Initial Biological Survey of Cypress Creek

Cypress Creek Project

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Freshwater Mussels and Macro-Invertebrates as Indicators of Water Quality
Final Report

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Contents

Abstract

The Meadows Center for Water and the Environment (MCWE) is currently assisting the Cypress Creek Project with efforts to gauge the ecological health of the watershed of Cypress Creek, Hays County, Texas. Freshwater mussels (Bivalvia) have been studied as ideal indicators of ecological health in other watersheds. Although mussels have not been recorded in Cypress Creek, nearby river systems in Texas were found historically to support healthy populations of various mussel species. The presence of these organisms constitutes a valuable tool for helping to evaluate the impacts of human activities on the ecology of Cypress Creek. Water quality and habitat conditions can be inferred from mussels, which can incorporate excess nutrients and other

pollutants and chemicals into their tissues. To this end, an extensive survey was conducted by MCWE to determine the presence of these organisms for future study.

Introduction

Freshwater ecosystems in equilibrium possess resilience to minor environmental fluctuations. These systems buffer against storms and flooding and filter water by recycling nutrients and detritus and other organic matter (Aylward et al., 2005; Jackson et al., 2001). Riparian vegetation along streams creates stable environments and captures, stores, and processes nutrients and agricultural chemicals (Lowrance et al., 1985). If flanked by healthy-functioning riparian lands, water bodies such as streams, lakes and groundwater aquifers will tend to contain higher quality water in augmented, more stable amounts.

This balance and resilience, however, have been increasingly disrupted, in many cases over-whelmed, on a frequent and wide-spread scale. Caused by human population growth and accompanying industrial, agricultural, and urban development, deleterious impacts have overwhelmed buffering capabilities and disrupted ecosystem processes. Elimination of riparian vegetation, dams and impoundments, toxic materials and excessive sediments, habitat destruction, over-exploitation, and the introduction of exotic species have altered the hydrologic characteristics of streams and rivers and threatened their biodiversity.

Ecosystems out of equilibrium suffer decreased biodiversity. The imbalances create smaller and more isolated populations, making them susceptible to extinction as food sources are eliminated. The severity and extent of impacts from human activity is driving extinction rates in freshwater systems equal to that of tropical rainforests (Riccardi and Rasmussen, 1999). Furthermore, of all freshwater groups of organisms, freshwater mussels (known as unionids) are the most imperiled (Williams et al., 1993).

Biologists have only recently realized the degree to which freshwater mussels are declining (Graf and Cummings, 2007). Changes in watershed landscapes have upset balances needed to control sediment loading in water ways, destroying the preferred habitat of mussels by excessive siltation. Additionally, mussels as filter feeders are susceptible to accumulations of toxic materials and their reproduction has widely been blocked by the construction of dams.

Extirpation of unionid populations can result in disruptions in freshwater ecosystems. (Vaughn and Hakencamp, 2001). Freshwater mussels actively contribute to stabilization by filtering water and processing nutrients, and thus by modifying their environment, they can be considered ecosystem engineers.

Mussels and Freshwater Ecosystems

Freshwater mussels belong to the subclass Paleoheterodonta, class Bivalvia, and phylum Mollusca (Bogan, 1993). The order Unioniformes contains the largest number and diversity of species, with 180 out of 206 genera and 797 out of 1026 species. The family Unionidae is the largest, comprising nearly 80% of both the genera and species within the order (Bogan and Roe, 2008). As the order Unionidae is the most diverse, the majority of research focused on it.

The life cycle of freshwater mussels is remarkable. Male mussels release sperm into the water, and sperm are then filtered by females. Fertilized eggs develop into microscopic, parasitic larvae called glochidia. As parasites, they attach themselves to the fins or gills of a fish as a dispersal mechanism for their populations. Mussels are species-specific regarding which fish their glochidia parasitize. After being attached to a fish for one to several weeks, glochidia drop from their host fish and sink to the bottom, where they spend the rest of their lives. Life span is typically eight to 20 years, but the Eastern Pearlshell, found in small trout streams throughout Connecticut, has been reported to live over 100 years.

Freshwater ecosystems worldwide are in crisis, with losses in biodiversity approaching 10,000-20,000 species currently known to be extinct or threatened (Abell, 2001; IUCN, 2007; Strayer and Dudgeon, 2010). All taxonomies of freshwater organisms are facing unprecedented declines with freshwater mussels (also known as unionid or pearly mussels) being particularly affected.

In North America, mussels are considered the most imperiled of aquatic organisms. 67% of North American mussel species are considered threatened, with 35 species having gone extinct since 1900 (Williams et al., 1993). Biologists have estimated a 1.2% per decade extinction rate for this group, and unless conservation measures are taken, an additional 127 species are likely to be extirpated within the next 100 years (Ricciardi and Rasmussen, 1999). Losses to mussel biodiversity are attributable to human impacts, including effluents from wastewater treatment plants, industry, agriculture and mining, as well as urbanization. A major cause of the decline in mussel populations in river basins throughout North America can be attributed to excessive sedimentation caused by poor land use practices, and excessive sedimentation has long been suspected as a cause of unionid mussel declines (Kunz 1898).

51 species of freshwater mussels have, or previously had, historic ranges in Texas (Howells et al., 1996). Of this total, 16 are listed federally or by the state of Texas as Threatened or Endangered. These species are sensitive to disturbance because they have sedentary lifestyles and depend on good water quality. Competition from introduced species, illegal and over-harvesting, and habitat alteration and loss are some of the factors causing their decline (TPWD 2013).

Endemism is another major reason for the high rates of extinction in this order of organisms. Endemic species have a limited geographical range, often limited to a single drainage basin or lake, and often have adapted over time to the unique characteristics pertaining to a specific water body (Strayer and Dudgeon, 2010). Species with limited distributions face a much higher risk of extinction when an entire population is subjected to environmental stresses simultaneously (Gaston, 1998). Climate change and associated extremes of floods and drought impact isolated, more vulnerable populations with deteriorated genetic pools. Populations attempting to recover through recruitment from other populations are limited in species with low dispersal ability, such as Unionid mussels (Burlakova et al., 2010). In eastern Texas, already low dispersal abilities have been attenuated even more from the construction of reservoirs which has impeded fish migrations essential to mussel reproduction (Howells, 2010).

Mussels in the Hill Country - Cypress Creek

Cypress Creek is a tributary of the Blanco River, located in the Hill County of central Texas in Hays County. Mussel diversity and abundance were surveyed in the Blanco River in 1979

(Horne and McIntosh1979). These authors observed that "mussels of the Blanco River seemed to have been adversely affected by enrichment from the secondary sewage of San Marcos". Biologist Clint Robertson of TPWD recently did a follow-up survey of the sites examined by Horne and McIntosh, not finding any mussels at all in the Blanco (personal communication).

The lower segment of this spring fed creek begins at Jacob's Well and usually flows year-round northwest to southeast for 5.5 miles. The stream gradient of the lower part of the creek is 21.4 feet per mile. The upper segments are ephemeral after major storm events. Exposed limestone formations along Cypress Creek are indicative of this karstic area, which supports groundwater recharge to the underlying aquifer (HTGCD, 2008). Karst areas contain soluble rocks, where conduits and channels have formed and been augmented by underground flows to an aquifer.

The region experiences extremes in weather patterns, oscillating between flash floods and drought. Climate in central Texas is characterized as semi-arid. From 1971-2000, average annual temperature in Hays County was 76 to 78 °F (24.4 - 25.6 °C), rainfall was 35 inches (889 mm), and during the years 1950-1979, annual gross lake surface evaporation averaged 60-65 inches (1,524 – 1,651 mm) (TWDB, 2007). The watershed of Cypress Creek encompasses 38 mi² (98 km²), most of which is low-intensity ranching, except for dense residential development in Woodcreek and commercial/residential development in the City of Wimberley.

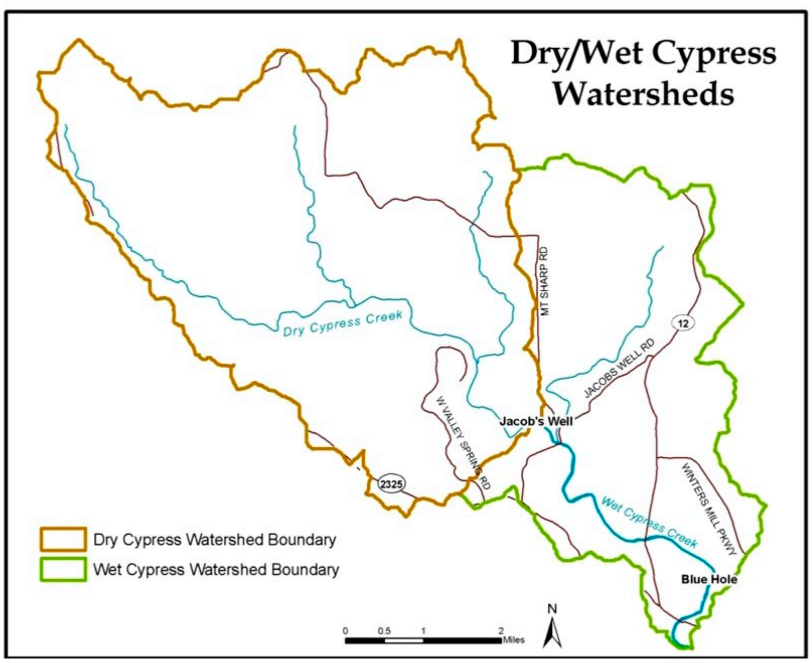

Figure 1. Cypress Creek Watershed, Dry and Wet Portions

Land and water resources of the Cypress Creek watershed are under increasing demands from increasing population growth. The entire region is undergoing rapid urbanization, being located between the major metropolitan areas of Austin and San Antonio. Hays County is listed as the 31st fastest growing county in the United States. The County's population grew from 157,107 in 2010 to 168,990 in 2013, an increase of 7.56%. According to the Texas State Data Center (2010), Wimberley and Woodcreek's combined population grew approximately 21% from 2000-2009. By the year 2040, population in Hays County is expected to grow from 97,589 in 2000 to over 130,000, or possibly as high as 574,000 (TSDC, 2009).

Figure 2. Texas Fatmucket (Lampsilis bracteata). Photo courtesy of Clint Robertson, TPWD

Table 1. Typical fishes in the Blanco River watershed as known glochidial hosts of bivalve mollusks in North American water bodies (Ashton, 2009).

Common Name	*Scientific Name*
Central Stoneroller	*Campostoma anomalum*
Common Carp	*Cyrinus carpio*
Yellow Bullhead	*Ameiurus natalis*
Redbreast Sunfish	*Lepomis airitus*
Green Sunfish	*Lepomis cyanellus*

Bluegill	*Lepomis macrochirus*
Redear Sunfish	*Lepomis microlophus*
Smallmouth Bass	*Micropterus dolomieu*
Largemouth Bass	*Micropterus salmoides*

Figure 3. Texas State Department of Biology Faculty and Graduate Student Performing Site Evaluations in Cypress Creek

Study Site Description

The length of Cypress Creek as a study site is variable, with few uninterrupted stretches of riffles and runs. Many dams, impoundments, and low water crossings interrupt natural flows to create pools with heavy sedimentation and over-grown aquatic vegetation, mostly in the upper reaches of the creek. Where water flows unimpeded, bedrock substrate is exposed with few gravel and cobble deposits from past flood events. Low flows from the creeks origin at Jacob's Well (0.04 cubic meter/ second) is supplemented by numerous springs or seeps along its route, although water clarity can be impeded for several days after major storm events. Average water temperature at Jacob's Well is 20.6°C. Riparian cover shades the majority of the creeks length, but is characterized by old growth trees above areas whose understory has been mechanically cleared. Dominant tree types are Bald Cypress (Taxodium distichum), American Sycamore (Platanus occidentalis), and Live Oak (Quercus virginiana).

Surveying Method

Seven sites were originally selected with the use of satellite/ internet-based imagery. The total length to be initially surveyed was calculated to be a total of 5.13 miles, extending from the confluence with the Blanco River up to its origin at Jacob's Well. Once on site, stream stretches were eliminated from consideration of where depositions of excessive sediments and heavy aquatic vegetation occurred. Sediments and instream vegetation are not conducive to mussel establishment. Permissions for access to private property were procured from the property owners beforehand, since the majority of Cypress Creek runs through privately-owned lands. Rigorous visual inspections with masks and snorkels, as well as hand searches, were performed along the majority of the length of Cypress Creek. The field work effort for this study totaled 42 man-hours. Water depths ranged from inches to a few feet. Only Blue Hole (site 3) was examined with scuba-diving equipment because water depths up to 17 feet deep were encountered. These deeper areas were inspected in coordinated parallel searches moving up stream. As exposed limestone bedrock frequently scoured by floods comprised the majority of the streambed, any areas perceived as refuge from high currents, such as immediately downstream of large boulders, received special attention.

Figure 4. Texas State Department of Biology Faculty and Graduate Students Performing Site Evaluations in Cypress Creek/Blue Hole.

Results and Conclusions

No evidence of living Unionid mussels along the entirety of Cypress Creek was found, and only two shell fragments were encountered, in a gravel deposit at the confluence of Cypress Creek with the Blanco River. The invasive Asian clam *Corbicula fulminea* were present, although still scarce. In Texas, *Coricula* were found to be rare to absent in the smallest of streams (Karatayev, 2005). In nearby Blanco River, historical mussel populations were adversely affected by excess enrichment from a San Marcos, TX sewage treatment plant (Horne and McIntosh, 1979). In tolerance tests with ammonium (NH^3-N), the same authors also noted that *Corbicula* was more tolerant than locally-occurring mussel species.

The geomorphology of Cypress Creek may not be conducive to the establishment of mussel populations. The stream bottom and substrate composition observed during this survey provided scarce loose sand and cobble substrates as ideal habitat. Deep anoxic silt has accumulated behind cement dams while the majority of the length is exposed bedrock exhibiting signs of heavy scouring from high velocity flooding. The creeks ephemeral nature during drought conditions offers little refuge to organisms of limited mobility although spring inputs of groundwater into the creek may function as refuge during drought. In addition, the length of Cypress Creek is frequently crossed by bridges, dams, and culverts that impede necessary migration of fishes for Unionid reproduction. Areas immediately upstream of these structures create unsuitable habitats, where excessive fine sediments are deposited and are plagued with noxious growths of exotic macrophytes, particularly in the upper reaches.

Biodiversity Loss

The unionid mussel component of freshwater biodiversity is often overlooked, even though it is the most threatened component (Ricciardi and Rasmussen, 1999; Williams et al., 1993). To our knowledge no mussel survey had been undertaken in previous years. Mussels have important functions in their ecosystems (McCall et al., 1995; Strayer et al., 1999; Vaughn and Hakencamp, 2001), and influence benthic community diversity (Aldridge et al., 2007; Gutierrez et al., 2003; Spooner and Vaughn, 2006). Disruptions in reproduction, availability of proper foods, and habitat destruction, as well as exploitation of valuable shell and pearls, have contributed to worldwide declines (Bogan, 1993; Vaughn, 1997).

The causes of the decline in unionid biodiversity are the same as those for freshwater diversity in general; namely, pollution, habitat destruction, overharvest, altered flows, invasion by non-native species, and climate change. The severity of these impacts is exacerbated by the high degree of endemism of unionid populations (Strayer et al., 2004). Solutions to the declining biodiversity are straight-forward, but contrary to short-term human interests. Reducing pollution (Caruso, 2000; Lowrance et al., 1997), restricting harvesting (Strayer et al., 2004), ensuring ecologically-sustainable flows (Arthington et al., 2006; Layzer and Scott, 2006), habitat protection and restoration (Miller et al., 2010; Muotka et al., 2002; Wilson et al., 2011), combating non-native invaders (Strayer, 2008b), mitigating and planning for the effects of climate change (Heino et al., 2009; Poff et al., 2002), creating connected freshwater protected areas (Heino et al., 2009; Saunders et al., 2002) and artificially enhancing wild populations (Cope and Waller, 1995; Strayer et al., 2004), are all crucial to restoring freshwater ecosystems and the mussels occupying them. It is clear that any successful conservation plan must be large-scale and long-term in scope, and simultaneously alleviate the multiple chronic stressors disrupting freshwater ecosystems.

Causes of Declines in Mussel Populations

There are many causes for the observed decline in freshwater mussel biodiversity (Strayer et al., 2004; Downing et al., 2010). Dudgeon et al. (2006) describe five major contributors to the loss of freshwater biodiversity in general, including pollution, sedimentation, flow modification, exotic species invasions, habitat modification and destruction, and over-exploitation. Our observations on Cypress Creek point to possible elimination of shallow riffle areas with stable substrates essential to the establishment or maintenance of mussel populations. Higher velocity flooding waters may have exacerbated instream erosion and washed away riffle reaches. Flow velocities may have been augmented through clearing of riparian vegetation, evident along the creeks entire length. Riparian vegetation dissipates stream energy and slows flow velocities. Runoff velocities from upland areas have also been increased through clearing of vegetation. This runoff has resulted in excessive sedimentation deposited behind dam structures accompanied by noxious aquatic vegetation deleterious to mussel habitat. This problem is particularly acute in the upper reaches of Cypress Creek.

Pollutants. Mussels are long-lived organisms which can bio-accumulate small concentrations of pollutants. Chronic exposures can increase susceptibility to infection or predation, or cause direct mortality. Pollutants come from many different sources, including municipal wastewater effluent, industrial waste, and agricultural and mining runoff (Bogan, 1993). Unionids accumulate toxins that can have long-term effects on populations (Strayer et al., 2004). Water pollution, including siltation, is endemic to almost all inhabited parts of the world, being consistently ranked as one of the major threats to freshwater ecosystems (Richter et al., 1997). Freshwater mussels can suffer direct mortality from acute or long-term exposure to high levels of organic and inorganic pollutants, as well as experiencing sub-lethal effects on growth, enzyme production, abnormal shell growth, reduced metabolism, and reduced fitness in general (Keller et al.,2007). Unionid complex life cycles present several life stages in which different sensitivities to pollutant levels can disrupt recruitment and reduce populations (Cope et al., 2008).

Excessive sedimentation. Unnaturally high quantities of fine particle sediments can be significant water pollutants. Sediments foul mussel feeding siphons and gills, and diminish algal production by blocking sunlight (Brim Box and Mossa, 1999), reducing the visibility necessary for fish hosts to be lured by breeding female mussels (Haag et al., 1995). Siltation can also create unsuitable substrate for burrowing (Gordon et al., 1992). Excessive sediments are generated by poor forestry management, loss of riparian vegetation and erosion of stream banks, dredging operations, uncontrolled runoff from construction sites, agriculture and urban areas, and changes in hydrologic patterns.

Flow alteration. Restrictions or modifications of instream flows have caused declines in mussel populations. Natural flow regimes are altered by dams and affect substrate stability, the composition of particulate organic matter as food, and water quality and temperature (Poff et al., 2007). Mussel populations have suffered below large dams. Downstream increases in distance from dams correlates to population increases (Strayer, 1993; Vaughn and Taylor, 1999). Altered flow regimes following dam construction have resulted in either the extinction or local extirpation of several species (Layzer et al., 1993). Dams impair the recruitment of juveniles through changes in fish assemblages vital to the dispersal of glochidia (Watters, 1999). Urbanization of catchment basins can also alter flow regimes through increases in impervious cover, and channelization of storm water runoff. Flows from storm events become higher, faster, and more frequently erosive in these areas (Walsh et al., 2005). Human consumption of surface and groundwater reduces available habitat, increases temperatures, and impairs feeding, respiration, and reproduction (Golladay et al., 2004; Hastie et al., 2003).

Head-cutting, channelization, and other modifications in river geomorphology alter mussel habitat. Head-cutting of the bottom of a stream causes washouts that can progressively move up river, deepening and widening the channel to release excessive quantities of sediments. This process physically destroys mussel habitat, and smothers previously-suitable downstream habitat as well (Harfield, 1993). Channelization through dredging for boat and barge traffic deposits sediments which can smother mussels and prevent re-colonization. Dredging can also drastically alter the natural flow regime, and homogenize the habitat and flow regime (Watters, 1999). Gravel mining operations modify pools and riffles, changing species diversity, abundance of fishes and invertebrates (Brown et al., 1998). These changes have negatively impacted freshwater mussels. Most unionids require shallow riffle areas with stable, moderately coarse substrates, and are extremely intolerant to disturbances, especially in their larval stages (Brim Box and Mossa, 1999).

Non-native organisms. Invasion of exotic species is a global phenomenon that threatens both terrestrial and aquatic ecosystems. The Asian clam (*Corbicula fluminea*) is one of the non-native species of greatest concern in North America (although there is some debate over the specific impacts of *C. fluminea*) (Strayer et al., 1999). They compete for food and habitat with native mussels.

Habitat destruction and alteration. Loss of habitat is one of the greatest threats to freshwater ecosystems and mussel populations worldwide (Ricciardi and Rasmussen, 1999; Richter et al., 1997; Sala et al., 2000; Osterling et al. 2010). Habitat modification encompasses many of the threats to mussels, including sedimentation, flow alteration, substrate modification, and others, as well as such activities as gravel and sand mining, channelization for boat transportation, clearing of riparian vegetation, and bridge construction (Watters, 1999). Increasing quantities of sediments, either from land surface runoff or instream erosion, is one of the largest contributors to loss of mussel habitat, since it makes existing habitat unsuitable for many mussel species (Brim Box and Mossa, 1999). Altered stream behavior caused by modified flows, poor riparian zone management, and runoff from impervious cover can also result in habitat loss through bed scouring, channel morphology changes, and altered sediment regimes in the system (Brierley and Fryirs, 2005).

Data Collection and Recommendations for the Future

Since no freshwater mussels were found which could be used to monitor changes in the health of the Cypress Creek ecosystem, a survey of aquatic insect larvae was undertaken. Known as aquatic macro-invertebrates, this group is commonly studied as bio-indicators whose function, population, status, and function can reveal the degree of environmental integrity present. Macro-invertebrates as bioindicators can reveal the cumulative effects of different pollutants in an ecosystem and provide quantitative information on the quality of a watershed, a stream, and even portions within that stream. This method is employed to monitor changes which may assist in pinpointing problems within the ecosystem.

A summary of 6 surveyed reaches of Cypress Creek is presented below. The findings may reflect deteriorated areas affected by: 1) excessive sedimentation and frequency of dams in the upper portions of the creek and; 2) access of livestock to the immediate riparian edges along the middle portions of the creek.

Site	1) Confluence Blanco River 29°59'29.75"N 98°05'42.00"W	2) Wimberley Bridge 29°59'45.91"N 98°05'53.38"W	3) Downstream Blue Hole 30°00'06.51"N 98°05'31.11"W	4) Gumbert Property 30°00'36.10"N 98°05'47.15"W	5) Cypress Creek Lane 30°00'56.46"N 98°06'47.82"W	6) Joanna Ranch 30°01'14.84"N 98°07'17.44"W
% EPT	73.1%	66.1%	46.2%	59.4%	55.5%	50.5%
% Chironomidae	10.5%	6.4%	4.3%	10.4%	3.0%	0.0%
Taxa Richness	15	11	15	14	16	8

1. **Percent EPT taxa**. This metric is the ratio of the number of individuals within the orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) to the total number of individuals in the sample multiplied by 100. In general, this metric tends to decrease with increasing disturbance of physicochemical factors as the majority of taxa in these orders are pollution sensitive.

2. **Percent Chironomidae**. This metric is the ratio of the number of individuals in the family Chironomidae to the total number of individuals in the sample multiplied by 100.Chironomidae are relatively ubiquitous in aquatic habitats and many of the species are facultative or pollution tolerant. Excessive representation within the community often reflects environmental perturbation.

3. **Taxa Richness**. Relatively lower taxa richness values reflect lower biotic integrity. Decreases in taxa richness may result from disturbance of physicochemical factors.

Our bio-assessment provides good baseline data (Appendix A) for future monitoring of Cypress Creek. Further periodic surveys is a recommendation in the Cypress Creek Watershed Protection Plan being submitted to the USEPA and the TCEQ in Texas in the Fall of 2014 (cypresscreekproject.org).

This study and methodology also serves as an example for future monitoring efforts of other rivers and streams by the Meadows Center for Water and the Environment (MCWE) in conjunction with various citizen science groups around Texas and entomologists associated with the US Fish and Wildlife Service (USFWS).

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Appendix – Macroinvertibrate Data Collected

Cypress Creek Rapid Bio-Assessment

Site	**1) Confluence Blanco River**	**2) Wimberley Bridge**	**3) Downstream Blue Hole**	**4) Gumbert Property**	**5) Cypress Creek Lane**	**6) Joanna Ranch**

	29°59'29.75"N 98°05'42.00"W	29°59'45.91"N 98°05'53.38"W	30°00'06.51"N 98°05'31.11"W	30°00'36.10"N 98°05'47.15"W	30°00'56.46"N 98°06'47.82"W	30°01'14.84"N 98°07'17.44"W
Ephemeroptera						
Potamanthidae	54	13				
Baetidae			82			1
Heptageniidae			1		20	22
Leptohyphidae		36		57	26	
Leptophlebiidae					6	23
Caenidae						2
total/site	**54**	**49**	**83**	**57**	**52**	**48**
Odonates						
Coenagrionidae	55	7	1	11	12	16
Gomphidae	3	42	82	11	18	
Lestidae			3			
Calopterygidae		5	15	8	5	15
Petaluridae			3			
total/site	**58**	**54**	**104**	**30**	**35**	**31**
Tricoptera						
Philopotamidae	289	58	14	54	48	
Hydropsychidae	74	47	19	15	11	
Polycentropodidae			1			
total/site	**363**	**105**	**34**	**69**	**59**	**0**
Plecoptera						
Pteronarcyidae	8					
Perlidae	1					
Perlodidae	11					
total/site	**20**	**0**	**0**	**0**	**0**	**0**
Diptera						
Chironomidae	63	15	11	22	6	
Anthericidae				12	28	
total/site	**63**	**15**	**11**	**34**	**34**	**0**
Hemiptera						
Gerridae	12	8	18	4	7	
Mesoveliidae	5		1		3	10
Veliidae	1		2	5		
total/site	**18**	**8**	**21**	**9**	**10**	**10**
Lepidoptera						
Pyralidae	17				1	
total/site	**17**	**0**	**0**	**0**	**1**	**0**
Megaloptera						
Corydalidae	0	3	11	3	1	
total/site	**0**	**0**	**0**	**0**	**0**	**0**

Colembola						
Entomobryidae	1					
total/site	**1**	**0**	**0**	**0**	**0**	**0**
Coleoptera						
Dytiscidae	4	2		2		
Hydrophilidae				6		
Haliplidae					1	
Elmidae				5	8	6
total/site	**4**	**2**	**0**	**13**	**9**	**6**