Aquatic Life Assessment of an Intermittent Stream Experiencing Off-Road Vehicle Activity

Melissa L. Mullins
Adam S. Whisenant
Joan A. Glass

Texas Parks and Wildlife Department
4200 Smith School Road
Austin, Texas 78744

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ABSTRACT

Environmental conditions encountered by aquatic biota inhabiting small intermittent Texas streams are variable and can be harsh. From a regulatory standpoint, intermittent streams in Texas are generally considered to have a limited aquatic life use. Recent controversy over driving motorized vehicles in riverbeds has focused public attention on various stream systems. Much of the controversy has centered on relatively large rivers, but this activity may represent pressure for smaller streams and creeks as well. To better understand potential impacts from this activity, habitat, physico-chemical parameters, and fish and benthic communities were assessed in Cedron Creek; a small intermittent stream experiencing off-road vehicle use. Areas experiencing off-road vehicle impacts were compared to areas with little or no use. Little variation was found between study areas. Data analysis indicates the creek supports good overall water quality, high quality habitat, and a healthy fish and benthic community. Study results suggest that this stream, and potentially others like it, represent a largely undervalued resource which may deserve more protective measures than are typically afforded them.

INTRODUCTION

Streambeds are among the largest class of public lands in Texas, and with many shallow water areas accessible for driving, they have attracted off-road enthusiasts around the state. Organized off-road outings in the Nueces River near Uvalde have involved in excess of a hundred vehicles at a time, and regular activity has been reported for the Llano, Brazos, and Frio rivers, Village Creek near Beaumont, Spring Creek in Houston and Cibolo Creek north of San Antonio (Carmody 2001, Cockerill 2001, Winninhgam 2001).

Evidence of off-road vehicle activity is readily apparent in riparian areas. In moderately used areas, this may consist of visible tracks, while in heavily used areas vegetation may be completely denuded [personal observations at United States Army Corps of Engineers (USACE, "Corps") off-road vehicle use area at Waco Lake, Texas]. Concern over environmental damage caused by motorized off-road vehicles is not new. Executive orders were issued in the 1970's regarding use of off-road vehicles on public lands (Code of Federal Regulations, 1972). Studies have demonstrated a direct relationship between how heavily an area is driven and the amount of vegetation loss (Payne et al. 1983 as referenced in Texas Chapter of the American Fisheries Society (TCAFS) Policy statement 2002) and soil erosion is many times greater in areas of off-road vehicle use than in comparable areas without use (Snyder et al. 1976 in TCAFS 2002). Off-road vehicles have also been implicated in the spread of exotic weed species (Lacey et al. 1997 in TCAFS 2002) and in negatively impacting aquatic communities at multiple trophic levels (Edwards and Burns 1986, Peterson 1994 in TCAFS 2002).

A report to the Texas Parks and Wildlife Commission (Task Force on the Use of Motorized Vehicles in Navigable Streambeds 2002) summarized the findings of a diverse task force of stakeholders formed in 2001. The report identified several issues upon which the members of the task force agreed, including: natural events have significant effects on streambeds, Texas streambeds are diverse and must be considered individually, and pollution is a significant problem in many Texas streambeds. The task force was unable to reach consensus on several important issues, among them whether the use of motor vehicles in streambeds directly affects fish and wildlife resources or habitat. Attempts at legislative action culminated in passage of Senate Bill 155 (78th Texas Legislature, 2003) prohibiting operation of motor vehicles in defined protected freshwater areas.

In the absence of site-specific data, intermittent streams in Texas are presumed to have no significant aquatic life use, and intermittent streams with perennial pools are presumed to have a limited aquatic life use. The water quality standards designed to be protective of aquatic life, for instance dissolved oxygen levels, are less stringent the lower the aquatic life use category (Texas Administrative Code, §307.4(h)(4)). Capone and Kushlan (1991) found fish community structure to be correlated with environmental conditions in a hydrologically variable Texas river and physical factors may be critical in assemblage organization in variable environments, as opposed to biotic interactions in more stable environments. Low dissolved oxygen (DO) and warm temperatures in intermittent streams may select for stress-tolerant benthic assemblages with sensitive taxa first to disappear as the environment becomes harsher (Davis et al. 1999). In this study, we assessed habitat and aquatic communities of a central Texas intermittent stream experiencing off-road vehicle use. We expected the stream to score relatively low in terms of aquatic life use, based on regulatory assumptions regarding intermittent streams, and hypothesized that the area of the stream experiencing off-road vehicle use would have lower scores than an upstream area where activity was restricted.

MATERIALS AND METHODS

<u>Study site</u>

Cedron Creek, a small third-order stream, flows into Lake Whitney (Brazos River basin) in Bosque County, TX. A study segment beginning 100-m upstream of state highway 56 bridge and extending upstream for 500m, and a second segment beginning 100-m downstream of the bridge and extending downstream for 500-m were sampled in May and July of 2002 during periods of measurable flow. Cedron Creek runs through a large ranch and then onto USACE property. The study reach lies within USACE property. Adjacent land use is primarily range or pastureland upstream and forested downstream, with a rural housing community located nearby. Off-road vehicle use is not permitted on the Corps property by policy (USACE Whitney Project office, personal communication). However, vehicle tracks and garbage, as well as vehicles actually in the streambed, were observed during the course of the study in the downstream reach. A pipe fence erected across the stream at the bridge appeared to hamper vehicle activity in the upstream reach. Location of the study site is depicted in Figure 1. The only permitted discharge of which we are aware is a small package plant for a summer camp located in the upper watershed.

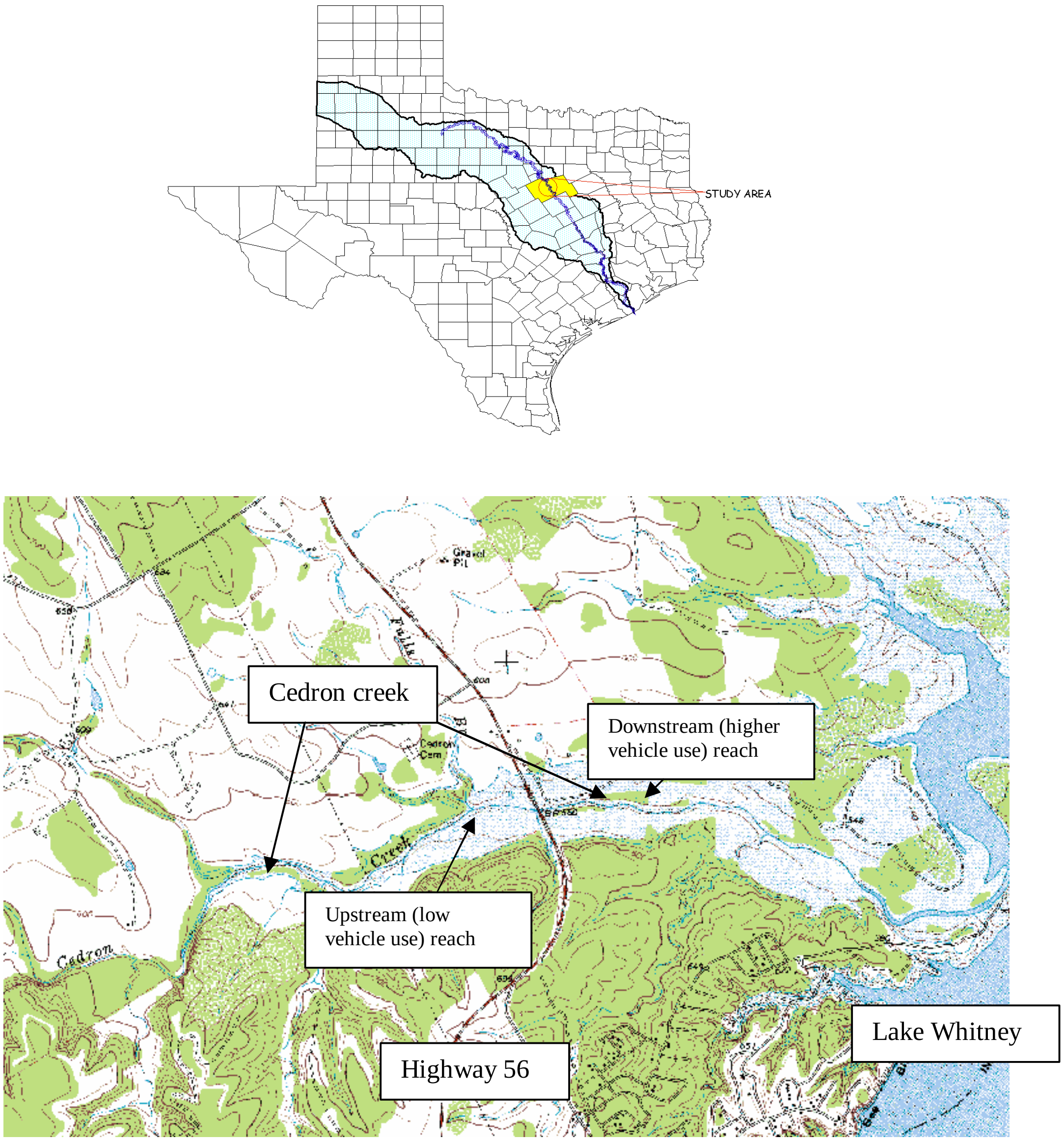

Figure 1. Cedron Creek Study Site.

Field water quality measurements

Dissolved oxygen, pH, conductivity and temperature were measured every 30 minutes for 24-hours using YSI 600 XLM datasondes. Datasondes were deployed simultaneously in the middle of each reach in areas of flowing water. Instruments were calibrated before and after deployment. Instantaneous flow measurements were made following standard procedures accepted by the state's environmental regulatory agency, using a Marsh-McBirney flowmeter (Flo-Mate) and top-setting wading rod (Texas Commission on Environmental Quality (TCEQ) 1999b) at a point midway between the two reaches.

Habitat assessment

Habitat was assessed in May, adhering to standard TCEQ habitat assessment procedures (TCEQ 1999a). Measurements were made at each of six evenly spaced transects within each segment. Primary instream channel attributes along with secondary morphology attributes and tertiary riparian attributes were assessed. Embeddedness, as defined by the United States Environmental Protection Agency (USEPA 1999) was also estimated. Digital photographs were taken of each bank, as well as upstream and downstream at each transect. Physical characteristics were summarized and habitat metrics calculated, according to TCEQ guidelines.

Fish

Fish were collected with seines and a backpack shocker (Smith Root model 12 in May, model LR-24 in July); however, due to battery failure in May, only the downstream reach was electrofished. All habitat types were sampled working upstream through each reach; shocking duration was at least 900 seconds (actual shock time). A twenty foot seine with 3/16" delta-weave mesh was used to make a minimum of six successful seine hauls. More seine hauls were made if needed to adequately sample habitats or if new species were generated in the previous haul. An estimate of distance seined was recorded. Fish were identified, enumerated and released when possible. Preserved fish were identified to species level using a key for Texas freshwater fishes (Hubbs et al. 1991) and other keys and guides (Page and Burr 1991, Robison and Buchanan 1988, Eddy and Underhill 1978). Identifications were confirmed by qualified biologists independent of the project. Eleven index of biotic integrity (IBI) fish metrics developed for Ecoregions 27, 29 and 32 in Texas were used to evaluate data (Linam et al. 2002). Drainage basin size was estimated to be 135 km^2. Scores for the individual metrics were summed and aquatic life use categories determined for both the upstream and downstream reaches.

Benthic macroinvertebrates

Benthic macroinvertebrates were collected at three riffles within each reach during each sampling event. In May, quantitative sampling using a surber sampler was performed. In July, two sets of samples were collected—surber samples and kicknet samples. Results for July presented herein are for kicknet samples only.

In May, a surber sampler was randomly placed in each riffle, and the substrate disturbed thoroughly for five minutes. The entire contents of the net were preserved in the field. Samples were processed in the laboratory by repeated picking and sorting of macroinvertebrates until all organisms were removed. Macroinvertebrates were counted and identified to the family level (Merritt and Cummins 1984, McCafferty 1981, Thorp and Covich 1991, Smith 2001). Following quality assurance and identification to genus level, the data were evaluated by using the draft benthic index of biotic integrity (B-IBI) metric criteria developed for the Central Bioregion of Texas (Davis 1997).

In July, benthic macroinvertebrates were sampled by kicknet using a D-frame aquatic insect net. Sampling proceeded from downstream to upstream for 5 minutes in each riffle, covering as much of the length and width of the riffle as possible. We attempted to pick a minimum of 100 organisms from each sample in the field; these were placed directly into ethanol for later identification in the laboratory. Upon identification, actual numbers of organisms recovered in each sample ranged from 56 to 132; the mean number was 96. Organisms were identified to family level. Following quality assurance and identification to genus level, this data was evaluated in accordance with the draft metric criteria developed for kicknet samples by Harrison (1996).

RESULTS

Water quality

Water quality data are summarized in Table 1. Temperature, pH and conductivity were comparable between the two sites in both May and July. Both water temperature and conductivity were slightly higher in July, as average daytime temperatures increased and flow decreased. Dissolved oxygen measurements were most comparable between the sites in July. Dissolved oxygen (and related, pH) measurements exhibited a typical diel pattern. All water quality measurements met state water quality standards (Texas Administrative Code, §307) for the parameters measured. Stream discharge was 2.87 cfs in May and 0.35 cfs in July. Rainfall amounts for May through July 2002 in the Waco area were normal, with percentage of average precipitation ranging from 81% to 107% (Texas Climatic Bulletin, 2002).

Habitat assessment

Selected habitat data are presented in Table 2. Many primary habitat characteristics were similar, as might be expected given the segments were nearly contiguous. One visible difference between the two reaches was riparian zones, with the downstream reach consisting primarily of forested area and the upper being bordered by more pasture or rangeland. This observation is reflected in the riparian percent composition as well as percent tree canopy. The downstream segment contained more pool habitat than the upstream segment, but both had significant pools to serve as refugia for aquatic organisms during no or subsurface flow periods. The final pool in the downstream reach presents a possible confounding factor in the study because it is likely often connected to the lake. The upstream reach was slightly narrower and deeper on average. Average bank slope was higher upstream, largely due to a cliff which occurs along one side for a distance. The downstream reach contained a higher number of riffles than the upstream reach; some of these riffles appeared to be artificially created by tire tracks. Embededdness fell between 0- 25% at all transects upstream except for one pool with silt substrate where the metric was not applicable. The downstream reach had, in addition to 0-25% embedded range scores, two transects in the 26-50% embedded range, and 1 in the 51-75% range. Habitat quality indices were calculated for both the upstream and downstream reaches by assigning numerical scores to the habitat characteristics (TCEQ 1999a). Both segments were classified as having "high" quality habitat.

Fish

Fish data are summarized in Table 3. Fifteen species were collected overall for Cedron Creek during the summer of 2002. Seven species were collected at both sites during both sampling events: central stoneroller (*Campostoma anomalum*), blacktail shiner (*Cyprinella venusta*), western mosquitofish (*Gambusia affinis*), bluegill (*Lepomis macrochirus*), longear sunfish (*L. megalotis*), largemouth bass (*Micropterus salmoides*) and orangethroat darter (*Etheostoma spectabile*). Common carp (*Cyprinus carpio*), bullhead minnow (*Pimephales vigilax*), and gray redhorse (*Moxostoma congestum*) were collected downstream during at least one of the two sampling events but were not collected upstream during either sampling event. A single channel catfish (*Ictalurus punctatus*) was collected upstream during July and this species was not collected downstream during either sampling event. Species composition was similar between the two sites. Central stoneroller was the most abundant species, comprising 54% of the total individuals collected downstream and 52% upstream. Among sunfish, bluegill was most common, making up 13% of the total individuals collected upstream and 9% downstream. The single species of darter collected made up approximately 2% upstream and 3% downstream of the total individuals collected. Largemouth bass comprised 6% of the total individuals collected upstream and 12% downstream. This may be a reflection the downstream section being more likely to be inundated by the reservoir's waters.

The downstream site had an IBI score of high for each sampling event; the upstream site had a limited score in May (seine data only) and a high score in July. IBI metrics (Linam et al. 2002) and scores are presented in Table 4 for May and Table 5 for July. In May, the higher score downstream was due to a higher species richness; greater number of benthic invertivore species and sunfish species; a higher percentage of individuals as invertivores and piscivores; and a greater number of individuals captured per unit effort. In July, the higher score downstream was attributable to a greater number of benthic invertivore species; a lower percentage of individuals as omnivores and non-native species; and a greater number of individuals captured per unit effort. For the July sampling event, the upstream site scored higher in the species richness and the percentage of individuals as invertivores metric categories.

Benthic macroinvertebrates

Benthic macroinvertebrate data is summarized in Table 6. The metrics and scoring for surber samples taken in May (B-IBI) are shown in Table 7 (Davis 1997). The metrics and scoring for kicknet samples taken in July (rapid bioassessment protocol) are shown in Table 8 (Harrison 1997).

The stream tended to score consistently high for some metrics, regardless of method employed, scoring protocol followed or month, and consistently lower for certain others. Total number of taxa was relatively high, and Ephemeroptera taxa, % EPT taxa, and EPT taxa abundance were also good. Scores related to dominance of particular groups tended to be low—for instance, % dominance (3 taxa), % dominant FFG (functional feeding group) and % predators. Some of these differences may be related to suitability of individual metrics for an intermittent stream. Both reaches scored a high aquatic life use overall in terms of benthic macroinvertebrates for both the May (surber) and July (kicknet) sampling events.

DISCUSSION

In this study, the area of the stream experiencing off-road vehicle use did not score lower than an upstream area where such activity was restricted, based on standard measures of aquatic life. However, contrary to the expectation that aquatic life use of this intermittent stream would be limited, the habitat, benthic invertebrate, and fish communities present in the stream during the harshest time of the year, indicated a high aquatic life use. The primary impact expected to a stream experiencing off-road vehicle activity, in advance of measurable impacts to biota, would be disturbance of abiotic components of the environment (an exception is vegetation, which is biotic but can be impacted directly and immediately by being driven over). Some individual assessment measures used may be beginning to show differences between the two sites (for example, the downstream site had some transects with greater embeddedness). The upstream reach was slightly narrower on average (8.98 m vs. 10.91 m wetted width) and deeper (0.22 m vs. 0.15 m) than the downstream reach. Some of this difference is probably natural, as the stream approaches its terminus with Lake Whitney. In areas where vehicles have driven, the cobble substrate tended to appear more flattened out— the impact is particularly evident on “hills” of material which may form during floods and which seem to be popular for driving activities. Flood events may tend to negate these impacts; conversely, changes in channel structure may also change the dynamics of flooding when it does occur.

Because biotic impacts were not quantified does not mean that impacts are not occuring. Several factors should be considered when addressing potential impacts of this type in future work. One consideration is that the environment experienced by aquatic biota inhabiting intermittent streams, or intermittent streams with persistent pools, may be less than optimal or even lethal (Mundahl 1990, Ostrand and Marks 2000), even in the absence of anthropogenic disturbances such as off-road vehicle traffic. Detecting stress in a system already accustomed to highly variable conditions may be more difficult than in less variable systems, and benthic metrics which tend to be correlated with flow permanence might not be well-suited for use in intermittent streams (Davis et al. 1999). Many of the metrics used to derive the overall aquatic life use scores (whether for fish, habitat or benthics) were not necessarily developed to detect the type of physical perturbation of concern here and may not be particularly good at discerning this type of impact. Most traditional assessment efforts have been aimed at organic pollutants or wastewater discharge impacts.

Another issue may be differences between the two reaches in terms of pool permanence during no-flow conditions, and access to potential re-colonizers when the water is higher. The reaches were basically continuous and scored out similarly for habitat. However, as referenced in the results of the habitat assessment, the terminal pool of the downstream reach is more lacustrine in nature and as water levels rise, lower reaches would experience connections to the lake sooner and more often. Fish communities have been shown to change in small warmwater streams as the habitat changes from shallower upstream reaches to more stable and heterogeneous habitats downstream (Schlosser 1982 in Capone and Kushlan 1991). Such effects may confound efforts to detect anthropogenic impacts, including those caused by off-road vehicles.

Another problem is one of scale, both spatial and temporal. In terms of spatial impacts, the study area, while obviously receiving off-road vehicle use, appears to receive a lower level of use than other areas of the state. Our study did not quantify level of use, and future work might compare multiple areas with quantified and varying use levels. The impacts in an area with a lower use level such as Cedron Creek might be more difficult to detect than those in higher use areas. Hannaford and Resh (1999) simulated heavy and light use for two all-terrain vehicle types and compared immediate impacts to vegetation with those seen one year later. Immediate impacts to vegetation were statistically significant for both levels of use, but recovery was seen after a year. Some effects from heavy use were still significant a year later. Temporally, impacts that may not be apparent in a "snapshot" in time study such as this one might be more evident upon repeated assessment over longer lengths of time. This might be especially true of subtle but cumulative impacts, such as a lower hatching rate of fish eggs due to increased siltation (Berkman and Rabeni 1987).

Our results regarding fish community impacts are similar to those reported by Saunders et al. (2004). Their study looked at sites with varying level of ORV use in the Nueces River, TX, during two sampling events in the summer of 2002. Impacts to the fish assemblage due to ORV use were not readily apparent, even though effects on vegetation, stream bank and substrate were visible. The study notes that the presence of cobble and gravel substrate and natural events such as flood flows may tend to reverse effects on the substrate due to compaction. The present study site had a similar substrate and also showed evidence of extreme variability in flow and flooding. As Saunders et al. conclude, other TX streams and rivers with sand and silt substrates may be much more susceptible to long-term effects, and caution should be used in drawing general conclusions. A related consideration may be difficulty in detecting impacts to fish, due to their generally higher mobility and range, compared to other biotic components assessed. They may be better able to avoid potentially damaging impacts, and to re-colonize following impacts.

From a resource protection standpoint, the relevant issue in terms of off-road vehicle impacts may be: do managers wish to wait until observed disturbances to a resource can be proven empirically before taking action to prevent further damage? Many states have said no, and some Federal agencies with public lands in Texas (for example the National Forest Service and USACE) have restricted activity to certain areas. In Texas, the issue of regulatory authority may now become clearer; state law effective September 1, 2003 adds language to the Parks and Wildlife Code to prohibit operation of motor vehicles in defined protected freshwater areas (Senate Bill 155, 78th Texas Legislature, 2003). Additionally, our results suggest that small intermittent Texas streams may have higher aquatic life use than presumed in the existing regulatory framework and therefore may need more protection than commonly believed.

ACKNOWLEDGEMENTS

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TABLE 1. Summary of water quality data collected in Cedron Creek, Bosque County, Texas during May and July 2002.

	Temp. range (º C)	**D.O. range (mg/l)**	**D.O. average (mg/l)**	**pH (range)**	**Conductivity average (µmhos/cm)**	**Flow (ft^3/s)**
UPSTREAM MAY	22.56-27.40	4.54- 12.70	8.18	7.62-8.23	357	2.87
DOWNSTREAM MAY	22.10-27.14	2.95- 10.57	6.61	7.56-8.11	360	
UPSTREAM JULY	24.54-28.35	3.8- 11.81	6.78	7.51-7.97	411	0.35
DOWNSTREAM JULY	25.06-28.48	4.28- 10.27	6.55	7.55-7.88	402	

TABLE 2. Summary of habitat data collected in Cedron Creek, Bosque County, Texas during May 2002.

<table>
<tr><th></th><th colspan="5">UPSTREAM REACH</th><th colspan="5">DOWNSTREAM REACH</th></tr>
<tr><td>Stream order</td><td colspan="5">3</td><td colspan="5">3</td></tr>
<tr><td>Average stream width (m)</td><td colspan="5">8.98</td><td colspan="5">10.91</td></tr>
<tr><td>Average stream depth (m)</td><td colspan="5">0.22</td><td colspan="5">0.15</td></tr>
<tr><td>Channel flow status</td><td colspan="5">low</td><td colspan="5">low</td></tr>
<tr><td>Maximum pool width (m)</td><td colspan="5">8</td><td colspan="5">20.5</td></tr>
<tr><td>Maximum pool depth (m)</td><td colspan="5">1.10</td><td colspan="5">0.95</td></tr>
<tr><td>Total number of stream bends</td><td colspan="5">1 (poorly defined)</td><td colspan="5">2 (poorly defined)</td></tr>
<tr><td>Total number of riffles</td><td colspan="5">3</td><td colspan="5">8</td></tr>
<tr><td>Dominant substrate type</td><td colspan="5">Gravel/ cobble</td><td colspan="5">Gravel/ cobble</td></tr>
<tr><td>Average percent substrate gravel sized or larger</td><td colspan="5">59</td><td colspan="5">79</td></tr>
<tr><td>Average percent instream cover</td><td colspan="5">34</td><td colspan="5">43</td></tr>
<tr><td>Number of stream cover types</td><td colspan="5">7</td><td colspan="5">6</td></tr>
<tr><td>Average percent stream bank erosion potential</td><td colspan="5">30</td><td colspan="5">28</td></tr>
<tr><td>Average stream bank slope</td><td colspan="5">53 º</td><td colspan="5">30 º</td></tr>
<tr><td>Average width buffer veg</td><td colspan="5">31 m</td><td colspan="5">> 40 m</td></tr>
<tr><td>Average riparian percent composition by: Trees/ Grasses and Forbes/ Cultivated Fields/ Other</td><td colspan="5">38/ 29/ 0/ 33 (shrubby understory)</td><td colspan="5">50/ 0/ 0/ 50 (shrubby understory)</td></tr>
<tr><td>Average percent tree canopy</td><td colspan="5">26</td><td colspan="5">39</td></tr>
<tr><td>Overall aesthetic appraisal</td><td colspan="5">natural</td><td colspan="5">natural</td></tr>
<tr><td rowspan="2">Embededness (number of transects in each % category)</td><td><u>pool</u></td><td><u>0-25</u></td><td><u>26-50</u></td><td><u>51-75</u></td><td><u>76 +</u></td><td><u>pool</u></td><td><u>0-25</u></td><td><u>26-50</u></td><td><u>51-75</u></td><td><u>76 +</u></td></tr>
<tr><td>1</td><td>5</td><td>0</td><td>0</td><td>0</td><td>0</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>Habitat Quality Index Total Score</td><td colspan="5">22 (High)</td><td colspan="5">23 (High)</td></tr>
</table>

TABLE 3. Fish species and number of individuals collected from Cedron Creek, Bosque County, Texas during May and July, 2002.

Species	Common Name	Upstream		Downstream	
		May SEINE ONLY	July	May	July
Cyprinus carpio	common carp	--	--	--	5
Campostoma anomalum	central stoneroller	146	74	184	501
Pimephales vigilax	bullhead minnow	--	--	4	--
Cyprinella venusta	blacktail shiner	16	2	56	12
Moxostoma congestum	gray redhorse	--	--	2	3
Ameirus natalis	yellow bullhead	--	24	1	--
Ictalurus punctatus	channel catfish	--	1	--	--
Gambusia affinis	western mosquitofish	8	26	3	123
Lepomis auritus	redbreast sunfish	6	13	55	--
Lepomis cyanellus	green sunfish	--	12	6	9
Lepomis machrochirus	bluegill	18	35	65	50
Lepomis megalotis	longear sunfish	2	5	2	1
Lepomis microlophus	redear sunfish	--	1	2	1
Micropterus salmoides	largemouth bass	9	16	55	100
Etheostoma spectabile	orangethroat darter	5	3	22	15

Table 4. Fish Regionalized Index of Biotic Integrity metrics and scores for Cedron Creek, Bosque County, Texas, May 2002.

Metric Category	Metric	Upstream SEINE DATA ONLY		Downstream	
		Raw value	Score	Raw value	Score
Species Richness and Composition	Species richness (score takes into account drainage basin size)	8	3	13	5
	Number of native cyprinid species	2	3	3	3
	Number of benthic invertivore species	1	3	2	5
	Number of sunfish species	3	3	5	5
	% individuals as tolerant species	8.6	5	15.5	5
Trophic Composition	% of individuals as omnivores	0	5	0.2	5
	% of Individuals as invertivores	26.2	1	46.2	3
	% of Individuals as piscivores	4.3	1	13.3	5
Fish Abundance and Condition	Number of individuals in sample (averages individual scores for number of individuals/ seine haul and number of individuals/ min electrofished)	210	1	457	3
	% of individuals as non-native species	2.9	1	12.0	1
	% of individuals with disease/ anomaly	0	5	0	5
	Index of Biotic Integrity Numeric Score		31		45
	Index of Biotic Integrity Aquatic Life Use Classification	Limited		High	

Aquatic Life Use Score Ranges: =49= Exceptional; 41-48= High;
35-40= Intermediate; < 35= Limited

Table 5. Fish Regionalized Index of Biotic Integrity metrics and scores for Cedron Creek, Bosque County, Texas, July 2002.

Metric Category	Metric	Upstream		Downstream	
		Raw value	Score	Raw value	Score
Species Richness and Composition	Species richness (score takes into account drainage basin size)	12	5	11	3
	Number of native cyprinid species	2	3	2	3
	Number of benthic invertivore species	1	3	2	5
	Number of sunfish species	5	5	4	5
	% individuals as tolerant species	22.6	5	7.8	5
Trophic Composition	% of individuals as omnivores	11.8	3	0.6	5
	% of Individuals as invertivores	40.1	3	25.0	1
	% of Individuals as piscivores	13.2	5	13.3	5
Fish Abundance and Condition	Number of individuals in sample (averages individual scores for number of individuals/ seine haul and number of individuals/ min electrofished)	212	3	820	4
	% of Individuals as Non-native species	6.1	1	0.6	5
	% of individuals with disease/ anomaly	0	5	0	5
	Index of Biotic Integrity Numeric Score		41		46
	Index of Biotic Integrity Aquatic Life Use Classification	High			High

Aquatic Life Use Score Ranges: =49= Exceptional; 41-48= High;
35-40= Intermediate; < 35= Limited

Table 6. Benthic macroinvertebrates collected in Cedron Creek, Bosque County,Texas, May and July 2002. Numbers are total for three riffles combined at each site.

Order	Family	Genus	May (surber)		July (kick)	
			Up	Down	Up	Down
Ephemeroptera	Baetidae	*Fallceon*	1096	1192	31	95
		Callibaetis	--	--	2	1
	Heptageniidae	*Stenonema*	1	11	2	1
	Tricorythidae	*Tricorythodes*	3	1	14	9
		Leptohyphes	--	1	--	--
	Leptophlebiidae	*Choroterpes*	40	32	3	25
	Caenidae	*Caenis*	--	1	--	--
Plecoptera	Perlidae	*Neoperla*	2	7	--	--
Trichoptera	Hydropsychidae	*Cheumatopsyche*	303	188	--	2
		Hydropsyche	1	--	--	--
	Helicopsychidae	*Helicopsyche*	30	30	3	2
	Hydroptilidae	*Ochrotrichia*	1	--	--	--
		Hydroptila	8	209	1	8
		Oxyethira	--	2	--	--
	Leptoceridae	*Nectopsyche*	4	1	4	1
		Oecetis	1	--	--	--
	Philopotamidae	*Chimarra*	4	7	--	2
	Odontoceridae	*Marilia*	4	--	--	1
Lepidoptera	Pyralidae		2	--	--	--
		Petrophila	9	2	--	--
Coleoptera	Elmidae	*Stenelmis*	6	4	--	--
	Hydrophilidae	*Berosus*	9	2	5	--
		Tropisternus	1	1	8	19
		Enochrus	--	--	12	4
		Hydrochus	--	--	--	1
	Haliplidae	*Peltodytes*	--	1	--	--
	Dytiscidae	*Uvarus*	1	1	8	4
Odonata	Coenagrionidae	*Argia*	6	2	19	38
	Calopterygidae	*Hetaerina*	2	--	3	--
	Libellulidae	*Brechmorhoga*	--	--	--	22
Hemiptera	Naucoridae	*Ambrysus pulchellus*	2	--	9	4
	Veliidae	*Microvelia*	--	2	6	2
		Rhagovelia	--	--	--	2
	Gerridae		--	1	--	--
		Trepobates	--	--	1	--
	Corixidae		1	--	--	--
	Hebridae	*Merragata*	--	--	--	1
Diptera	Chironomidae		1108	616	11	23
	Simuliidae	*Simulium*	23	32	--	1
	Athericidae	*Atherix*	--	--	--	1
	Tabanidae	*Tabanus*	--	--	5	4
	Stratiomyidae		1	2	--	--
		Euparyphus	--	2	1	1
		Stratiomys	--	--	2	--
Collembola			--	1	--	--
Amphipoda	Taltridae	*Hyalella azteca*	74	8	6	10
Limnophila	Physidae	*Physella*	389	110	3	5
	Lymnaeidae	*Fossaria*	57	3	--	--
	Planorbidae	*Gyraulus*	42	12	3	1

Order	Family	*Genus*	May (surber) Up	July (kick) Down	Up	Down
		Biomphalaria	--	--	1	--
		Helisoma	--	--	--	2
Hydracarina			2	16	--	3
Hirudinea		*Helobdella*	--	--	--	1
Turbellaria	Planariidae	*Dugesia*	15	4	57	47
Ostracoda			--	--	1	1
Oligochaeta			--	2	--	--

Table 7. Benthic macroinvertebrate metrics and scores (surber samples, B-IBI) for Cedron Creek, Bosque County, Texas, May 2002.

Metric	Upstream		Downstream	
	Value	Score (1-5)	Value	Score (1-5)
Total Taxa	32	3	34	5
Diptera Taxa	3	1	4	3
Ephemeroptera Taxa	4	3	6	5
Intolerant Taxa	11	5	11	5
% EPT Taxa	46	5	67	5
% Chironomidae	34	1	25	1
% Tolerant taxa	12	1	5	3
% Grazers	45	5	52	5
% Gatherers	30	5	38	5
% Filterers	10	1	9	1
% Dominance (3 taxa)	80	1	80	1
TOTAL SCORE		31		39
AQUATIC LIFE USE		High		High

Aquatic Life Use Point Score Ranges:

Exceptional: > 40
High: 31-40
Intermediate: 21-30
Limited: <21

Table 8. Benthic macroinvertebrate metrics and scores (kick samples, rapid bioassessment protocol) for Cedron Creek, Bosque County, Texas, July 2002.

Metric	Upstream		Downstream	
	Value	Score (1-4)	Value	Score (1-4)
Taxa richness	27	4	33	4
EPT Taxa Abundance (richness)	8	3	11	4
Biotic Index (HBI)	6.01	1	4.52	3
% Chironomidae	5	3	7	3
% Dominant taxon	27	3	28	3
% Dominant functional feeding group	55	1	42	3
% predators	55	1	42	1
Ratio of intolerant: tolerant taxa	0.55	1	0.94	1
% of total Trichoptera as Hydropsychidae	0	4	12.5	4
# of non-insect taxa	6	4	8	4
% collector-gatherers	27	3	28	3
% of total number as Elmidae	0	1	0	1
TOTAL SCORE		29		34
AQUATIC LIFE USE		High		High

Aquatic Life Use Point Score Ranges:

Exceptional: > 36
High: 29-36
Intermediate: 22-28
Limited: < 22