Standard Designation	Measured Statewide ALU	Measured Regional ALU
Cedar Bayou	cedr7500	11120	USGS	Critical	08/25/1997	High	Intermediate/High	High
			EIH	Index	05/03/2011		High	High
				Critical	07/21/2011		Intermediate	High
Clear Creek	cler7000	11452	USGS	Critical	08/25/1997	High	Intermediate	*
			EIH	Index	04/28/2011		Intermediate/High	Exceptional
				Critical	07/15/2011		Intermediate	High
Dickinson Bayou	dick0050	11467	USGS	Critical	09/04/1997	Intermediate	Limited/Intermediate	Limited
			EIH	Index	04/26/2011		Intermediate	High
				Critical	07/14/2011		Intermediate/High	High
Lake Creek	lake1367	11367	USGS	Critical	09/19/1997	High	High	High
			EIH	Index	05/10/2011		High/Exceptional	Exceptional
				Critical	07/22/2011		Intermediate/High	High
West Fork San Jacinto	wfsj8000	11245	USGS	Non-Index	03/05/1998	High	Intermediate	*
			EIH	Index	05/06/2011		High/Exceptional	High
				Critical	07/27/2011		High	High

Benthic Macroinvertebrates

The ALU designation of a water body dictates the benthic macroinvertebrate IBI score requirement for that water body to meet the ALU designation. Table 20 illustrates the current benthic macroinvertebrate IBI standards for each water body studied and the corresponding observed values from the 2011 EIH and 1997-98 USGS studies. Unfortunately there was no benthic data collected during the 1997-98 USGS study for the West Fork of the San Jacinto River site, thus no ALU value could be calculated for this site/event. The calculated benthic macroinvertebrate IBI for the Dickinson Bayou Site showed compliance with the designated use under all sampling events. In contrast, the observed IBI scores for the Lake Creek site indicated that the water body was not supporting benthic aquatic life at the assigned designated level during all sample events. At the remaining sites the use classifications based on the Benthic IBI had generally improved from historical 1997 levels.

Table 20. Summary of the aquatic life use standards and the observed benthic macroinvertebrate use values from the 2011 sampling by EIH and the 1997-98 sampling by USGS. Note the shaded cells are values that did not meet the standard.

Site Name	HGAC ID	TCEQ ID	Reporting Agency	Sample Period	Sample Date	Aquatic Life Use: Designated	Aquatic Life Use: Observed
Cedar Bayou	cedr7500	11120	USGS	Critical	08/25/1997	High	Intermediate
			EIH	Index	05/03/2011		High
				Critical	07/21/2011		High
Clear Creek	cler7000	11452	USGS	Critical	08/25/1997	High	Intermediate
			EIH	Index	04/28/2011		High
				Critical	07/15/2011		Intermediate
Dickinson Bayou	dick0050	11467	USGS *	Critical	09/04/1997	Intermediate	Intermediate
				Critical	09/04/1997		Intermediate
			EIH	Index	04/26/2011		High
				Critical	07/14/2011		High
Lake Creek	lake1367	11367	USGS	Critical	09/19/1997	High	Intermediate
			EIH	Index	05/10/2011		Intermediate
				Critical	07/22/2011		Limited
West Fork San Jacinto	wfsj8000 **	11245	EIH	Index	05/06/2011	High	High
				Critical	07/27/2011		Limited

* USGS reported two separate benthic samples for Dickinson Bayou site
** No benthic data collected at the West Fork San Jacinto by USGS study.

Physical Habitat

The ALU designation for a water body assumes that the physical habitat is sufficient to support the assigned use. The Physical Habitat IBI (PHIBI) rank based on the Habitat Quality Score (HQS) was used to evaluate whether the physical habitat is sufficient to support the assigned ALU designation. Table 21 illustrates the current ALU designations for each water body studied and the corresponding observed PHIBI values from the 2011 EIH study. Sufficient physical habitat data was not collected during the 1997-98 USGS study to calculate the PHIBI using the current metrics. However, it is expected that physical habitat was similar or likely was experiencing less anthropogenic influence in 1997 in comparison to 2011 levels based on similar hydrology and less overall urbanization in the region. The majority of the sites monitored did not appear to have adequate habitat to support the designated aquatic life use, although based on the fish and benthic IBI's this is not the case. The calculated physical habitat IBI for the Dickinson Bayou Site showed compliance with the designated use under all sampling events. It is important to note that some of the parameters used in the calculating metrics for the physical habitat IBI are somewhat subjective such as "aesthetics". Also, it is unclear how this metric directly affects aquatic life.

Table 21. Comparison of designated aquatic life use standards and observed physical habitat derived use rankings based on 2011 sampling conducted by EIH. Shaded cells are values that did not meet the standard.

					Aquatic Life Use	
Site Name	HGAC ID	TCEQ ID	Period	Sample Date	Designated	Physical Habitat Observed
Cedar Bayou	cedr7500	11120	Index	05/03/2011	High	Intermediate
			Critical	07/21/2011		High
Clear Creek	cler7000	11452	Index	04/28/2011	High	Intermediate
			Critical	07/15/2011		Limited
Dickinson Bayou	dick0050	11467	Index	04/26/2011	Intermediate	Intermediate
			Critical	07/14/2011		Intermediate
Lake Creek	lake1367	11367	Index	05/10/2011	High	Intermediate
			Critical	07/22/2011		Intermediate
West Fork San Jacinto	wfsj8000	11245	Index	05/06/2011	High	Intermediate
			Critical	07/27/2011		Intermediate

Interrelationships between Physico-chemical and Biological Community Metrics and Variables

We attempted to evaluate the possible relationship between selected physico-chemical variables measured during our study and the various habitat based (D.O. 24 hour average and minimum levels and HQS) and biological metrics (Fish IBI, Benthic IBI). This was done by using either the original data or converting rankings (e.g. poor, limited, good) to numeric scores (e.g. 1, 2, 3) and conducting a correlation analysis. The results of significant correlation analysis results between physico-chemical variables are depicted in Table 22. The results of significant correlation analysis results between physico-chemical variables and various habitat based, and biological metrics are depicted in Table 23. Based on the results of the correlation analysis between the various physico-chemical variables several potentially causal relationships between water quality variables were documented. For example, the strong positive correlation between TSS and secchi depth reflects the influence of TSS on water clarity. Upstream drainage area, stream order and flow exhibited the highest number of significant correlations with other variables. Assuming causative relationships, upstream drainage area and/or stream order appeared to influence flow regime, stream morphology and water quality more so than any other variables. Interestingly instantaneous measures of dissolved oxygen were not correlated with either 24 hour average or minimum values of that variable.

Examination of significant correlations between various biological and habitat metrics and physico-chemical variables suggest only benthic community and to a lesser extent HQS responded to changes in these variables within the range of conditions observed during our study (Table 23). High benthic IBI scores appeared to be associated with smaller drainage areas and stream orders and lower sediment sizes and volatile suspended solids (VSS) levels. In addition, high benthic scores were also associated with increased land development in the immediate area of the study area and channel slope. High habitat quality scores were associated with low land development scores and high number of riffles. Interestingly fish IBI scores were not correlated with any of the variables measured including the benthic IBI or HQS metrics over the range of conditions encountered during the study period. In addition, the benthic IBI and HQS were not significantly correlated. This lack of correlation between the observed metrics and many physico-chemical variables suggests that over the conditions measured most of the variables were within the range of values that support aquatic life. In addition, since our study only provides a “snap shot” of conditions at the site, we may have missed critical levels of variables that occur over a longer time series.

Table 22. List of significant ($p < 0.05$) correlation coefficients between various physico-chemical and habitat variables.

Variable 1	Variable 2	Correlation	p-value
Bank slope	No. Riffles	-0.82	0.004
Bank slope	Sed. Type	-0.72	0.018
Bank slope	% Tree Canopy	0.71	0.021
Bank slope	Wetted Width	-0.67	0.033
Bank slope	Depth	0.64	0.044
Cond	TDS	0.67	0.033
Depth	TOC	-0.73	0.017
Depth	DO	-0.65	0.041
Depth	No. Riffles	-0.64	0.048
DO	Temp	-0.68	0.030
DO	pH	0.67	0.034
24 Avg. DO	24 Min. DO	0.86	0.001
24 Min. DO	Ecoli	0.76	0.011
Upstream Drainage Area	Stream Order	0.96	0.000
Upstream Drainage Area	Reach Length	0.96	0.000
Upstream Drainage Area	Sed. Type	0.93	0.000
Upstream Drainage Area	Wetted Width	0.92	0.000
Upstream Drainage Area	NO2 & NO3	0.83	0.003
Upstream Drainage Area	LandDev	-0.81	0.005
Upstream Drainage Area	Bank slope	-0.80	0.005
Upstream Drainage Area	% Tree Canopy	-0.76	0.011
Upstream Drainage Area	Stream Slope	-0.73	0.017
Upstream Drainage Area	No. Riffles	0.69	0.026
Flow	NO2 & NO3	0.92	0.000
Flow	% Tree Canopy	-0.88	0.001
Flow	Wetted Width	0.86	0.002
Flow	TP	0.84	0.002
Flow	Reach Length	0.79	0.006
Flow	Upstream Drainage Area	0.64	0.045

Table 22. Continued. List of significant ($p < 0.05$) correlation coefficients between various physico-chemical and habitat variables.

Variable 1	Variable 2	Correlation	p-value
LandDev	Sed. Type	-0.87	0.001
LandDev	Stream Order	-0.87	0.001
LandDev	Reach Length	-0.72	0.020
LandDev	No. Riffles	-0.71	0.022
NO2 & NO3	TP	0.72	0.019
No. Stream Bends	TOC	-0.67	0.035
No. Stream Bends	TDS	-0.64	0.046
% Tree Canopy	NO2 & NO3	-0.93	0.000
% Tree Canopy	TP	-0.73	0.016
Reach Length	Wetted Width	0.97	0.000
Reach Length	NO2 & NO3	0.92	0.000
Reach Length	Sed. Type	0.82	0.004
Reach Length	% Tree Canopy	-0.81	0.004
Reach Length	Bank slope	-0.72	0.019
Secchi D.	TSS	-0.81	0.005
Secchi D.	VSS	-0.68	0.045
Sed. Type	No. Riffles	0.70	0.024
Stream Order	Sed. Type	0.91	0.000
Stream Order	Reach Length	0.90	0.000
Stream Order	Bank slope	-0.88	0.001
Stream Order	Wetted Width	0.83	0.003
Stream Order	No. Riffles	0.82	0.004
Stream Order	NO2 & NO3	0.75	0.013
Stream Order	% Tree Canopy	-0.70	0.025
Stream Order	Stream Slope	-0.66	0.039
Stream Slope	Sed. Type	-0.89	0.001
Temp	TDS	-0.68	0.029
TSS	VSS	0.68	0.042
Vel	Flow	0.84	0.002
Vel	TP	0.76	0.011
Wetted Width	NO2 & NO3	0.97	0.000
Wetted Width	% Tree Canopy	-0.89	0.001
Wetted Width	Sed. Type	0.73	0.017
Wetted Width	TP	0.66	0.037

Table 23. List of significant ($p < 0.05$) correlation coefficients between various measured variables and calculated metrics.

Variable 1	Variable 2	Correlation	p-value
BIBI	Upstream Drainage Area	-0.65	0.043
BIBI	Land Development.	0.64	0.046
BIBI	Sediment Type	-0.72	0.019
BIBI	Stream Order	-0.64	0.048
BIBI	Stream Slope	0.65	0.042
BIBI	VSS	-0.76	0.017
HQS	Land Development.	-0.65	0.041
HQS	No.Riffles	0.78	0.008

DISCUSSION

Based on the results of this study we can conclude that most of the sites are supporting aquatic life and their respective assigned aquatic life use categories and water quality standards. This conclusion is based on the "weight of evidence" provided by 1) water quality data, 2) fish community data, 3) benthic community data and 4) habitat data. Aquatic life use assessments using the regionalized fish IBI suggest that all sites are meeting their assigned ALU rankings and have either improved or remained constant during the period from 1997 to 2011. Generally speaking, the statewide IBI calculations tend to result in lower ALU rankings compared to the regional IBI calculations. This is likely due to the difference on how the IBI scores are calculated between the two methods. The current accepted regionalized fish IBI approach takes into account the maximum community integrity possible for a specific ecoregions due to the natural distribution of fish species. Consequently it adjusts for regional differences in expected community structure. Based on multivariate analysis of species composition, fish communities did not appear to have changed much since originally surveyed in 1997.

Aquatic life use assessments based on benthic communities also documented that most sites showed similar attainment of assigned ALUs and/or improvements since the 1997 USGS survey with the exception of Lake Creek (site 11367). In addition, taxa richness for each event show a general trend of increasing number of species collected during the EIH sampling events as compared to the USGS events with the exception of Lake Creek (site 11367), which exhibited higher taxa richness during the initial USGS study in 1997 as compared to a decreased richness observed during the critical period of the EIH study in 2011. In addition to the observed patterns in Benthic IBI scores and community metrics, the benthic community composition had changed since the 1997 survey. The taxa composition varied greatly between sites and between study years. Our analysis indicated that there were significant differences in species composition between the 1997 and 2011 collections. Based on these results we can conclude that these changes probably contributed significantly to the higher Benthic IBI scores observed in 2011 at most sites. Interestingly the fish IBI score was not correlated with the benthic IBI scores. This probably reflects the fact that impacts on fish communities are normally detected only when watershed scale stressors are affecting them. This is due to their mobility and ability to recolonize disturbed areas. In contrast benthic organisms are more sensitive to localized impacts.

Physical habitat data collected by EIH resulted in an intermediate habitat quality for all sites and sampling periods except for the critical period for Cedar Bayou (site 11120) which had a “high” rating, and the critical period for Clear Creek (site 11452) which exhibited a “limited” rating. Based on these rankings the majority of sites monitored did not appear to have adequate habitat to support the higher designated aquatic life use, although based on the fish and benthic IBI’s these sites were meeting their designated use. This suggests that for coastal and inland streams located in the study area the existing PHIBI algorithm may need to be further calibrated against existing biological community data. It is also important to note that some of the parameters used in the calculating metrics for the PHIBI are somewhat subjective such as “aesthetics”. For example, many inert items (e.g. construction debris, shopping carts) that are aesthetically offensive can nonetheless provide critical instream habitat in channelized urban streams. These items created from anthropogenic sources may provide hard substrate that serves as a velocity break for fish and an attachment site for primary producers and invertebrates not adapted to soft bottom substrate.

In contrast to the biologically derived fish and benthic IBI scores, several of the streams studied do not appear to be meeting assigned aquatic life uses based on diel dissolved oxygen data alone. Only one site (Dickinson Bayou) met the standard for 24-hrr average D.O. mg/L, however it did not meet absolute minima D.O. mg/L standard during the critical event. Only two sites, Cedar Bayou and the West Fork of the San Jacinto River, met the standard for the absolute minima D.O. mg/L standard during both sampling events. It was impossible to directly compare the 24-hr data from this study with the 1997 survey due to lack of available data from that time period in the SWQMIS database or in the published report. However, while comparisons of single data points cannot be statistically analyzed for significance, in every case the instantaneous D.O. measurements from the 1997-98 USGS data were greater than those of the EIH study from the same sample period nearly 14 years later. Dissolved oxygen is certainly a limiting factor for fish and benthic macroinvertebrate communities. However, fish and benthic invertebrates along coastal regions in southeast Texas may be adapted to the physico-chemical conditions (e.g. low velocity, salt wedge, turbid water, and high temperatures) which limit D.O. reaereation and are commonly encountered in slow moving coastal water bodies. The lack of a strong statistical correlation between any of the diel D.O. metrics and the fish and benthic IBI supports this observation. In contrast to 24-hr dissolved oxygen metrics, very few deviations were observed for the other remaining water chemistry parameters (*E. coli*, chlorides, and sulfates) which have listed standards for each water body.

Due to the drought conditions existing during the 2011 study and the lack of sufficient stream flow data during the USGS study, we highly recommend repeating this study within the next few years to evaluate the role of hydrology on the response variables including the 24-hr diel oxygen standards, water quality variables, physical habitat, biological communities and the various IBI metrics. We believe that the prolonged drought conditions encountered during the study period most likely influenced the flow regime, water quality and resulting biological communities. In addition, multiple sites representing replicate samples within each watershed should be evaluated to determine compliance with designated aquatic life uses to reduce the influence of a single aberrant observation.

Finally, we strongly recommend conducting a detailed analysis of changes in land-use and land-cover to evaluate the potential influence of this controlling variable on flow regime and resulting water quality and physical habitat. Based on our study there is evidence of potential degradation of aquatic life use in the Lake Creek watershed. This may be occurring due to changes in watershed scale land use and the resulting alterations in hydrology, physical habitat and water quality. It has been demonstrated that waterbodies undergoing urban development are subject to the effects of "urban stream syndrome". The term ''urban stream syndrome'' describes the consistently observed ecological degradation of streams draining urban land (Walsh et al. 2009). Symptoms of the urban stream syndrome include a flashier hydrograph, elevated concentrations of nutrients and contaminants, altered channelmorphology, and reduced biotic richness, with increased dominance of tolerant species. Most past research on urban impacts to streams has concentrated on correlations between instream ecological metrics and total catchment imperviousness. We suggest conducting a similar examination of this relationship along with reach scale measurements of hydrology, habitat and water quality which are needed to assess the relative influence of each on instream biotic communities.

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Appendices