THE HYDROLOGY AND BIOLOGY OF CYPRESS CREEK (HAYS COUNTY), A SUBTROPICAL KARSTIC STREAM IN SOUTH CENTRAL TEXAS

THESIS

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by

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San Marcos, Texas
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A SUBTROPICAL KARSTIC STREAM IN SOUTH CENTRAL TEXAS

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ABSTRACT

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This study describes the fish and benthic macroinvertebrate communities of the spring-fed Cypress Creek (Hays County). Jacob's Well is a karstic spring which discharges into Cypress Creek approximately 5 km northwest of Wimberley in west-central Hays County (at 30°02' N, 98°08' W), and is the primary spring source of water to the creek. The well issues from an inclined shaft 40 m deep from what is thought to be the most extensive underwater cave in Texas, along a fault line within the Edward's

Plateau. The creek flows southeast for approximately 23 km into the Blanco River in Wimberley (at 29°59' N, 98°06' W). Its flow is perennial only in the lower 23 km, where spring flows from the Trinity Aquifer at Jacobs Well sustain stream flow.

The Cypress Creek watershed drains 122.3 km^2 of agricultural and residential lands including developed areas such as Woodcreek and Wimberley. Cypress Creek (classified as Segment 1815 by the Texas Commission on Environmental Quality (TCEQ), enters the Blanco River at Wimberley. The Blanco River is 140 km in length, drains a watershed of 1,067 km^2, and is considered a priority conservation area according to The Nature Conservancy of Texas ecoregional planning exercise for the Edwards Plateau (Jester et al. 2007).

Historical records indicate that Jacob's Well once propelled water 2 m into the air. However, in recent years, changes in the usual flow regime have been observed. During the period between July and September 2000, Jacob's Well stopped flowing for the first time in recorded history. During this study, streamflow measurements ranged from 1.4 m^3/s during early March, to 0.06 m^3/s during the late summer and fall—no streamflow was observed at the most upstream sites in Cypress Creek during this period of drought. Twenty-one fish species and 31 benthic macroinvertebrate taxa were collected, and indices of biological and habitat quality indicated "high" (but not exceptional) water-quality.

Maintaining a natural flow regime is important for sustaining the ecological integrity of flowing water systems. Native plant and animal species have adapted to natural patterns of water flow to survive and reproduce. Although flow regime alteration (as a result of aquifer pumping, channelization, dams, and other human modifications) may be advantageous for some exotic and predator species, changing the natural flow regime generally is detrimental to native fish species, particularly sensitive species. Major alterations in rivers and streams may also lead to changes in species abundance and composition. These alterations can affect the overall health of the ecosystem. Aquatic ecosystems subject to extremes in flooding and drought cycles may affect fish assemblage composition by selecting for disturbance tolerant fish, while habitat variability (i.e. habitat complexity) can decrease the effect of this disturbance by providing refugia.

Four sites along Cypress Creek were sampled for fish by seining and backpack electrofishing. Benthic macroinvertebrates were sampled simultaneously using a D-frame kicknet. Habitat variables were measured at each site to determine the relationship between stream discharge, habitat variability and fish and benthic macroinvertebrate assemblage structure. Preliminary findings indicate the fish and macroinvertebrates of Cypress Creek are well adapted to the natural flow regime, however, fish and macroinvertebrate indices of biotic integrity (IBIs) showed lower scores than the exceptional aquatic life designation for Segment 1815 Cypress Creek (TCEQ 1999).

INTRODUCTION

Four study sites were sampled for fish and macroinvertebrates seasonally during 2005 (Figure 1). Monthly streamflows were recorded at these four sites and five additional sites (

Figure 2) for a total of nine sites along the creek using a FlowTracker Handheld ADV® (Acoustic Doppler Velocimeter).

The Cypress Creek watershed is located within the Guadalupe River basin in south-central Texas, in Hays County southwest of Wimberley, Texas (Figure 3). “Exchanges of organisms, energy and resources” take place between rivers and their tributaries (Beckman et al. 2005a), and tributaries serve as vital habitats for early life stages of fish and benthic macroinvertebrates. For organisms that have modified their life histories in order to avoid floods or droughts, the timing of noteworthy flow events may be a crucial to their survival. Life-history adaptations of some aquatic organisms my require the synchronization of a life cycle event to long-term flow regime dynamics, as opposed to immediate responses to short-term flow regime changes, which may be detrimental to the organism. Life-history adaptations are particularly important for organisms with complex life cycles that allow temporary escape from flood or drought prone environments, such as aquatic insects with aerial adult stages. Organisms with life histories adapted to specific flow-regimes could be adversely affected by long-term flow-regime changes, and “extreme” flow events occurring at unanticipated times of the year

(Lytle & Poff 2004), such as the cessation of flow in Cypress Creek during summer of 2000.

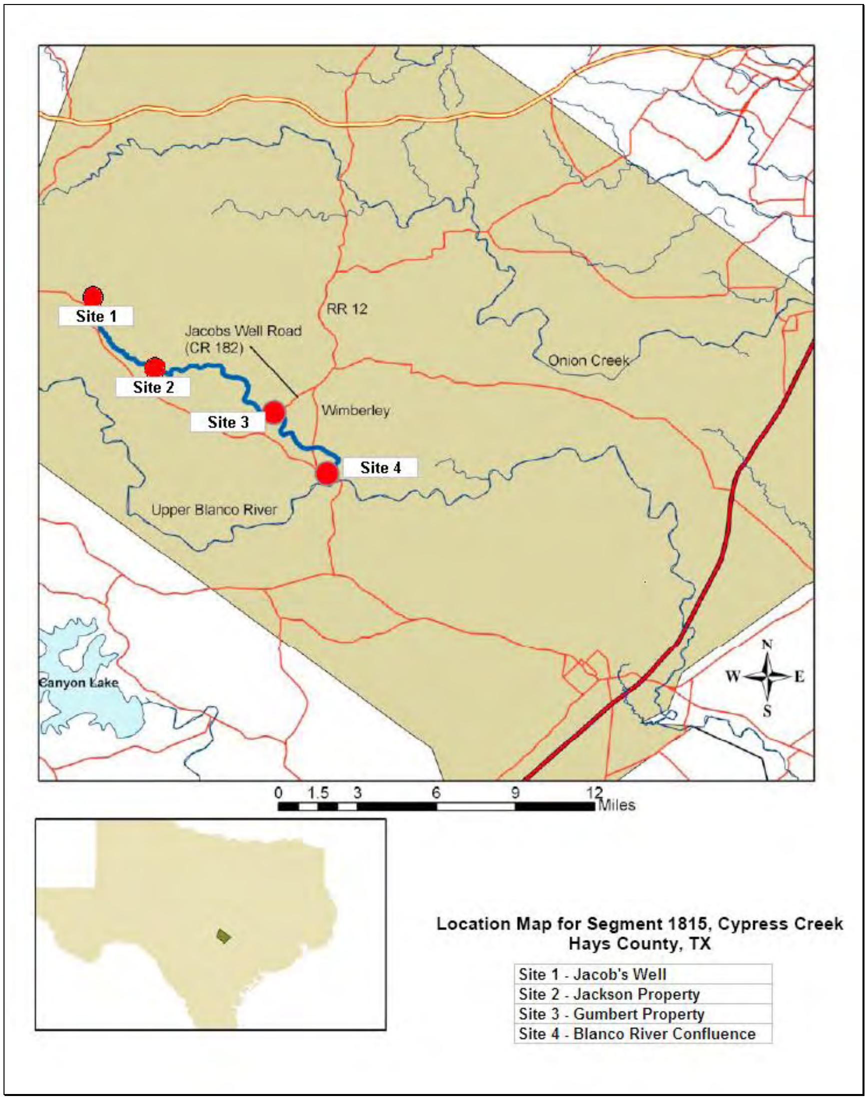

Figure 1 Map of fish and benthic macroinvertebrate sampling sites. Hays County, Wimberley, Texas.

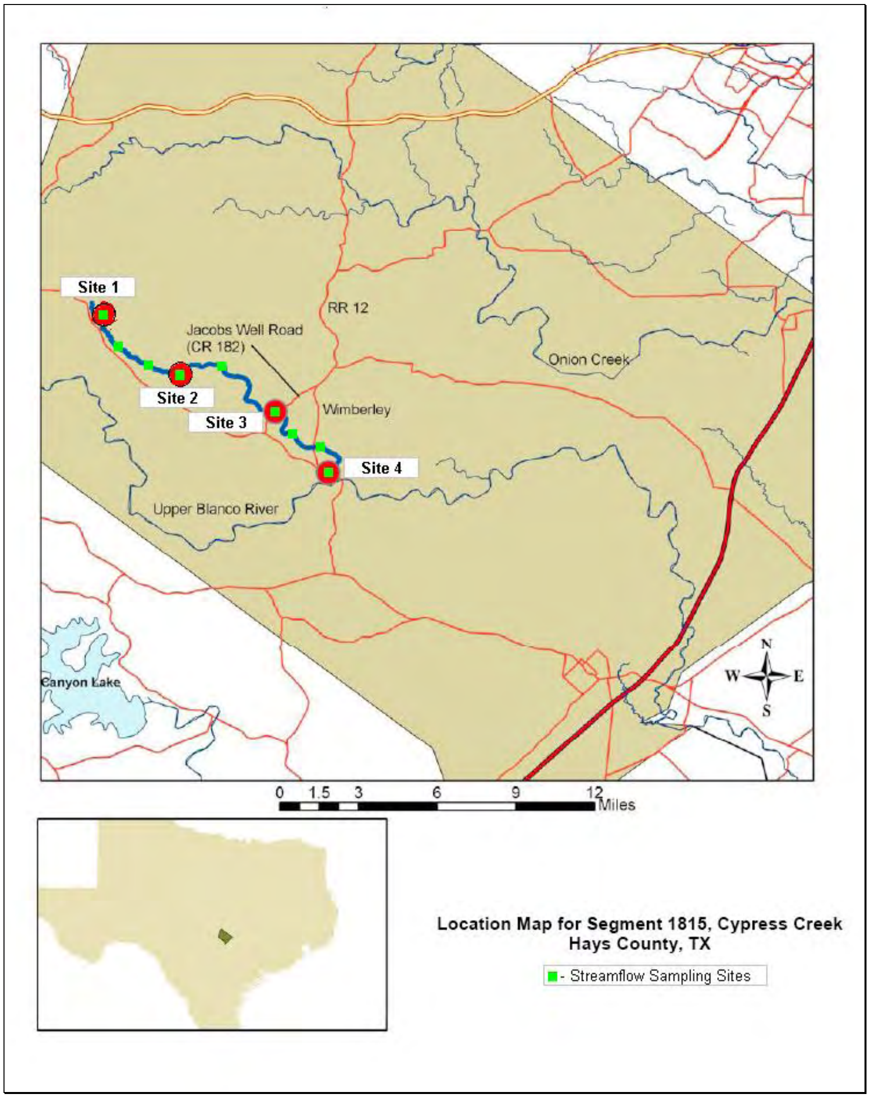

Figure 2. Stream-flow sampling sites.

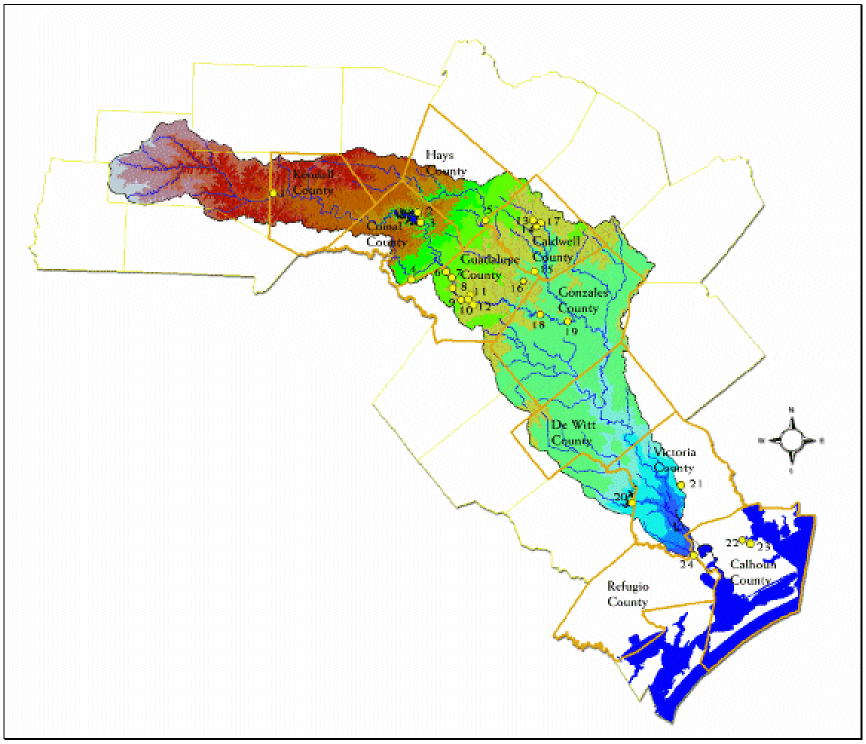

Figure 3. Guadalupe River Basin, TPWD 2002.

Changes in normal streamflow conditions may have further deleterious effects on fish survival. In many Texas streams and rivers, particularly in semi-arid areas such as south central Texas, flow can change dramatically over a period of hours or days due to heavy storm events. Non-native fishes may not be well adapted to flood events, and may be washed downstream during severe precipitation events (Minckley & Deacon 1991), which are common in the south central Texas region. A study by Meffe (1984) showed that the Gila topminnow (*Poeciliopsis occidentalis*), was locally extirpated by the Western mosquitofish (*Gambusia affinis*), in an area where the effects of flash flood events were restricted by upstream dams, however, the native minnow species persisted within the naturally flashy streams. The environmental changes induced in the dammed areas allowed the mosquitofish to outcompete the native topminnow in those specific areas.

In the southwestern United States, where many native river fish are listed as threatened under the Endangered Species Act, undammed rivers are one of the few remaining sanctuaries of native river fishes (Minckley & Deacon 1991 and Minckley & Meffe 1987).

Cypress Creek is a 44 km freshwater spring-fed tributary of the Blanco River in Hays County within the Guadalupe River Basin. The flow is perennial in the lower 22 km, below Jacob's Well, and intermittent above. Major land uses in this watershed include agriculture and residential development. The drainage basin of the Blanco River at Wimberley is 920 km^2, and land use in the Blanco River watershed is "87-percent rangeland and forest, 11-percent pasture, and 1-percent urban" (Gandara et al. 1997). During 2003-2004, the Blanco River Assessment Project was funded by the Nature Conservancy of Texas to the Edwards Aquifer Research and Data Center and the Aquatic Resources Department at Texas State University-San Marcos. During this study, fish, macroinvertebrates, and water quality were assessed within the Blanco River watershed. The cause of the 2000 cessation of streamflow at Jacob's Well is unknown, however, drought, coupled with increasing water consumption in the region in recent decades, are two possible causes. Over the past few decades, aquifer pumping has increased significantly in conjunction with extensive development throughout the Wimberley Valley and Woodcreek area of Texas. Most water for domestic use is withdrawn from the Trinity Aquifer (Figure 4) the region's main source of groundwater, and a contributing source of water to Jacob's Well.

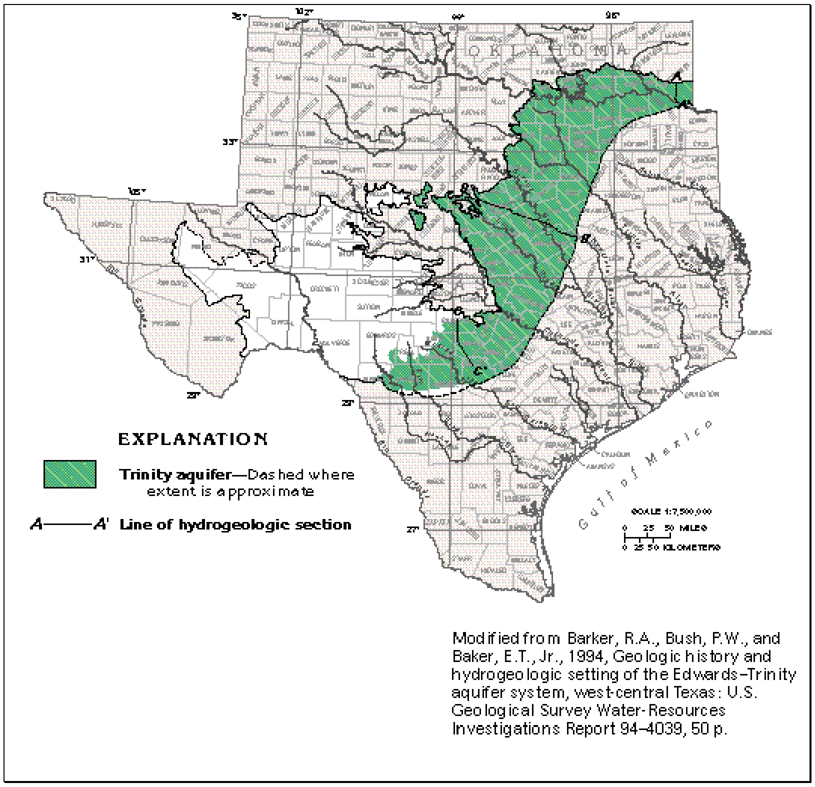

Figure 4. Map of the Trinity Aquifer.

This study was initiated because the City of Wimberley realized that managing water resources was of paramount importance for the continued visual beauty, health of the ecosystem, and welfare of local citizens and the local economy. The picturesque Cypress Creek and the Blanco River enhance Wimberley's attractiveness for tourism and residential development. The aesthetics of this crystal clear stream add value to the overall attractiveness and value of the area. Both of these water bodies are supported by spring flow and baseflow from the Trinity Aquifer. All drinking water in the Wimberley Valley, with the exception of rainwater collection systems, comes from local groundwater sources. The Cypress Creek watershed has significant local water use, with total combined water use in Wimberley and Woodcreek of 1,166 ac-ft during 2000 (Texas Water Development Board 2006). The Blanco River and Cypress Creek have been nominated by the Texas Parks and Wildlife Department as Ecologically Significant River and Stream Segments. The Texas Commission on Environmental Quality classifies Cypress Creek in terms such as high water-quality, exceptional aquatic life, and high aesthetic value (TCEQ 1999).

One objective of this study was to assess the hydrology and the biological condition of the fish and benthic macroinvertebrate communities in the Cypress Creek watershed. Recently, there has been "an increasing awareness that effective research, inventory, and management of environmental resources must be undertaken with an ecosystem perspective." (Omernik 1995).

Omernik (1987) employed criteria such as topography, vegetation type, etc. in order to divide the United States into "ecological regions that exhibit more or less distinct sets of physical habitats and species." According to Omernik's classification, Region L includes parts of five ecoregions (Figure 5): (Central Texas) Edward's Plateau (which contains the area addressed in this study), Southern Texas Plains, Texas Blackland Prairies, East Central Texas Plains, and the Western Gulf Coastal Plains.

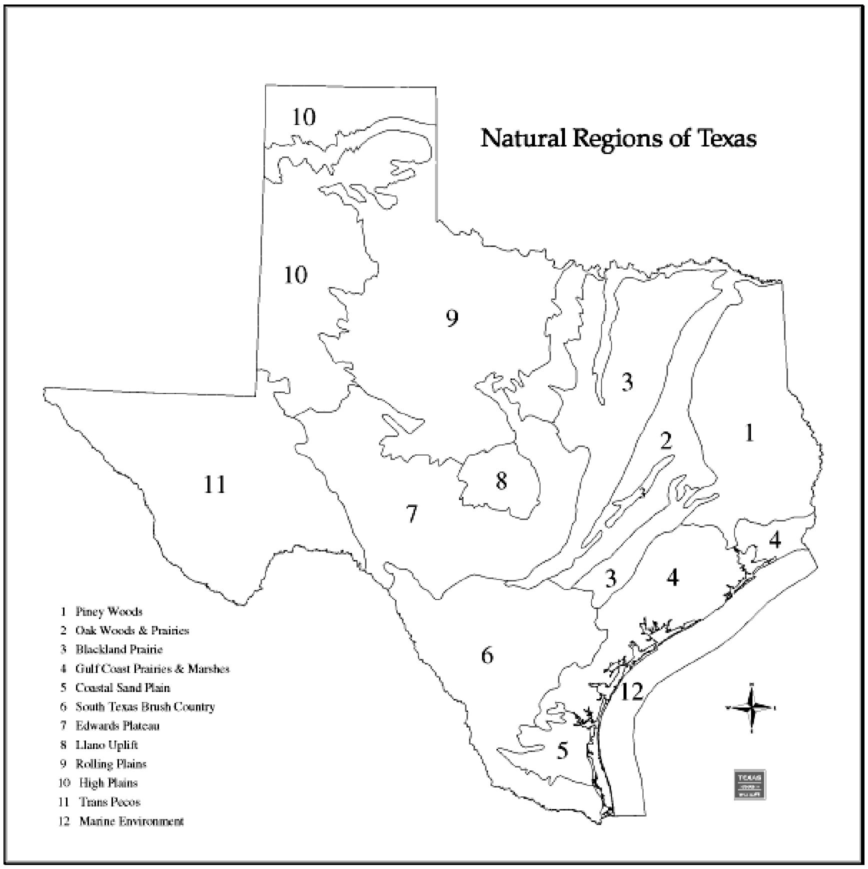

Figure 5. Natural Regions of Texas (TPWD 2002).

The major population centers in Region L are located along the eastern and southern margins of the Edwards Plateau, where of wooded canyons and springfed streams are interconnected among the cavernous limestone of the Edwards's Aquifer which supplies the present major water supply for the region (Texas Water Development Board 2006).

Rapid Biological assessment for streams has progressed considerably in the past decade, and now consists of methods for fish (Karr et al. 1986; Ohio EPA 1987, 2005; Barbour et al. 1999) and benthic macroinvertebrates (Plafkin et al. 1989; Kerans et al. 1992; Kerans & Karr 1994; Barbour et al. 1999). These methods assess biological condition by comparing the stream being evaluated with a regional reference stream which is assumed to represent the best attainable condition of the water resource within the region. A set of fish, macroinvertebrate and habitat assessment procedures developed by the Texas Commission on Environmental Quality (1999b) for the Central Texas (Edward's) Plateau - Region 30 (Linam et al. 2002), were used to describe the physical habitat at each location during this study. These procedures use regional criteria and consider differences in landforms, vegetation, and other factors among the ecoregions to "provide a better representation of the integrity of fish assemblage" as compared to previously developed statewide criteria. Results from the fish and macroinvertebrate samples were used to calculate biological integrity scores using Rapid Bioassessment Protocols (Barbour et al. 1999).

Addressing Cypress Creek from an ecosystem perspective allows the for the observation of not only local, but also at regional anthropogenic influences, which can result in significant deposition of sediments and harmful compounds that may impact spawning areas, and affect the production of macroinvertebrates, which are one of the primary food sources for fish populations. While the City of Wimberley is a growing community, the subwatershed of Cypress Creek shows relatively limited anthropogenic influence when compared to other regions, due to a combination of factors. Private land ownership and responsible stewardship of land adjacent to the creek, no current municipal or industrial discharges into the creek (Segment 1815, TCEQ 1999), the creation of a 52-hectare limited access Wimberley Blue Hole Regional Park during 2005, funded by the Land and Water Conservation Fund (LWCF), and the recent (2006) existence of the Jacob's Well Preserve, an approximately 20-hectare spherical buffer-zone which now surrounds Jacob's Well Spring. The private landowner dams that do exist along the creek, which have been in place for several decades or more, are all ≤ 2.5 m in height, and while they may in fact serve as a barrier to repopulation of the upper reaches of the creek, serve private recreation and aesthetic purposes only.

Water in Hays County runs approximately northwest to southeast. The Blanco and San Marcos Rivers are the major waterways. The Blanco River contains several flood control dams located along private property. The Guadalupe Basin includes ten counties and drains an area of 4,279 km^2. The Blanco Basin feeds the San Marcos River and joins the Guadalupe near Gonzales. The Blanco Basin drains an area of approximately 920 km^2 (USGS).

The climate of south-central Texas can be classified as subtropical, with the summer months influenced by the Gulf of Mexico, causing sweltering heat, and mild winters influenced by the more continentally temperate climates. Figure 6 shows the monthly precipitation rates at Jacob's Well during the period between January 1990 and July 2006.

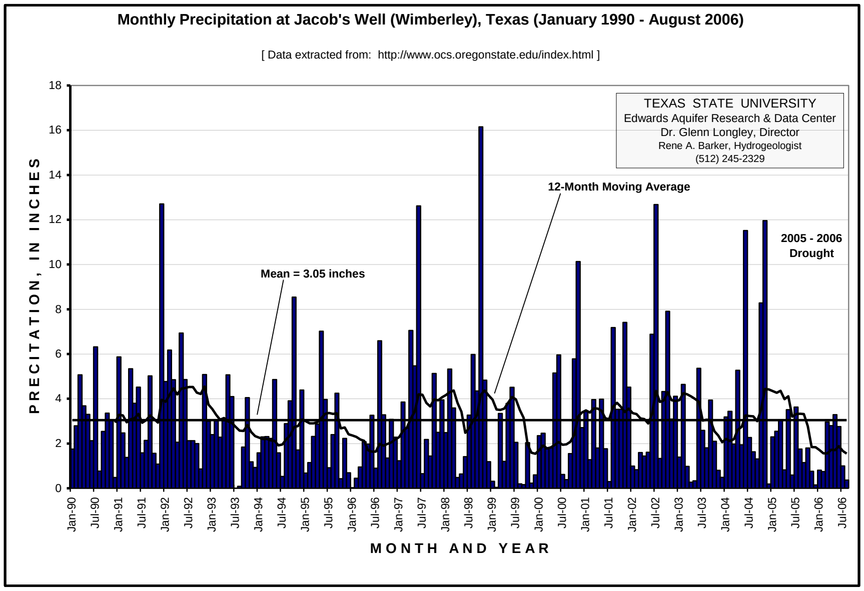

Figure 6. Monthly Precipitation at Jacob's Well (Wimberley), Texas (January 1990 - July 2006) [Data extracted from: http://www.ocs.oregonstate.edu/index.html]

South central Texas precipitation may fall during the entire year, but as evidenced by Figure 6 above, frequently large part of annual rainfall may occur within only a few months of the year in the form of thunderstorms (Natural Fibers Information Center 1987:12, 49–50). The entire Guadalupe River Basin lies within an area of Texas referred to as ‘Flash Flood Alley’, and is considered one of the “three most dangerous regions” in the United States for flash flooding (GBRA, 2002). According to Slade & Patton (2003), both the Atlantic and Pacific Oceans flank Texas, and major storms are pulled in from both water bodies with often severe consequences, with respect to flooding, for some south central Texas regions. In the spring and fall, warm, dry air from Mexico is pulled into Texas and collides with humid air from the Gulf of Mexico, which may result in severe weather (Texas Water Development Board 2007).

Ecological Communications Corporation (ECOMM) of Austin, Texas, conducted a biological data study as part of an 303(d) list for nonsupport of aquatic life uses impairment project on Cypress Creek during 2002. Fish, benthic macroinvertebrate, and habitat data were collected in accordance with the Texas Commission on Environmental Quality (TCEQ) Receiving Waters Assessment Procedures Manual (TCEQ 1999b) and Rapid Bioassessment Protocols (Barbour et al. 1999). The Texas Engineering Experiment Station (TEES) and Conrad Blucher Institute for Surveying and Science (CBI) collected physical and chemical data in an effort to provide a comprehensive assessment of the water-quality within the creek. This assessment showed that some instantaneous dissolved-oxygen concentrations measured in the lowest 11.3 km portion of the stream (RR12 Bridge near the town square) were lower than the criterion established to assure optimum conditions for aquatic life. The aquatic life use criterion for dissolved oxygen in the region is 5.0 mg/L (TCEQ 1999). Previously (2001), TCEQ contracted the services of the South Texas Environmental Institute at Texas A&M University-Kingsville (TAMUK), together with CBI at Texas A&M University-Corpus Christi, and ECOMM to design and implement a monitoring plan. The TAMUK team conducted sampling at two stations on Cypress Creek during August through December 2002 to provide the TCEQ with additional 24-hour dissolved oxygen, physical and chemical analyses, as well as a biological assessment. In-stream, multi-probe data loggers measured dissolved oxygen, temperature, pH, and conductivity over a 24-hour period. Data collected by the TAMUK/CBI team and the Guadalupe-Blanco River

Authority on Cypress Creek showed conclusions that indicated no impairment due to depressed levels of dissolved oxygen in the water. Because of these physical and chemical findings, Cypress Creek was removed from the 2004 303(d) list for nonsupport of aquatic life uses due to low dissolved-oxygen concentrations.

One of the objectives of this study was to develop a database of groundwater and surface-water conditions and document the status of the associated aquatic ecosystem. During this study, streamflow gain/loss and groundwater-level data was collected during 2005 in order to contribute toward a better understanding of interactions between the local hydrogeologic and ecological environments. Water-level observations and streamflow measurements were made at nine sites along the creek during 2005 (see Figure 2). With assistance from the Hays Trinity Groundwater Conservation District (HTGCD), observation wells were canvassed and selected in order to allow the measurement of water levels in the Trinity Aquifer. The selected wells were used to measure groundwater levels concurrently with observations of streamflow (including USGS records of spring flow) and aquatic biota along Cypress Creek. The resulting water-level data were used to (1) construct a potentiometric map of groundwater levels, (2) delineate the principal directions of groundwater flow, and (3) evaluate the extent of hydraulic connection between Cypress Creek and the adjacent (underlying) middle zone of the Trinity Aquifer. In addition to being one of the more efficient tools for detecting imbalances between recharge and discharge, tracking groundwater levels over time is useful as a means of better understanding the effect of aquifer pumping on spring flow. Why Jacob's Well stopped flowing during the period between July – September, 2000 is uncertain. However, recent increases in groundwater demand in response to increasing urbanization are likely contributors. Aquifer pumping has increased significantly since 1980 as a result of the area's explosive growth in population, particularly within the project area north of the Blanco River within Hays County. Figure 7a shows the elevation profile moving downstream. As seen in Figure 7b, there does not appear to be a clear-cut pattern of downstream gains or losses, regardless of the seasonal variations in streamflow. Furthermore, these measurements do not indicate a substantial degree of stream-aquifer interaction. This can be inferred since the variations in streamflow between sites 1 – 9 are all within the operational margin of error for the FlowTracker Handheld ADV®(Acoustic Doppler Velocimeter) (Wahl et al. 2002). The slight variations observed in the streamflow data measurements could possibly be accounted for by other phenomena, such as numerous privately owned backyard pumps withdrawing water along the creek.

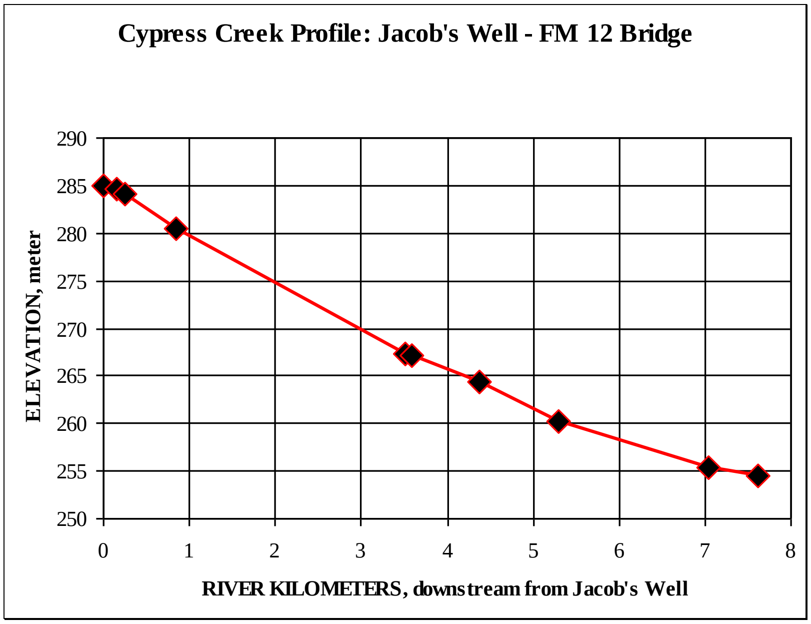

Figure 7. Elevation profile moving downstream.

Table 1. Elevation profile moving downstream.

Site	Cum. meters	River km	Elevation
0	0	0	284.9
1	152	0.145	284.7
2	259	0.257	284.07
3	838	0.837	280.4
4	3520	3.52	267.3
5	3581	3.59	267.2
6	4373	4.38	264.3
7	5288	5.29	260.3
8	7056	7.04	255.4
9	7604	7.61	254.5

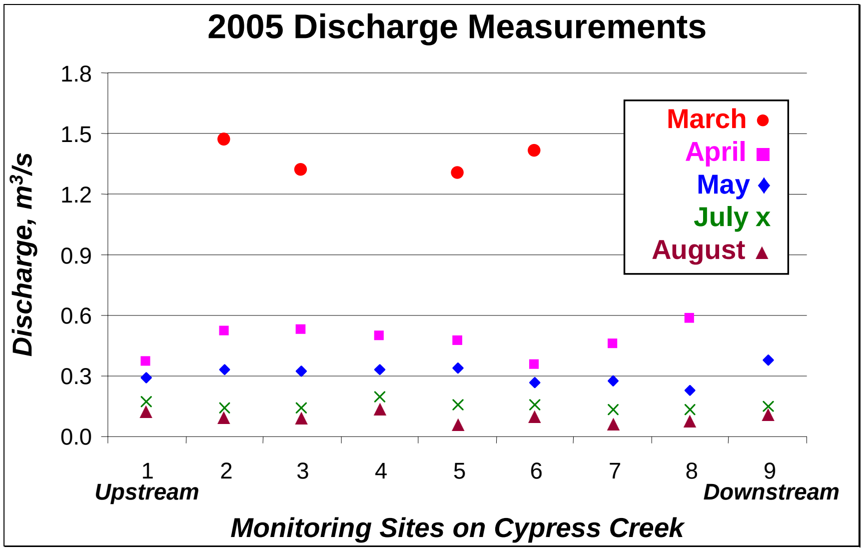

Figure 8. Discharge of Cypress Creek (2005) at various measuring stations 2005.

Figure 8 shows the potentiometric gradient determined from groundwater data collected during 2005. It shows that middle Trinity flow paths trend generally from northwest to southeast—or essentially parallel to the Cypress Creek watercourse.

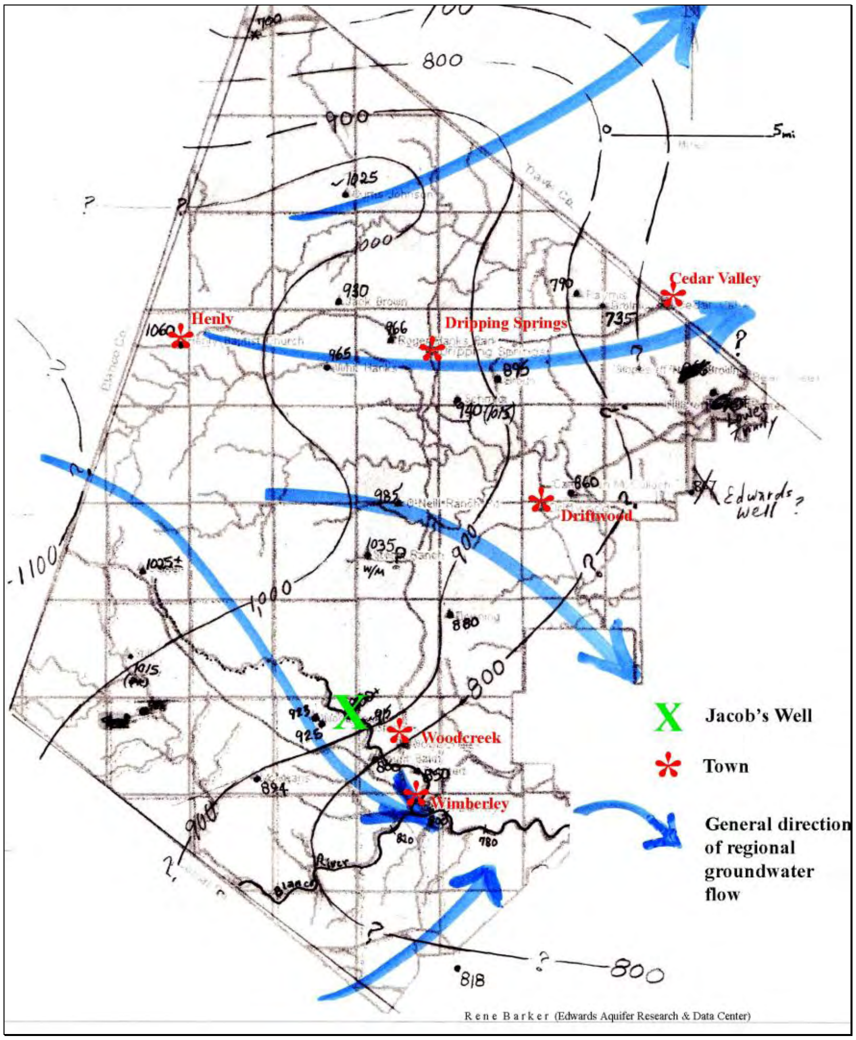

Figure 9. Map of estimated water-level (feet) for middle zone of the Trinity Aquifer; created June, 2006.

While it is a rough approximation of actual dynamic conditions, it is detailed enough for drawing conclusions in regard to the directions of regional groundwater flow and the seemingly minor amount of hydraulic interaction between Cypress Creek and the middle zone of the Trinity Aquifer, and these findings are collaborated by the results of the gain-loss data shown in Figure 7b. Although the control for the potentiometric map is sparse, the contours presumably represent lines of equal hydraulic (pressure) head. The sweeping blue lines and arrows indicate the general (regional) directions of groundwater flow, assuming isotropic and homogeneous field conditions. Notwithstanding the weak control, this map indicates that the bulk of groundwater flows from west-to-northeast in northern Hays County (where influenced by the Pedernales River basin) and from west-to-southeast in southern Hays County, the area studied during this research, (where influenced by the Blanco River drainage).

Cross sections developed by Broun (2004) support the possibility that the Jacob's Well discharge results from a combination of: (1) the structural dislocation and associated hydraulic short-circuiting across an otherwise continuous Hammett Shale just west of Jacob's Well, coupled with (2) the "damming" effect caused by one or more barrier faults to the east. One useful analogy might be to envision a balloon filled with water (the Trinity Aquifer), and punching a hole in it with a needle (Jacob's Well).

Whereas the hydraulic head in Jacob's Well (280 + meters) is consistent with that in lower Trinity strata of that area, it is roughly 40 meters *higher* than that in the nearby (Mt Baldy) middle Trinity well (Barker, personal communication). Although Jacob's Well might receive some contribution of lateral inflow from adjacent Lower Glen Rose, Hensel and Cow Creek rocks, the vertical head gradient in that particular area appears to be overwhelmingly upward. This geologic phenomenon provides for the existence of

Jacob's Well. Given Broun's depiction of a completely detached Hammett Shale just upgradient of Jacob's Well, in addition to the site's prevailingly upward hydrodynamic energy and long-term average rate of springflow, it seems highly likely that the bulk of Jacob's Well discharge must originate from Hosston/Sligo strata Broun, (personal communication). One of the sections developed by Broun shows that the Hammett Shale (which typically overlies, confines, and physically separates the lower Trinity from everything above) is severed and completely offset across a vertical fault just upgradient of Jacob's Well. Assuming that this structural displacement is sufficient to breach the Hammett "seal" (even if only across the fault plane), it could provide not only the "artesian" head for Jacob's Well, but also the source of most of the water discharging from this spring. It helps to remember here that groundwater always flows downgradient--in the direction of decreasing hydraulic (pressure) head. Although structural dip and topography can certainly affect or even control the hydraulic gradient, groundwater ultimately doesn't care whether it flows updip, downdip, uphill, or downhill; like electricity--it can only move from higher to lower potential. These observations contribute toward a scientific baseline of relations among groundwater and surface water in the Cypress Creek watershed, and are directly transferable to the larger study of the entire Blanco River Basin although on a smaller scale.

Widths and lengths of the conduits within the rock, the quantity and extent to which these conduits interconnect among and with other conduits, the influence of numerous fractures, and the respective permeabilities of the rock layers themselves, as well as the contribution of surface water input in the region, determine both the permeability (perpetually affected by dissolution of the limestone) and retention time of the aquifer. Some of the different hypothetical scenarios can be seen in Figure 9 similar to patterns proposed by Palmer (1991).

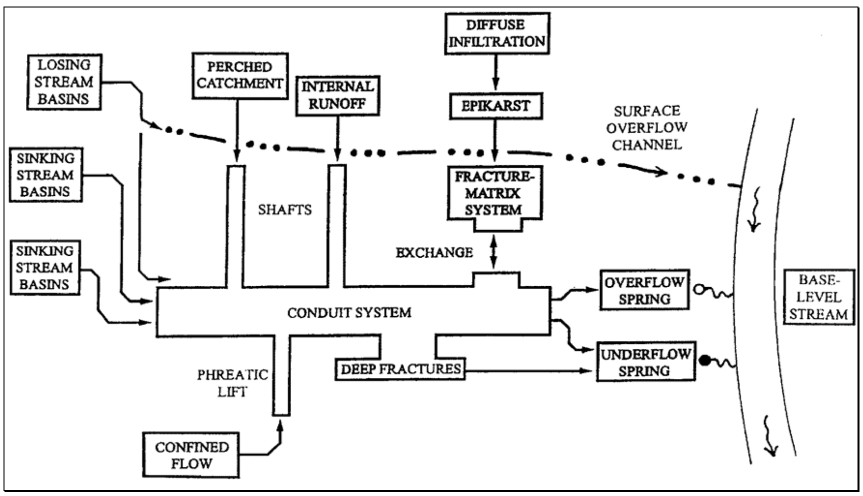

Figure 10. Conceptual model for a karstic aquifer (White 1999).

While it is still uncertain where exactly within White's model the Jacob's Well discharge falls, present research indicates that it is likely a combination of contributing sources (e.g. groundwater input from the Hammett Shale formation, conduits, and possibly other unknown sources) that supply water to this "perched well" (Barker, personal communication).

Although the Trinity Aquifer is recognized by the State as a major aquifer (Ashworth and Hopkins, 1995), its production may be "250 times lower" than that of the Edwards Aquifer. According to DeCook (1963), the Edwards Limestone in Hays County mainly consists of "light-gray, brittle, thick-bedded to massive limestone, commonly dolomitic, containing minor beds of argillaceous or siliceous limestone and calcareous shale. Bedded or nodular chert and flint characterize much of the formation." The Trinity Aquifer consists of Cretaceous rocks formed from thick layers of carbonates formed from the accumulation of various calcareous shells of organisms, forming a series of strata including layers of greens sand, clays, and chalks.

The Cypress Creek system lies within the Central Texas Edward's Plateau region of south-central Texas. The upper member of the Glen Rose Limestone is recognized by "its characteristic stair-step topography caused by the differential weathering of the nonresistant marl and resistant limestone and dolomite beds" (Stricklin et al. 1971).

A study by the University of Texas Department of Geosciences (Steinhauer et al. 2006) compared geochemical signatures among the waters of upstream reaches of the Blanco River water, water flowing from Jacob's Well, and the water chemistry of a losing segment of the Blanco River west of the Jacob's Well Spring. According to the Steinhauer study, the geochemistry of Jacobs's Well geochemistry is inconsistent with the geochemistry of the Trinity Aquifer system. Although previous geologic investigations indicated that the source of the Jacob's Well discharge emanated from the Hosston/Sligo strata of the Trinity Aquifer, results from the Steinhauer research showed that the geochemistry of Jacob's Well is more consistent with Blanco River waters than Trinity Aquifer waters, which adds another level of complexity to the origin(s) of the Jacob's Well discharge. During the Steinhauer study, the geochemistry of Jacob's Well was highly correlated with only the upper reaches of the Blanco River, not the geochemistry of the Blanco River water sampled near Wimberley, so further research is needed, and it appears that the source(s) of the Jacob's Well discharge are highly intricate.

MATERIALS AND METHODS

Assessments for fish and macroinvertebrates give valuable insight into the biological health of streams in the Guadalupe River Basin. Little information exists on the biological communities of the Cypress Creek tributary, which hinders long-term comparisons between biological assessments. The rapid biological assessment (RBA), a major tool for biological assessment of fish and macroinvertebrates, was used to quantify biological indices at four sites along the creek. Aquatic biota were collected seasonally during 2005, for a total of four fish and four macroinvertebrate collections at each of the four sites. The mean station length was 150 m with a range of 145 m – 155 m. Sampling length was kept as consistent as possible at each station throughout the study. Variability in length of sampling reaches was associated with the locations of natural and man-made structure such as large meanders, pools, shallow riffle areas, or impoundments. However, each reach included at least one example of pool, riffle and run. All fish handling and transporting procedures were approved by the Institutional Animal Care and Use Committee of Texas State University (IACUC # 03DE136862_3). Texas scientific collecting permits (TPWD Permit # SPR-0290-007; Federal Fish and Wildlife Endangered Species Permit # TE802211-0) and state fishing licenses were obtained prior to fish collection activities.

Samples were collected during April, June, August, and October (Table 2). Aquatic invertebrates were collected qualitatively from all available habitats with a D-frame kick net with a 500 μM mesh net. All collections were made according to Rapid Bioassessment Protocols (Barbour et al. 1999) from a set of fish and macroinvertebrate assessment procedures developed by the Texas Commission on Environmental Quality (1999b) specifically for the Central Texas (Edward's) Plateau - Region 30 (Linam et al. 2002).

All benthic macroinvertebrates in each sample were captured, removed and identified. The specimens were then separated into Orders. An additional search was conducted through the debris in the examination pan afterwards, in order to double-check and provide a more thorough site by site taxa list in the event that any rare or particularly elusive organisms may have been excluded during sampling efforts (Vinson 2000). All identified invertebrates removed from each sample were deposited into an individual vial with a plastic lid. Internal sample labels were written in pencil on waterproof paper. Information on each label includes the sampling location and sampling date. Vials were filled with 70% ethanol. The data are presented as the number of individuals per sample.

Fish Collection.-- Four sites on Cypress Creek in Hays county, Texas were sampled during late April and early March, June, August, and October, 2005. Available fish habitat within each study area was sampled using seines and backpack electrofishing equipment. A minimum sampling effort of 10 seine hauls and 15 minutes of actual shocking time was conducted at each site; however sampling continued until all habitats had been sampled and no additional new species were collected. Block nets were placed upstream and downstream at each of the sampled areas, in an attempt to limit fish eluding capture efforts. Sites were at Jacob's Well, near the confluence of Cypress Creek with the Blanco River, and two sites in between at the Jackson Property on Cypress Creek

Lane and at the Gumbert Property off of RR12 (Figure 1). Table 2 shows the summary of species collected during 2005 sampling.

Different capture methods were used to represent available habitat types in a consistent manner, so that similar effort was expended at each site. These collections were supplemented by other opportunistic sampling methods in order to obtain a species list for each site, and to ensure that rare or elusive species were not missed during sampling efforts. In addition to the standard monitoring approach described above, two minnow traps and two hoop nets were set in the largest pool area at each site. Hook and line methods were also used in deep pools that showed larger fish which eluded traditional sampling efforts. These three additional methods were used in an attempt to capture any rare, particularly elusive, or previously undescribed species, however, for the sake of continuity for the assessment, none of the specimens captured by these additional methods were included in the computation of IBIs or RBAs. These methods were used simultaneously with standard fish collection methods. Fish-collection observations were also supplemented by daytime snorkeling surveys to determine relative distributions and in an attempt to detect any changes in longitudinal relative abundance of fish species. Before each snorkel survey, individual snorkelers practiced estimating fish body lengths under water by viewing fish of known lengths. One large pool was designated in each sample reach, 2-3 persons each spent 20 or more minutes inspecting all available habitats and assessing presence, sizes, and subjective abundance of each species encountered, however, due to the exceptional water clarity of Cypress Creek, the data collected from these efforts was sparse, and snorkeling surveys were abruptly discontinued, as the fish quickly evaded our observation efforts.

Table 2. Summary of scientific and common names of species of fishes collected from Cypress Creek (Hays County), Texas, 2005.

Order: Cypriniformes

Family: Cyprinidae (Carps and Minnows)

Campostoma anomalum (Rafinesque, 1820) **central stoneroller**

Cyprinella venusta Girard, 1856 **blacktail shiner**

Dionda episcopa Girard, 1856 **roundnose minnow**

Notropis amabilis (Girard, 1856) **Texas shiner**

Pimephales vigilax (Baird & Girard, 1853) **bullhead minnow**

Family : Catostomidae (Suckers)

Moxostoma congestum (Baird & Girard, 1854) **gray redhorse**

Order: Characiformes

Family: Characidae (Characins)

Astyanax mexicanus (Filippi, 1853) **Mexican tetra**

Order: Siluriformes

Family: Ictaluridae (Bullhead Catfishes)

Ictalurus punctatus (Rafinesque, 1818) **channel catfish**

Order: Atheriniformes

Family: Poeciliidae (Livebearers)

Gambusia affinis (Baird and Girard, 1853) **Western mosquitofish**

Order: Perciformes

Family: Centrarchidae (Sunfishes)

Lepomis auritus (Linnaeus, 1758) **redbreast sunfish**

Lepomis cyanellus Rafinesque, 1819 **green sunfish**

Lepomis macrochirus (Rafinesque, 1819) **bluegill**

Lepomis megalotis Rafinesque, 1820 **longear sunfish**

Lepomis microlophus (Günther, 1859) **redear sunfish**

Lepomis punctatus (Valenciennes, 1831) **spotted sunfish**

Micropterus dolomieu Lacepède, 1802 **smallmouth bass**

Micropterus salmoides (Lacepède, 1802) **largemouth bass**

Micropterus treculi (Vaillant & Bocourt, 1874) **Guadalupe bass**

Family: Percidae (Perches)

Etheostoma spectabile (Agassiz, 1854) **orangethroat darter**

Etheostoma lepidum (Baird & Girard, 1853) **greenthroat darter**

Family: Cichlidae (Cichlids)

Cichlasoma cyanoguttatum (Baird & Girard, 1854) **Rio Grande cichlid**

Fish data (Table 2) from the four sampling events were used to characterize fish diversity and longitudinal changes in fish community composition along the length of the sample area. A Smith-Root LR-24 backpack unit powered by 12 amp-hour 12-volt deep-cycle batteries was used for electrofishing. Each fish-sampling team consisted of 2 to 3 people. Fish were placed in a 5-gallon plastic water bucket temporarily for subsequent identification and inventory. The sampling team moved in an upstream direction, targeting logs and snags, vegetated banks, large stones or gravel-based riffles, and other locations associated with fish habitat. Active sampling (time when current was on) was performed for a minimum of 15 minutes. Block nets were placed upstream and downstream at each of the sampled areas, in an attempt to limit fish eluding capture efforts. Upon completion of electrofishing, fish specimens were identified, data were recorded, and the fish were returned to the water as soon as possible in order to minimize mortality. Fish not identified in the field were anaesthetized in ice, preserved in a 10% formalin solution, and transported to the Edwards Aquifer Research and Data Center (EARDC) aquatic lab for later identification. One individual from each field-identified species was retained as a voucher specimen.

Electrofishing collections were complimented by seining at all sites where seining was possible. A straight seine measuring 9m x 1m with 0.3cm mesh was used. Ten seine hauls, each approximately 10m long, were done during each sampling event. Only successful seine hauls were counted. Those that encountered obstacles that could have resulted in the escape of fish (heavy snags or rocks that prevented, or impaired the lead line from passing across the bottom substrate were not included. Block nets were placed upstream and downstream at each of the sampled areas, in an attempt to limit fish eluding capture efforts. Fish were identified to species using Hubbs et al. (1991) and Chilton (1997). Twelve RBP metrics for the region (TCEQ 1999) were used to assess fish community structure at each site.

Macroinvertebrate Collection.--A D-frame kicknet (mesh size 500 μM) was used to sample the downstream extent and edge of riffle habitats. One square meter of substrate was disturbed upstream (by one person shuffling their feet in the gravel and sediment upstream of the D-net) in order to displace macroinvertebrates into the net. Leaf litter and detritus were collected, if present. Debris was scoured by hand with tweezers, with the D-frame net placed directly underneath the sample. Macroinvertebrates were also were collected from large rocks in the sampling reach. Specimens were fixed in 70% ethanol. Sampling continued until a minimum of 100 benthic macroinvertebrates were collected, however, some sites yielded less. Macroinvertebrates were identified to lowest-possible taxon using Pennak (1978) and Merritt & Cummins (1984).

Table 2. Summary of benthic macroinvertebrate families and species collected from Cypress Creek (Hays County), Texas, 2005.

Class Insecta

Order: Odonata

Coenagrionidae *Argia*

Libellulidae *Erythemis*

Macromiidae *Macromia*

Order: Ephemeroptera

Heptageniidae *Stenonema*

Baetidae Callibaetis

Baetidae Baetis magnus

Baetidae Fallceon quilleri

Tricorythidae *Leptohypes*

LeptophlebiidaeThraulodes gonzalesi

Leptophlebiidae *Neocoroterpes*

Leptophlebiidae *Farrodes*

Order: Trichoptera

Philopotamidae *Chimarra*

Hydropsychidae Cheumatopsyche

Hydropsychidae *Hydropsyche*

Leptoceridae *Nectopsyche*

Polycentropidae *Polycentropus*

Helicopsychidae *Helicopsyche*

Order: Coleoptera

Gyrinidae *Dineutus*

Hydrophilidae Tropistemus berosus

Elmidae Macrelimis

Elmidae Hexacylloepus

Haliplidae *Peltodytes*

Dryopidae *Helicus*

Psephenidae *Psephenus*

Order: Megaloptera

Corydalidae *Corydalus*

Order: Hemiptera

Veliidae Rhagovelia

Naucoridae *Ambrysus*

Gerridae Limnoporus

Belostomidae Belostoma Latreille

Order: Diptera

Chironomidae

Tabanidae *Tabanus*

Simulidae *Simulium*

Class: Gastropoda

Physidae *Physella*

Pleuroceridae *Elimia*

Planorbellidae *Trivolvis*

Order: Amphipoda

Hyallelidae *Hyallela azteca*

Class: Pelecypoda (Bivalva)

Corbiculidae *Corbicula*

In order to calculate the RBAs, pollution tolerance values for macroinvertebrates were designated based on values established by the Texas Commission on Environmental Quality Surface Water Quality Standards (TCEQ 1999), the EPA (Barbour et al. 1999) and from Lenat (1993). Functional feeding groups for macroinvertebrate families were designated based on classifications obtained from Merritt and Cummins (1996). Metrics were used to produce an estimate of aquatic community health at each site.

Physical characteristics of each site were recorded seasonally and any differences in land use, stream structure, dominant sediment type, channel morphology, and water level, were noted during the habitat assessment.

8)*Habitat Assessment.*--To assess habitat quality, 8 metrics described by TCEQ habitat assessment guidelines (TCEQ 1999) were used. Habitat measurements were done once in April 2005 according to the TCEQ habitat assessment Receiving Water Assessment Procedures Manual established specifically for the Edward's Plateau Region – Document TCEQ-20156-C (TCEQ 1999b). The habitat metrics included: (1) Available Instream Cover, (2) Bottom Substrate Stability, (3) Number of Riffles, (4) Dimensions of Largest Pool, (5) Bank Stability, (6) Channel Sinuosity, (7) Riparian Buffer Vegetation, and (8) Aesthetics of Reach.

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Taxonomic Identification - Major taxonomic identification resources used in this study included Brown, 1976, Burch, 1973, Burch 1973, 1980, 1982, 1988, Emdunds, et al. 1976, Johannsen, 1977, Klemm, 1985, McCafferty, 1981, Needham, et al. 2000, and Westfall et al. 1996.

Permits Required – The following permits were obtained for this study: (1) IACUC # 03DE136862_3 submitted on 7/3/03 by Dr. Tim Bonner and expires on 7/2/08, (2) Texas Parks and Wildlife Permit # SPR-0290-007. Issued to Glenn Longley on March 11, 2005 and expires on December 1, 2008, and (3) Federal Fish and Wildlife

Endangered Species Permit # TE802211-0. Issued to Edward's Aquifer Research and Data Center on May 14, 2003 and expires May 31, 2008.

RESULTS

Site Descriptions--. All sites exhibited exceptional water clarity. Stream discharge varied from flood to drought conditions throughout the sampling year, and into 2007. Fish species collected can be seen in Table 3.

Table 3. Number of individuals of 21 fish species collected from the four collection sites on Cypress Creek, Hays County, Texas during April (Ap), June (J), August (Au), and October (O), 2005.

Station→	**1**				**2**				**3**				**4**			
Month→	**Ap**	**J**	**Au**	**O**	**Ap**	**J**	**Au**	**O**	**Ap**	**J**	**Au**	**O**	**Ap**	**J**	**Au**	**O**
Campostoma. anomalum	39	108	194	51	88	116	63	38	---	---	---	---	---	---	---	---
Dionda. episcopa	29	131	---	---	91	---	131	---	8	57	96	41	39	92	17	23
Notropis. amabilis	34	54	4	140	3	---	169	---	126	21	34	26	76	31	45	145
Pimephales. vigilax	---	---	---	9	---	---	9	---	---	16	20	24	36	23	16	14
Cyprinella. venusta	---	91	31	---	---	120	---	---	---	---	---	---	---	---	---	125
Moxostoma. congestum	---	---	---	---	---	3	---	---	7	7	3	---	6	1	1	2
Astyanax. mexicanus	---	---	12	---	5	3	---	10	2	5	1	7	---	---	---	---
Ictalurus. punctatus	---	12	3	1	9	7	---	8	3	4	1	---	9	4	1	---
Gambusia. affinis	12	37	8	15	27	18	10	3	4	20	23	34	34	34	23	12
Lepomis. auritus	10	19	3	1	7	---	25	3	17	19	20	18	9	26	---	17
L. cyanellus	7	3	6	6	3	3	7	7	3	1	9	8	7	11	5	8
L. macrochirus	8	5	23	7	26	16	5	7	23	13	6	17	4	13	5	7
L. megalotis	2	10	16	19	26	8	20	41	31	17	11	19	15	8	19	32
L. microlophus	2	4	---	---	---	---	---	---	17	9	20	18	---	---	---	5
L. punctatus	---	---	---	---	---	---	---	---	1	1	7	2	2	4	1	2
Micropterus. dolomieu	---	---	---	---	---	---	---	---	4	1	1	---	4	5	1	2
M. salmoides	---	---	1	26	---	---	---	---	6	4	1	3	---	6	12	---
M. treculi	12	15	6	41	12	3	---	34	---	---	---	---	---	1	1	---
Etheostoma. spectabile	3	9	21	41	20	16	18	---	20	14	7	27	9	35	4	15
E. lepidum	---	---	---	---	---	---	---	---	---	---	2	---	---	---	---	---
Cichlasoma cyanoguttatum	---	10	1	---	---	4	20	13	8	14	8	8	---	2	10	---

At Site 1, 50 m downstream of Jacob's Well, instream habitat included a large pool with a bedrock and cobble substrate, an absence of aquatic macrophytes, and several submerged snags formed by large logs. Riffle and run areas were represented. Riparian vegetation was nearly absent along the left back (facing downstream), which consisted of a rock wall. The right bank was heavily lined with brush, small cypress trees, and grasses.

Site 2, upstream of the Jim Jackson property, on Cypress Creek Lane, consisted of a 30 m stretch of shallow run, several riffles and a pool of 2.7 m deep with fallen tree on the left bank which caused the pool to display a deep undercut on the same side. At the downstream extent of the site was Chili Pepper Falls. At the upstream extent of the site was a 2 m impoundment. Instream cover included bedrock, gravel, and medium to large-sized boulders, and several snags partially submerged within the gravel areas of the stretch. Riparian vegetation included brush, small deciduous trees, and grasses.

Site 3, on the Gumbert Property, consisted of a relatively deep channel with a pool and run area. Instream cover was mostly cobble and small-sized gravel, and a backwater area on the right (facing down stream) bank with extensive aquatic macrophytes, which flowed into the main channel during all samplings. Riparian vegetation small deciduous trees, and grasses. The area also showed an overhead canopy along the sampled stretch provided by large deciduous trees.

Site 4 showed the most diverse habitat and was atypical from the other sites due to prolific aquatic macrophytes. It contained a cement-lined channelized stretch 30 m long and prolific aquatic macrophytes in the pool habitat. Logs and root wads were common and the riparian vegetation grew to the rivers edge, and was a dense cluster of grasses, brush, and deciduous trees such as oak and cedar elm.

Fish Collections--. Twenty-one fish species were found in the Cypress Creek system during this study. Fish species and number of individuals collected from each of the four sampling sites can be seen in Table 3. Across all four sites, April sampling yielded 988 specimens representing 19 species. June sampling yielded 1325 specimens representing 14 species. August sampling yielded 1217 specimens representing 16 species. October sampling yielded 1164 specimens representing 18 species. Cumulative data indicate that site 4 had the highest species richness (18). Site 1 showed the greatest number of specimens (n=1352). Site 4 habitat was the most diverse of any site and likely the reason for species richness being greatest there.

The four most numerous species were the central stoneroller, the roundnose minnow, the Texas shiner, and the blacktail shiner. At Site 1 the dominant species in April and August was the central stoneroller, in June the roundnose minnow, and in October was the Texas shiner. At Site 2 the dominant species in April was the roundnose minnow, in June was the blacktail shiner, in August the Texas shiner, and in October was the central stoneroller. At Site 3 the central stoneroller was completely absent from sampling. The Texas shiner was dominant in April, and the roundnose minnow was dominant in June, August, and October. At Site 4 the central stoneroller was completely absent from sampling. The Texas shiner was dominant in April, August, and October, with the roundnose minnow being dominant during June sampling.

Gray redhorse *Moxostoma congestum* was the only sucker species collected and was present at all sites except Site 1. A particularly numerous and large-sized population of approximately 20 adult specimens was observed on numerous occasions, but was in an area too deep for sampling methods used, in the impounded area at the Jacob’s Well Road crossing (see Figure 2) were a small reservoir was formed above an 2.5 meter high privately owned dam.

Only one catfish species was collected, the channel catfish *Ictalurus punctatus,* and was found at all 4 sites. Nine centrarchid species were collected with longear sunfish being the most numerous, followed by redbreast sunfish *Lepomis auritus.* Three species of bass (largemouth bass *Micropterus salmoides*, smallmouth bass *Micropterus dolomieu*, and Guadalupe bass (*Micropterus treculi*) were also collected.

Three intolerant or sensitive species (Linam & Kleinsasser 1998) were collected. These species included roundnose minnow, Guadalupe bass, and greenthroat darter *Etheostoma lepidum*. The roundnose minnow represented 12% of the combined sample at Site 1, 17% of the combined sample at Site 2, 21% of the combined sample at Site 3, and 18% of the combined sample at Site 4. Greenthroat darter represented <0.2% of the combined sample at Site 3, and was absent from sampling at all other sites. Guadalupe bass represented 5% of the combined sample at Site 1, 4% of the combined sample at Site 2, was absent from sampling at Site 3, and represented <0.2% of the combined sample at Site 4.

Table 4. Percent relative abundance of fish family by site**.**

Station→	**1**				**2**				**3**				**4**			
Month→	**Ap**	**J**	**Au**	**O**	**Ap**	**J**	**Au**	**O**	**Ap**	**J**	**Au**	**O**	**Ap**	**J**	**Au**	**O**
Cyprinidae	59	76	70	39	57	74.4	76	23	51	41	60	38	60	49.3	43.3	72
Catostomidae	0	0	0	0	0	0.9	0	0	2.7	3.4	1.2	0	2.4	0.3	0.6	0.5
Characidae	0	0	3.6	0	1.6	0.9	0	6.1	0.8	2.4	0.4	3.0	0	0	0	0
Ictaluridae	1.7	24	0.9	0.2	2.8	2.2	0	4.9	1.1	1.9	0.4	0	3.6	1.4	0.6	0
Poeciliidae	5	7.3	2.4	31	8.5	5.7	2.0	1.8	1.5	9.7	9.3	14.5	13.6	11.5	0	2.8
Centrarchidae	19	11	9.7	19.7	23.3	9.5	12	56	32	23.3	24	21.3	16	25	35	17.2
Percidae		1.3	1.8	6.4	6.3	5	3.7	0	7.6	6.8	2.8	11.5	3.6	11.8	2.2	3.5
Cichlidae	14	17	0.3	0	0	1.3	4.2	7.9	3	6.8	3.2	3.4	0	0.7	5.6	0

Data Analysis.—Data from each site were analyzed using index of biotic integrity (IBI) metrics developed for the Central Texas Plateau ecoregion (Linam et al. 2002). The IBI provides a means of assessing fish assemblage degradation. Results are reported as an aquatic life use. Possible rankings include exceptional, high, intermediate, and limited.

Variation in species composition between sample periods was noted (Table 4). At Site 1, central stoneroller accounted for 25% of the total number of specimens collected in April, 21% of the total number of specimens collected in June, 59% of the total number of specimens collected in August, and 14% of the total number of specimens collected in October. At Site 1, roundnose minnow accounted for 18% of the total number of specimens collected in April, 26% of the total number of specimens collected in June, and was absent from August and October sampling. At Site 1, Texas shiner accounted for 22% of the total number of specimens collected in April, 11% of the total number of specimens collected in June, 1% of the total number of specimens collected in August, and 39% of the total number of specimens collected in October. At Site 1, blacktail shiner was absent from April sampling, accounted for 18% of the total number of specimens collected in June, 9% of the total number of specimens collected in August, and was absent from October sampling.

Variation in species composition was also noted at Site 2. Central stoneroller accounted for 28% of the total number of specimens collected in April, 37% of the total number of specimens collected in June, 13% of the total number of specimens collected in August, and 23% of the total number of specimens collected in October. Roundnose minnow accounted for 29% of the total number of specimens collected in April, was absent from June sampling, 28% of the total number of specimens collected in August, and was absent from October sampling. Texas shiner accounted for 9% of the total number of specimens collected in April, was absent from June sampling, 35% of the total number of specimens collected in August, and was absent from October sampling. At Site 3, central stoneroller and blacktail shiner were absent from all sampling. Roundnose minnow accounted for 3% of the total number of specimens collected in April, 28% of the total number of specimens collected in June, 38% of the total number of specimens collected in August, and 18% of the total number of specimens collected in October. Texas shiner accounted for 48% of the total number of specimens collected in April, 10% of the total number of specimens collected in June, 14% of the total number of specimens collected in August, and 11% of the total number of specimens collected in October. At Site 4, central stoneroller was absent from all sampling, and blacktail shiner was absent from all sampling except October, when it represented 30% of the total number of specimens collected. Roundnose minnow represented 16% of the total number of specimens collected in April, 31% of the total number of specimens collected in June, 11% of the total number of specimens collected in August, and 6% of the total number of specimens collected in October. Texas shiner represented 30% of the total number of specimens collected in April, 10% of the total number of specimens collected in June, 28% of the total number of specimens collected in August, and 35% of the total number of specimens collected in October.

Based upon IBI, aquatic life use across all sites ranged from intermediate to high. The aquatic life use designation is used to assess existing uses according to the health of the sampled biological communities as compared to established water quality standards. Average scores of all components generally were lower than the exceptional aquatic life use designation for Cypress Creek Segment 1815. The low scores for Regional IBI may be due to the 2005 drought, a function of low sample size due to scour and drought, and does not necessarily indicate poor water quality. The only site that did not attain a high rating during at least one of the sampling events was Site 2 (Jackson Property) which showed a consistent intermediate score throughout sampling. Site 1 (Jacob's Well) showed the highest score of 49.

Cypriniformes dominated the fish collections, most likely indicating successful reproduction and recruitment in spite of a natural flow regime of harsh extremes. Overall, the two minnow traps captured 488 fish over the course of the study: (61%) Texas shiner, (21%) blacktail shiner, (11%) roundnose minnow, and (7%) centrarchids. The two hoop nets captured 241 individuals: (68%) sunfish, (25%) blacktail shiner, and (7%) round nose minnow. These additional methods were used only in an attempt to identify previously unidentified or rare fish species, were not part of the bioassessment protocols, and were not included in the bioassessment. All specimens collected were released unharmed if possible. Quantitative biological scoring for evaluating aquatic life use subcategories, based on fish regional criteria, ranged from 37-44, indicating an intermediate to high aquatic life use designation (Table 5). Scoring criteria can be found in Table 6. Results from the September 2002 sampling study conducted by EComm (Walther & Palma 2005) showed regional IBI scores of 54 for sampling conducted near Jacob's Well and 40 at their study site near the confluence with the Blanco River. During 2005 sampling, similar IBI scores were shown for the Site 4 near the Blanco Confluence, however lower scores were shown for Site 1 near Jacob's Well. This may be a repercussion of gradually decreasing annual flows from the well, and may foreshadow a possible continuing degradation occurring due to decreasing flow from Jacob's Well in recent years, due to aquifer pumping and development.

Table 5. Biological and habitat data for segment 1815-Cypress Creek

Site	Date	Discharge (m^3/s)	Regional IBI	RBP	HQI
Site 1	4/16/05	0.374	41	30	20
	6/11/05	0.278	37	23	20
	8/07/05	0.125	44	32	22
	10/03/05	<0.05	49	31	22
Site 2	4/16/05	0.473	39	19	23
	6/11/05	0.283	39	26	23
	8/07/05	0.130	35	33	24
	10/03/05	<0.05	39	29	24
Site 3	4/16/05	0.428	43	24	23
	6/11/05	0.258	39	31	23
	8/07/05	0.080	37	30	25
	10/03/05	<0.05	35	31	25
Site 4	4/16/05		39	20	27
	6/11/05	0.345	40	26	27
	8/07/05	0.130	43	32	29
	10/03/05	<0.05	43	30	30

Table 6. Quantitative biological scoring for evaluating aquatic life use subcategories. Region 30 – Edward's Plateau. Texas Commission on Environmental Quality, 1999.

Subcategory	**Statewide IBI**	**Regional IBI (Region 30)**	**RBP**	**HQI**
Limited	<34	<30	<22	<14
Intermediate	40-44	30-41	22-28	14-19
High	48-52	42-51	29-36	20-25
Exceptional	58-60	>51	>36	26-31

Benthic macroinvertebrate species and number of individuals collected from each of the four sampling sites can be seen in Table 7.

Table 7. Benthic macroinvertebrates collected from four collection sites during April through October, 2005.

		1				2				3				4			
Taxon	**†Functional Group**	**Ap**	**J**	**Au**	**O**	**Ap**	**J**	**Au**	**O**	**Ap**	**J**	**Au**	**O**	**Ap**	**J**	**Au**	**O**
Argia	p	5	17	15	6		4	10	10	5	4	7	3	4	3	1	12
Hetaerina	p		1		4		1		6		4		16		2		14
Brechmorhoga	p				8		4	4	4		4	4	5		18	1	6
Erpetogomphus	p		1			1	1	13	2		2				2	9	
Macromia	p	2															
Stenacron	cg/scr	2				4				34							
Stenonema	scr/cg			1	14			1	1	1	1	16	1	8	1	2	2
Isonychia	fc	2															
Callibaetis	cg	10												6			
Baetis magnus	cg/scr	2		7	10			2	7		2	8	15		2	2	2
Caenis	cg/scr	5															
Fallceon quilleri						4				17							
Tricorythodes	cg		2	4	5		14	7			4	4	4		4	4	4
Leptohypes											8		2		17		
Thraulodes gonzalesi															2	9	
Neocoroterpes	cg/scr			4	4												
Farrodes	cg/scr			10				7								12	1
Chimarra	fc	20	15	19	11			7	23			25	12		4	19	15
Cheumatopsyche	fc		10	18	2	1	18	10	11	3	18	18	3		14	18	9
Hydropsyche	fc		1	2	2		2	2	16		2	3	2		2	2	2
Smicridea							6										
Polycentropus											6						
Polyplectropus	fc/p				4												
Dineutus	p	3				1											
Tropistemus berosus	p	2					1			4							
Stenelmis	cg/scr	2								3				1			
Hexacylloepus									6								
Peltodytes	shr/p	1															
Helicus						1											
Psephenus	scr			23				17			22	3				1	11
Corydalus	p				3		2		2		2	2			2		4
Rhagovelia											3						
Limnoporus											2				2		
Neogerris											1				3		
Belostoma								1								2	
Chironomidae	p/cg/fc	18	20	4	12	61	4	9	8		4	5	4	56	13	2	8
Tabanus	p		2	4	5		5				4				4		
Simulium	fc		5	4	6		3	9	4		4	2	4		4	16	4
Physella	scr	1			2	1	3		1		1	1	11	3	1		3
Elimia								7									
Hyallela azteca	cg/shr	31	2	2	2	2	2		2		2	1	16	4	2	1	3
Corbicula	fc			10				2		12							

†p-predator, scr-scraper, cg-collector/gatherer, fc-filtering collector, shr-shredder

No strong seasonal patterns were detected, which may be due to scour during spring sampling and an unusually dry year (Figure 6). Cypress Creek's historically variable hydrological regime, as evidenced by common flash floods in the region known as "Flash Flood Alley", due to flow over the limestone bedrock of the Edward's Plateau, where shallow soils predominate and rainfall events are brief and often intense, may be further exacerbated by long-term flow alteration associated with increasing anthropogenic development in the form of urban sprawl, and could possibly alter the composition and distribution of the fish and benthic macroinvertebrate assemblages.

Water Quality - Environmental data was collected included dissolved oxygen, water temperature, pH, conductivity, fecal coliform, (*Escherichia coli*) *E. coli*, ammonia nitrogen, total phosphorus, orthophosphate phosphorus, nitrate nitrogen, and total suspended solids (Table 8).

Table 8. Selected water-quality data† for Cypress Creek (Hays County), April 2005.

Site	DO	Temp	pH	SC	**Fecal**	E. coli	**NH_3-N**	Total P	**PO_4-P**	**NO_3-N**	TDS
1	6.22	20.16	6.91	570	1	4.45	0.02	0.04	0.051	0.319	333
2	6.71	20.9	7.45	526	70.3	89.8	0.02	0.045	0.011	0.10	308
3	7.44	20.13	7.7	520	84.6	125.7	0.02	0.053	0.012	0.11	289
4	7.89	20.4	7.9	539	25	45	0.02	0.021	0.015	0.22	275

† All values are in mg/L, milligrams per liter (equivalent to parts per million) except fecal and E. Coli which use col/100 mL, colonies per 100 milliliters, specific conductance (SC) which uses µS/cm, and temperature which uses °centigrade.

The dissolved oxygen levels showed a continual increase at each site as waters flowed towards the Blanco River confluence, as the water moved downstream and oxygen was introduced through physical mixing and photosynthesis.

Nutrients are vital to a productive ecosystem. While quantities sufficient to assist in the formation of a healthy ecosystem are desirable, high quantities can disrupt and impede richness, abundance, and overall biodiversity. Specific conductance values were highest at the Jacob's Well site. All conductivity values were within the expected range. Acceptable values for *E. coli* and fecal coliform are less than 125 colonies per 100 mL. The presence of fecal coliforms and *E. coli* bacteria in samples indicates the presence of pathogens from warm-blooded animals in surface waters. Trinity Aquifer waters that surface at Jacob's Well met bacteria criteria for drinking water. Indicator levels increased slightly as waters moved downstream, and values showed a peak level of 125.7 colonies / 100 mL, however this was well below state standards. Although bacteria values are typically expected to increase after rain and higher flows, due to drought conditions, post-precipitation measurements were unavailable. Normal pH values occur within the range of 6.5 – 9.0 standard units. pH levels at the Jacob's Well site were slightly acidic. The buffering capacity of the water and limestone bedrock caused pH levels to increase in a downstream direction, and all values were within an acceptable range.

DISCUSSION

Cypress Creek discharge can increase by several orders of magnitude and quickly return to normal flows during periods of severe precipitation common to the south central Texas region. In a region known as Flash Flood Alley, with respect to precipitation events (e.g. floods and droughts), and the large amount of scour, debris, uprooted trees, and alterations of stream channels and riparian habitats that may occur during such events, the sheer resilience of the aquatic inhabitants of the region to frequent flooding and drought is particularly remarkable.

The predominance of macroinvertebrate organisms (*Baetis* and *Hydropsyche*) which are quite tolerant to nutrient and organic enrichment, and the RBP/HQI scores of "high" but not "exceptional", may be an indication of a possible impairment, and necessitate further inquiry, however, 2005 was a particularly dry year.

A gradual increase in the number of fish species, longitudinally (e.g. influence from fish migration from the Blanco River into Cypress Creek) appears to have been impeded, in part, due to at least five landowner weirs or dams creating small reservoirs along the creek which may have prevented fish movement above and below these points. The largest of which is 500 m downstream of the Jacob's Well Road crossing, the second one near the Woodcreek Golf Course, and three smaller landowner impoundments upstream where observed between Site 2 and Site 3. In addition two concrete channelized sections downstream of both RR12 bridge crossings, apparently constructed to expedite runoff during flood events, may have additional scouring or other unknown effects on the creek.

Two greenthroat darter specimens were collected from Site 3 (Figure 1). Forty-one greenthroat darters were collected near Jacob's Well in the 2002 study conducted by Ecomm (Walther & Palma 2005). Greenthroat darters (*Etheostoma lepidum*) are native fishes of Edwards Plateau streams, and inhabit spring-fed waters in the Colorado River southward to the Nueces River basin (Hubbs et al. 1991). They have previously been undescribed in Hays County. In the Edwards Plateau streams, greenthroat darters are associated with aquatic plants, and are known to congregate near silted and gravel substrates found in close proximity to spring-fed sources, and riffle habitats (Edwards et al. 2004). Increased water consumption and urban development, leading to decreases in streamflows, in combination with other factors, may put this species at risk (Vequist 1999).

Causes of the apparent decrease in fish diversity in Cypress Creek as shown by the less than exceptional habitat and biological assessment scores, may be associated with the effects of private impoundments and private water pumping along the creek, coupled with the reductions in stream flows over the past decade in association with increased water well-drilling activities in response to development. The effects of increasing urbanization are particularly evident during critical low-flow drought periods, which, according to local residents living adjacent to Cypress Creek, grow longer with each passing year. However, there is a current proposal to pipe water from the Canyon Lake Reservoir to the Wimberley Woodcreek area, in order to reduce demand on the Trinity Aquifer caused by extensive development in the Wimberley and Woodcreek areas

(TWDB 2006). This would be a great benefit to all involved, yet would most certainly promote more development in the region. Additional changes in land and water use may also be required to sustain the hydrologic regime necessary to support this unique spring-fed aquatic system. Additionally, results of this and future investigations may allow the comparison of dispersal dynamics among native fishes, and lead to future endeavors which encourage further research to help to preserve this exceptional aquatic ecosystem, and possibly repatriate native stream fishes into the upper reaches of this distinctively irreplaceable subtropical karstic stream of south central Texas.

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VITA

John (Eric) Dedden was born in Fort Wayne, Indiana, the son of Audrey Ann Dedden and John Robert Dedden. After completing his undergraduate degree in chemistry at Indiana University-Bloomington, he enlisted in the Indiana Army National Guard 2/150 Field Artillery Unit of the 54th Field Artillery Brigade as a Combat Medic, and transferred to the Texas Army National Guard 4/133d Field Artillery unit of the 49th Armored Division in New Braunfels, Texas, where he served abroad from 1993-1996, while teaching high school biology and chemistry in Floresville, Texas. He enlisted a second time with the United States Army, and served on active duty from 1997-2000 with the 86th Combat Support Hospital (CSH) of the 101st Airborne Division at Fort Campbell, Kentucky. During November 1998 he was deployed with the 86th CSH to San Salvador, El Salvador in support of Operation Fuerte Apoya (Strong Support) in the aftermath of Hurricane Mitch. Water quality analysis, epidemiological & entomological surveys, and food service & entomological inspections were conducted. The findings revealed foodborne illness outbreaks, poor camp sanitation, and contamination in the water distribution system. After working in the medical field for four more years as a cilivian at The Central Texas Medical Center in San Marcos, Texas, he entered the Aquatic Biology Master's Program at Texas State University-San Marcos. During the following years he work as a volunteer for the A. E. Wood Federal Fish Hatchery, and as an aquatic biologist intern with the Texas Commission on Environmental Quality

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