FINAL ASSESSMENT OF THE ECOLOGICAL INTEGRITY OF WOLF CREEK (LEAVENWORTH COUNTY, KANSAS)

Final report on the investigation of habitat, water quality, and biological conditions in Wolf Creek

by

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Introduction

Streams and rivers provide many important services to humans including irrigation, waste dilution, transportation, drinking water, fish for harvest and sport, power generation, and recreation (Cushing and Allan, 2001). These systems however, are continuously being disturbed and as a result few unaltered river segments remain in the United States (U.S. EPA, 1996). For example, the U.S. Environmental Protection Agency has reported that 36% of the rivers surveyed throughout the United States are impaired.

Agriculture is a major source of disturbance to streams within the midwestern United States (U.S. EPA, 1996; Smith, 2003). The application of fertilizers and manure to farmland has severely degraded the quality of water in rivers in agricultural regions by creating elevated nutrient loads. While all plants and animals need nutrients, mainly nitrogen and phosphorus, excess amounts can be detrimental to both humans and aquatic organisms (Smith, 2003). In addition, riparian forests that buffer streams from their surrounding watersheds are increasingly being altered or destroyed in order to maximize the amount of land available for agricultural cultivation. This removal or loss of riparian forest can result in a number of detrimental stream impacts including increases in temperature, nutrients, and channel widths, as well as reductions in instream habitat, increased soil erosion, and increased sedimentation (Allen, 1995).

Bioassessment studies incorporating both spatial and temporal data are often used to document stream disturbances (Barbour *et al*., 1999). In this study, the Kansas Biological Survey (KBS) conducted a biological assessment of the overall ecological integrity of Wolf Creek, located in Leavenworth County, Kansas. Three sites were selected along Wolf Creek and sampled for a variety of physical, chemical, and biological variables in the spring, summer, and fall of 2003. Data collected from Wolf Creek was then compared to similar data collected from streams located within three reference watersheds. The reference watersheds were previously determined to have high habitat, water quality, and biological conditions. Due to the increasingly strong presence of anthropogenic disturbances within the Wolf Creek watershed, this analysis was used to determine if Wolf Creek has deviated from reference conditions. In addition, it will help build a framework for future Leavenworth County watershed management plans and objectives.

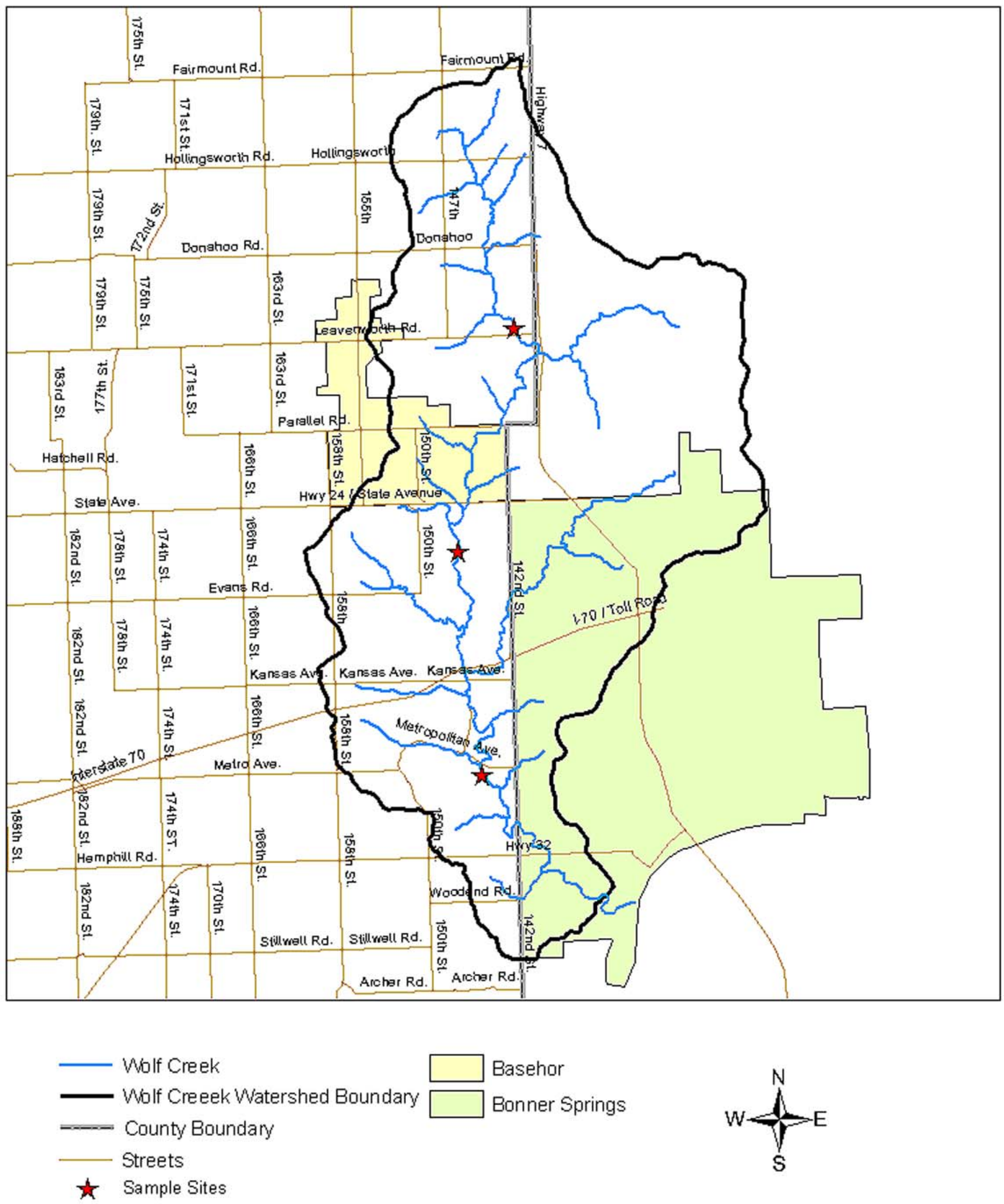
The KBS also re-assessed several sites along Stranger Creek, for which we previously conducted an ecological assessment in 2001 (Liechti and Dzialowski, 2001). Although fish habitat assessments were originally conducted at Stranger Creek, two of the three sites were directly below a bridge. Therefore, we re-sampled potential fish habitat outside the zone of influence of the bridges in order to obtain a more representative assessment of the habitat available at Stranger Creek.

Watershed Descriptions: *Wolf Creek and Reference Streams*

The Wolf Creek watershed is located in northeastern Kansas (Figure 1). The three reference watersheds that will be used in this study are located within the Western Corn Belt Plains (WCBP) ecoregion and they are roughly the same size as Wolf Creek and they have similar land use patterns: French (Nemaha County, KS), Straight (Jackson County, KS), and North Elm (Marshall County, KS). These watersheds were chosen based on a 1992-1994 KBS study that indicated that they generally had higher habitat and

Figure 1

Wolf Creek Watershed



water quality, and biological conditions than the streams of 14 other watersheds examined within the same ecoregion. The use of regional reference condition in biomonitoring provides an effective framework for assessing and detecting impairment (Hughes *et al*., 1986; Barbour *et al*., 1999)

Data Analysis: *Wolf Creek and Reference Streams*

In order to compare the physical, biological, and chemical conditions of the Wolf Creek and the reference watersheds, we graphed the data as box plots. The comparison of two or more populations using box plots is commonly used in bioassessement studies (e.g. Karr *et al*., 1986; Barbour *et al*., 1999). The horizontal line that divides the box into two parts is the median value. The upper part of the box represents the 75th percentile of the data set and the lower part of the box represents the 25th percentile of the data. The total height of the box therefore represents 50% of the data set, or the interquartile range (IQR). The whiskers that extend out from the box represent the 5th and 95th percentile of the data, and additional data points outside of the whiskers represent outliers.

Stream measurements from the three reference watersheds were combined and the resulting box plot was used as a benchmark of "good" or healthy conditions for each metric. The median line from the Wolf Creek data was then compared to the IQR values obtained from the reference watersheds in order to determine if differences exist between Wolf Creek and the reference watersheds. If the median line of a particular variable fell within the IQR of the reference watersheds, then the two streams were considered similar for that particular variable. However, if the median value of a variable collected at Wolf Creek fell outside of the IQR of the reference watersheds, this suggested that for that particular variable there were potentially significant differences between Wolf Creek and the reference watersheds.

Sampling of the streams within the three reference watersheds was conducted using methodology consistent with the sampling of Wolf Creek. Each watershed contained five stream sites that were sampled in the spring, summer, and fall of 1992, 1993, and 1994. Therefore, each reference stream was sampled 9 times. Efforts were made to temporally standardize the data sets between Wolf Creek and the reference watersheds in order to provide a suitable framework for comparison. For example, winter data collected from the reference streams was not included in our analysis because we did not collect winter data from Wolf Creek.

There were some differences between Wolf Creek and the reference streams with respect to the number of samples used to construct the box plots. For example, we combined all of the data from the three Wolf Creek sites to construct box plots and therefore each box was based on 9 habitat variables and 27 water quality variables. In comparison, the box plots constructed for the reference watersheds were based on a much greater number of samples (15 streams sampled 9 times each). With respect to biotic samples (macroinvertebrate and fish) we tried to standardize the number of samples because increased sampling effort usually increases the number of species found. Therefore we only used biotic data collected from the 15 reference streams from one year (spring, summer, and fall), which corresponds to the same level of sampling effort used for Wolf Creek.

We also plotted the data from each of the three Wolf Creek sites separately in order to determine if there were differences between sites. There were only three data points for some of the habitat variables however, and in these instances the results should be interpreted with caution. Finally, we plotted data collected from Stranger Creek in our initial analysis conducted in 2001 using similar methodology (Liechti and Dzialowski, 2002) to see if differences exist between Wolf and Stranger Creek's.

Sampling: Wolf Creek

Three sites were selected for analysis on Wolf Creek (Figure 1). Caution was taken when selecting these sites so that they were out of the influence of bridges. Each site was sampled during three individual sampling events one each in the spring (6 June), the summer (22 July) and the fall (9 October) of 2003.

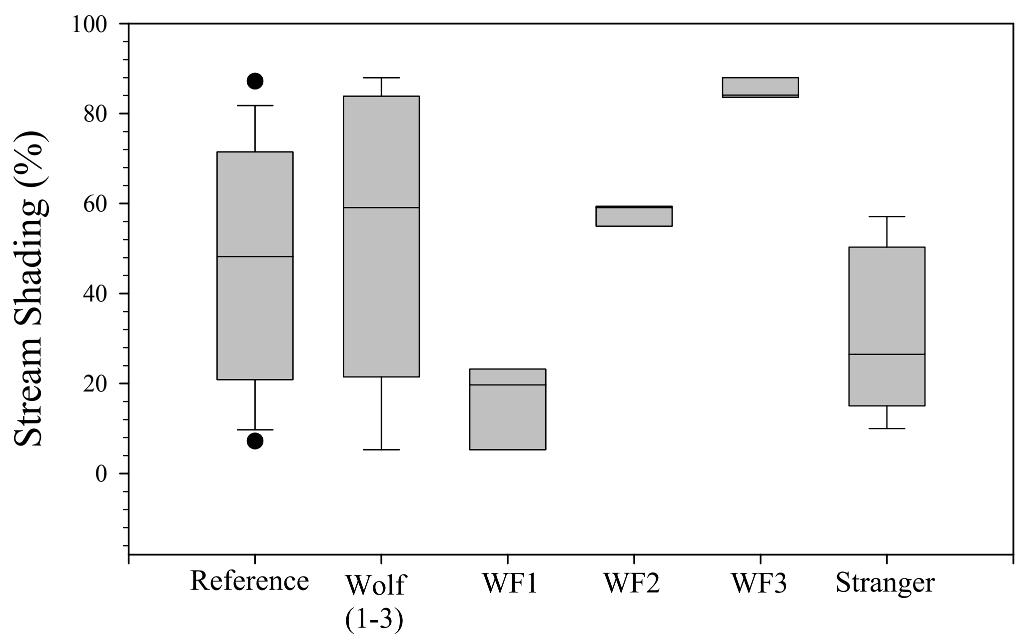
At each site a 50 m segment of stream was divided into three sections (upper, middle, and lower), each of which represented a distinct macrohabitat (run, riffle, or pool) when available. All three of these macrohabitats were present at each site during the first sampling event. However, on subsequent sampling events they were not always preset, and the available habitat was sampled. The physical, biological, and ecological conditions of Wolf Creek were then assessed using methodology from Platts *et al.*, (1987) and Barbour *et al*., (1999).

Wolf Creek Results - *Habitat Measurements*

Stream habitat is directly related to the biotic health of a system and as a result is often an important predictor of disturbance (Allan, 1995). In order to assess the habitat conditions at Wolf Creek, we measured a variety of near-stream and instream variables at each site. One of the most important near-stream variables is the riparian forest, which provides an effective buffer between streams and their catchments (Kalff, 2002). The alteration of riparian forest often results from agricultural activity where forests are cut to the river or stream edge in order to maximize the amount of land available for cultivation (Kalff, 2002). The overall riparian forest at each Wolf Creek site was assessed based on several variables including stream shading, riparian width, and riparian condition.

We estimated the percent stream shading from the canopy cover at each site along five transects using a concave, spherical densiometer. The median Wolf Creek values for stream shading (59.1%) fell within the reference IQR range (20.88 – 71.47%). There were site differences at Wolf Creek, however (Figure 2). For example, the median percent stream shading value at site 1 (19.7%) was just at the lower end of the reference

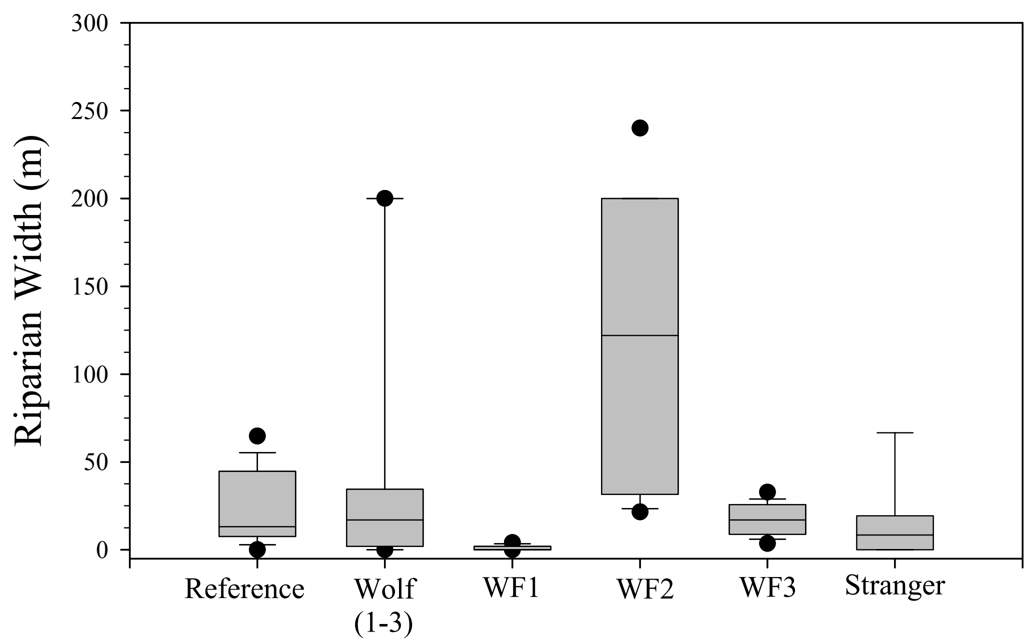
Figure 2. Box plots comparing stream shading (%) at Wolf Creek (all three sites combined) and reference streams. Data was also plotted from each Wolf Creek site separately in order to make comparisons between the three sites, and from Stanger Creek.



IQR, and the median value for site 3 (84.1%) was greater than the reference IQR. In addition, the median percent stream shading value for Wolf Creek was greater than the IQR for Stranger Creek (15.05 – 50.3%).

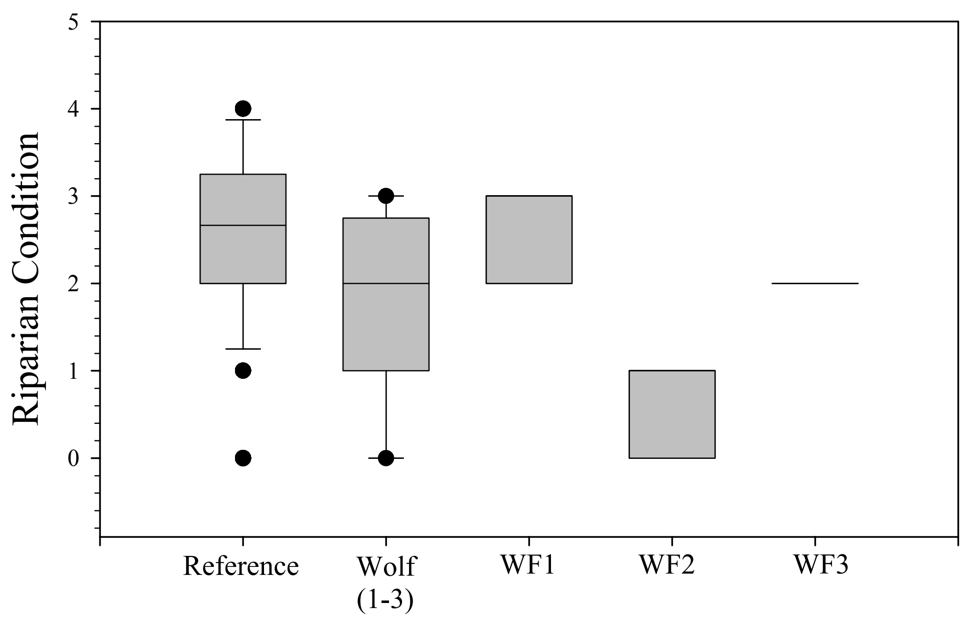
The riparian width was measured at each site at five transects along the bank of each stream segment. Based on these measurements, we found that the median riparian width (Figure 3) at Wolf Creek (17.05 m) was within the reference IQR range for riparian widths (7.60 – 44.65 m). In addition, the median riparian width at site 2 (122 m) was significantly greater than reference conditions (Figure 3). There were differences between the three Wolf Creek sites however, suggesting that there has been some loss of riparian habitat at Wolf Creek. For example, the riparian zone at site 1 has been significantly altered and is less than reference conditions.

Figure 3. Box plots comparing riparian width (m) of Wolf Creek (all three sites combined) and reference streams. Data was also plotted from each Wolf Creek site separately in order to make comparisons between the three sites, and from Stanger Creek.



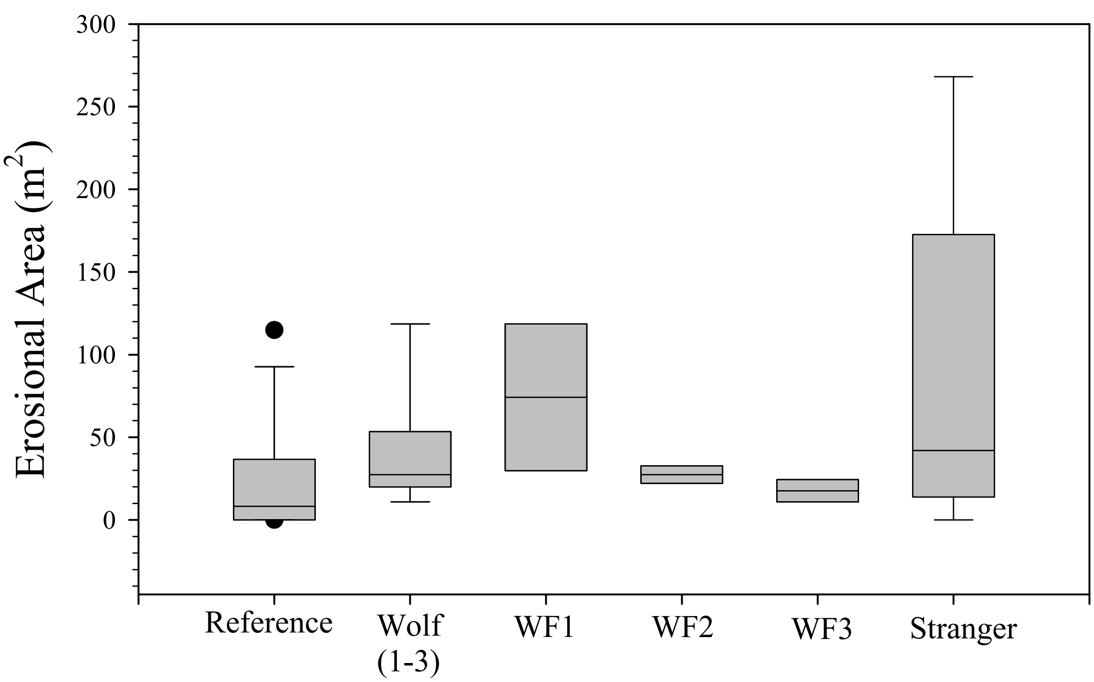
The final measure of the health of the riparian forest that was collected was the riparian condition. Riparian condition values are based on the density of the canopy and the diversity of vegetation and range from 0 to 4, with 0 representing a healthy system and 4 representing a poor system. The median riparian condition value at Wolf Creek (2) was within, and almost lower (indicating a better score) than the reference riparian condition IQR (2.00 - 3.25) (Figure 4). As with all measurements of the riparian forest, there were site-specific differences. For example, the median riparian condition at site 2 was actually better than at the reference streams.

Figure 4. Box plots comparing the riparian condition of Wolf Creek (all three sites combined) and reference streams. Data was also plotted from each Wolf Creek site separately in order to make comparisons between the three sites (no data from Stanger Creek was included in this analysis).



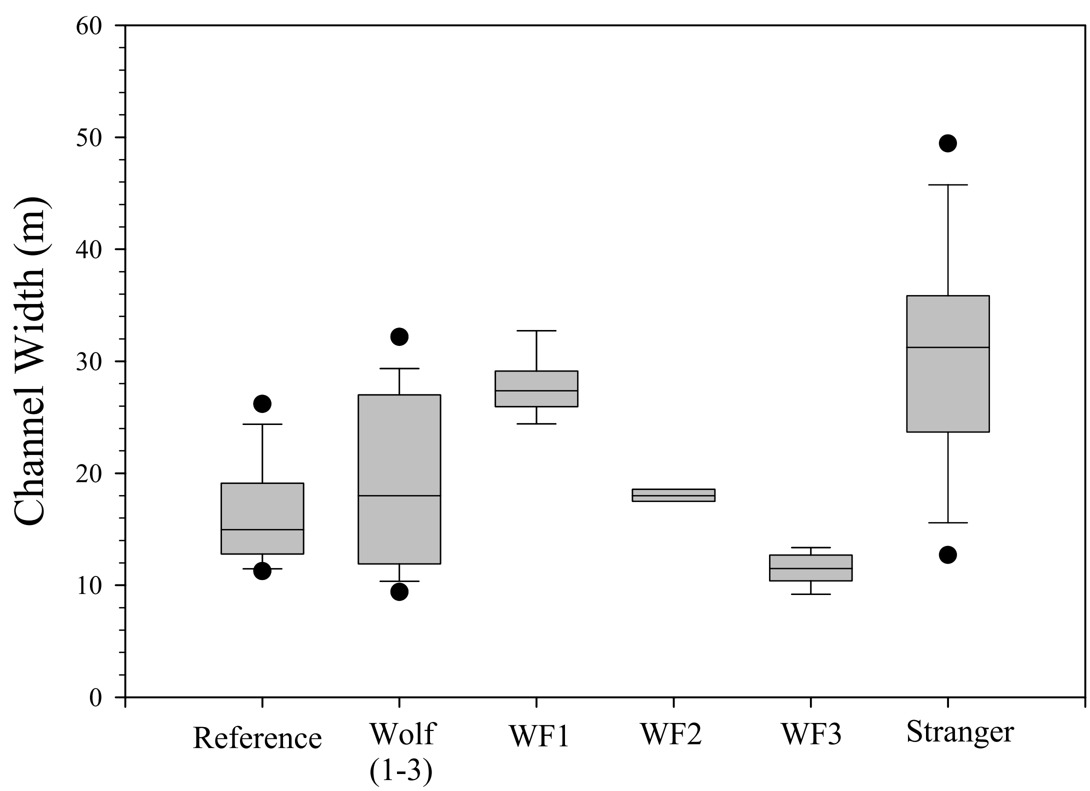
To determine if there were differences in erosion between Wolf Creek and reference streams, we measured the length and average height of all areas of active bank erosion and calculated the total area of bank erosion at each site. Based on this analysis, we found that the amount of active erosion at Wolf Creek was similar to the amount of active erosion at the reference streams (Figure 5). The median value for erosion area at Wolf Creek was 27.4 m^2 compared to the IQR range for reference streams that was 0 – 36.75 m^2. Similar to other habitat measures however, the median active erosion value for site 1 (74.2 m^2) was significantly higher than the reference IQR. Stream bank erosion can lead to direct soil loss, and a resulting increase in turbidity.

Figure 5. Box plots comparing erosion at Wolf Creek (all three sites combined) and reference streams. Data was also plotted from each Wolf Creek site separately in order to make comparisons between the three sites, and from Stranger Creek.



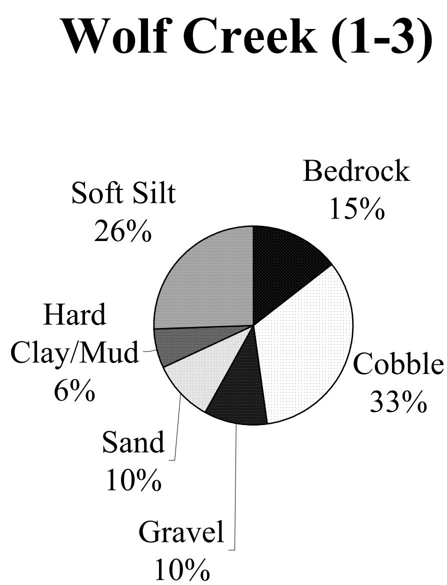
Channel widths were measured at five transects at each site. Overall, the median channel width from the three Wolf Creek sites (18.0 m) was within the reference IQR for channel widths (12.8 – 19.1 m). However, the median channel width at site 1 (27.4 m) was significantly larger than the reference IQR, and was similar to the channel widths observed at Stranger Creek in 2001 (Figure 6). Increased channel widths likely result from reductions in riparian habitat quality and quantity (see Figure 3).

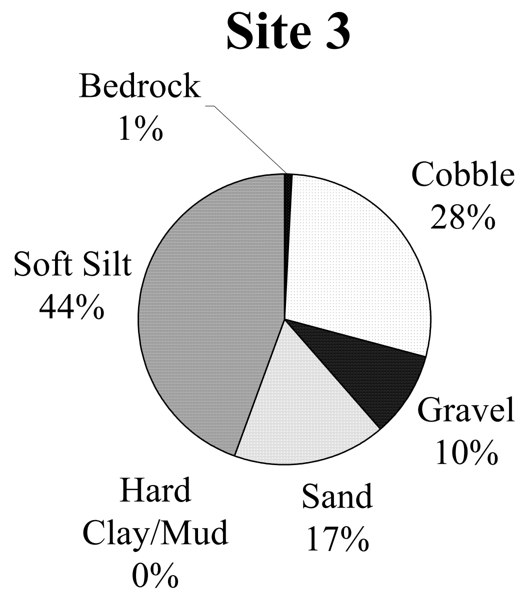
Figure 6. Box plots comparing erosion at Wolf Creek (all three sites combined) and reference streams. Data was also plotted from each Wolf Creek site separately in order to make comparisons between the three sites, and from Stranger Creek.

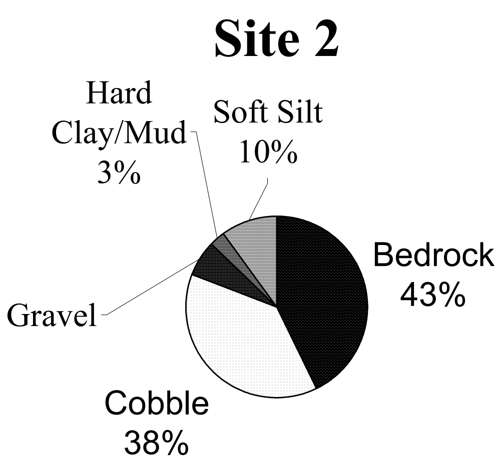


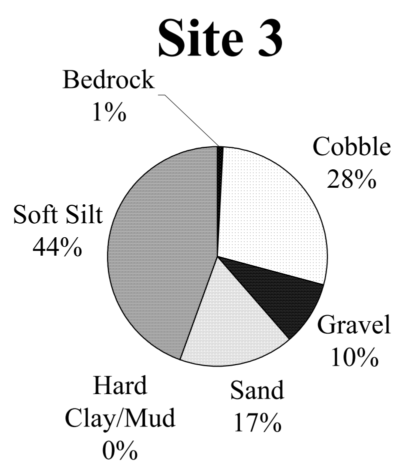
Inorganic substrate values (% cover) were recorded at each site to determine if there were differences in the substrate heterogeneity between Wolf Creek and the reference streams. Transects were established along each available macrohabitat, and the type of substrate that was present at 30 points within the section were measured. The overall inorganic substrate composition at all Wolf Creek sites combined was very diverse compared to that of the reference streams (Figure 7). The major substrate types present at Wolf Creek include cobble (33%), sand (10%), soft silt (26%), bedrock (15%), gravel (11%) (Figure 7). In addition, there was little difference between the three Wolf Creek sites as each was dominated by cobble. A major difference in the substrate between the three sites was the presence of a large amount of bedrock at site 2 (42%). In contrast, a single substrate type dominated the reference streams. Straight and French were dominated by sand (66.6% and 63.0% respectively) and North Elm was dominated by cobble (58.8%). Therefore, Wolf Creek has a more diverse inorganic substrate then the reference streams, which is directly related to biotic diversity (Allen, 1995).

Figure 7. Percent stream bottom cover for inorganic substrate occurring at Wolf Creek (all three sites combined). Data was also plotted from each Wolf Creek site separately in order to make comparisons between the three sites.









Water Quality:

In order to assess the water quality at Wolf Creek, a total of three grab samples were collected from each site (upper, middle, and lower) on each sampling date. The samples were taken back to the Ecotoxicology Laboratory at the KBS where they were analyzed for total phosphorus and nitrogen, alkalinity, hardness, chemical oxygen demand, fecal coliform concentrations, and atrazine a pesticide that is commonly used in this ecoregion. During each sample event we also used an Horiba H_20 multi-probe water quality analyzer to record *in situ* measurements of pH, turbidity (NTU), conductivity (uohms), and dissolved oxygen (mg/l) at each site.

pH data collected at Wolf Creek shows that there was no difference between Wolf Creek and the reference streams. For example, the median pH value at Wolf Creek was 7.77, which was within the pH IQR range for the reference streams (7.64 – 8.19) (Figure 8). Median pH values were lower at site 1 although only slightly (7.64). These median values are all within the Kansas surface water criteria for maintenance of aquatic life (6.50 - 8.50) suggesting that Wolf Creek has not experienced degradation with respect to pH. This was in contrast to our initial study of Stranger Creek, in which we found that median pH values (8.34) collected from Stranger Creek were higher than reference streams and near the upper limits of the Kansas surface water criteria.

Turbidity values were higher in Wolf Creek than in reference streams (Figure 9). The overall Wolf Creek median turbidity value (82 NTU), as well as the median turbidity values for two of the three sites were greater than the reference IQR (7 – 50 NTU). Site 1 was the only site that had turbidity values similar to reference condition. The median turbidity value for all Wolf Creek sites combined was also very similar to the median

Figure 8. Box plots comparing pH at Wolf Creek (all three sites combined) and reference streams. Data was also plotted from each Wolf Creek site separately in order to make comparisons between the three sites, and for Stranger Creek.

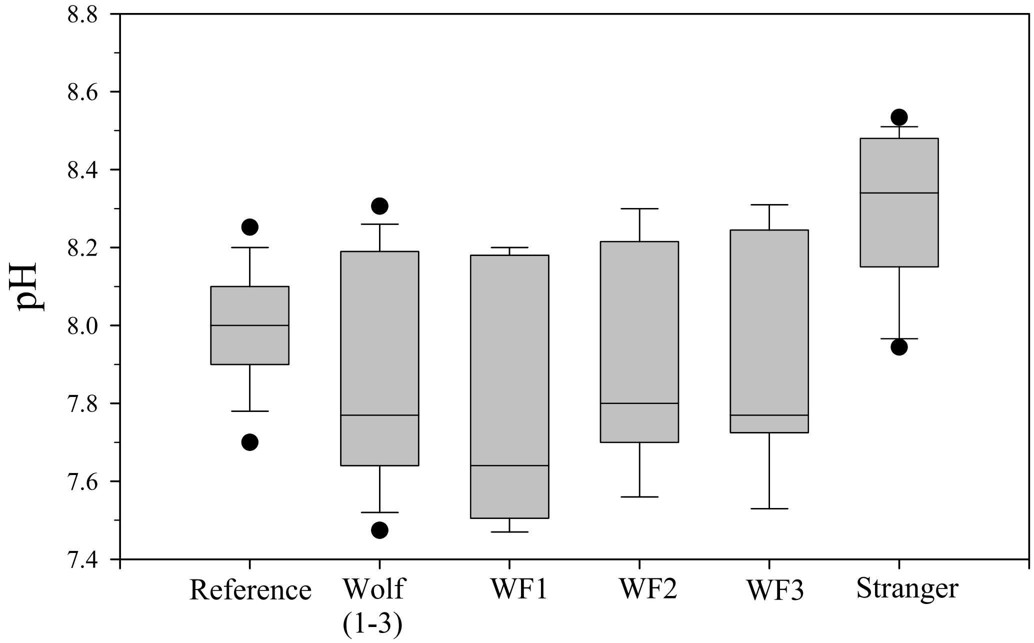
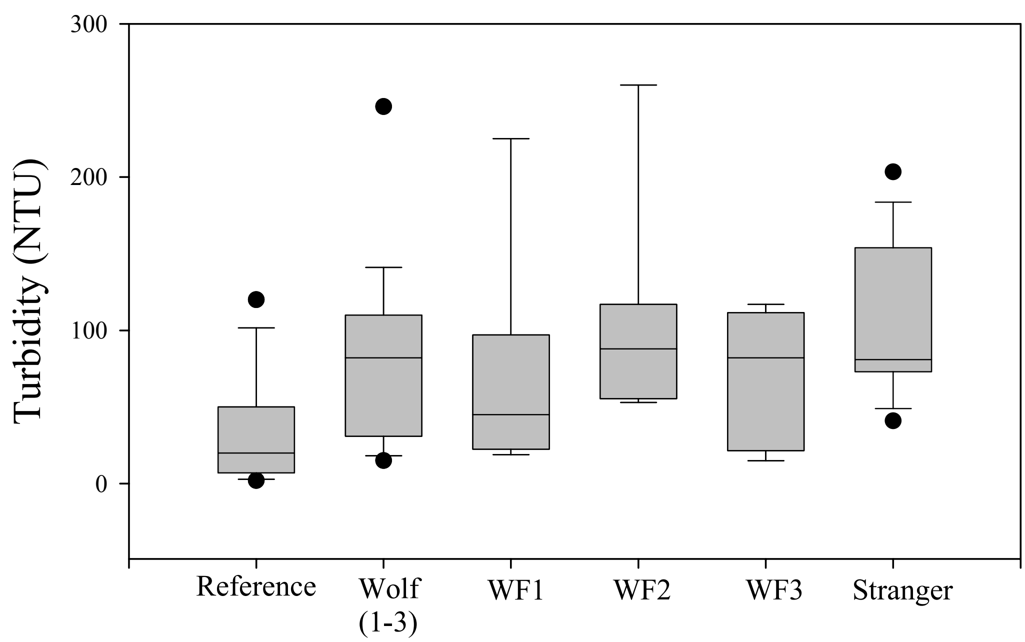


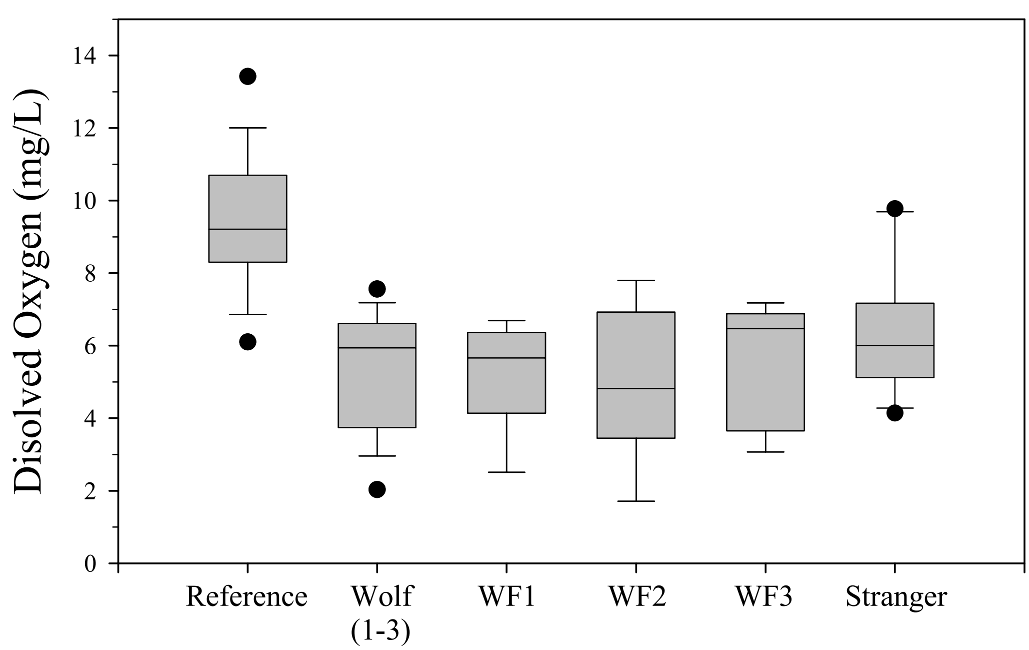
Figure 9. Box plots comparing turbidity at Wolf Creek (all three sites combined) and reference streams. Data was also plotted from each Wolf Creek site separately in order to make comparisons between the three sites, and from Stanger Creek.



turbidity value collected from Stranger Creek (81 NTU) in our initial analysis. The Kansas surface water quality standards for turbidity suggest that increased suspended solid levels shall not impair the behavior, reproduction, physical habitat or any other factors related to any organism utilizing surface water systems. Elevated turbidity likely results from increases in sediment load from the watershed or high rates of stream bed and bank erosion, and can lead to shifts in the species composition of stream biota (Allan, 1995).

Similar to turbidity, dissolved oxygen (DO) concentrations were lower in Wolf Creek than in reference streams (Figure 10). The IQR for DO in reference streams was 8.30 mg/L to 10.7 mg/L. The Wolf Creek median value was 5.66 mg/L, which was below the reference IQR. Dissolved oxygen levels were the lowest at site 1, where the

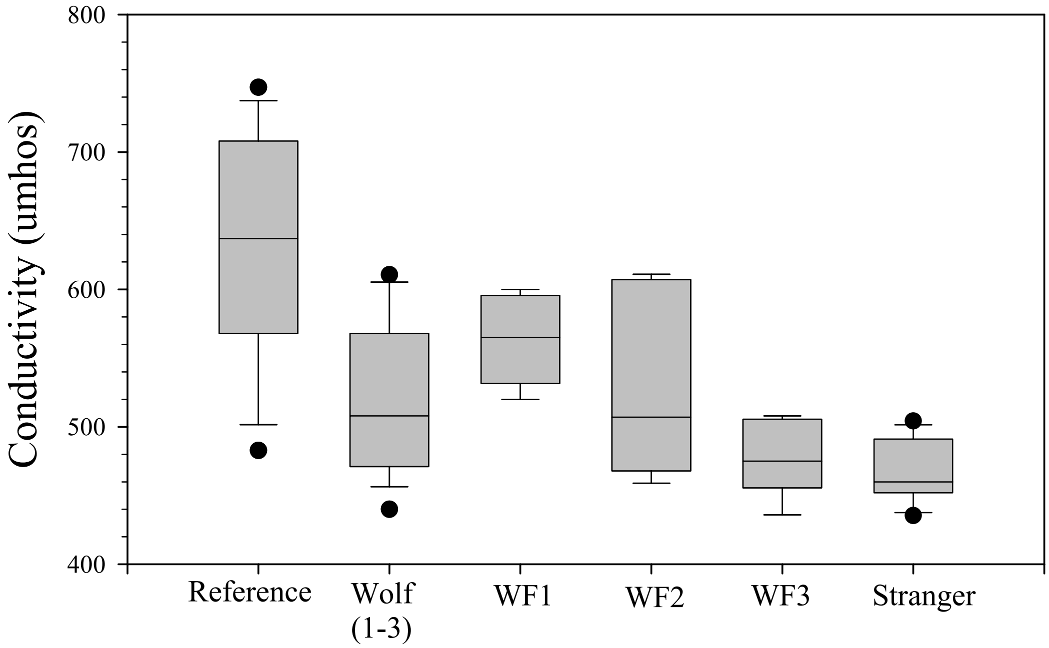
Figure 10. Box plots comparing dissolved oxygen (mg/L) at Wolf Creek (all three sites combined) and reference streams. Data was also plotted from each Wolf Creek site separately in order to make comparisons between the three sites, and from Stanger Creek.



median concentration (4.82 mg/L) was slightly below the Kansas surface water standard, which is set at 5.0 mg/L. The observed low DO levels in Wolf Creek may be the result of low primary productivity resulting from increased turbidity values (Figure 9). In addition, low DO levels may be the result of increased decomposition due to high inputs of organic matter from the watershed. However, these low values may have resulted from the presence of isolated pools at Wolf Creek due to periods of low flow observed throughout the study. These pools experience a high level of decomposition, but are not refreshed with oxygenated water from upstream. While it is difficult to determine the actual causes of the observed low DO values at Wolf Creek, the recorded values were below reference values and near the lower limit of the Kansas surface water standards. Therefore, more intense sampling and monitoring may be necessary to determine how degraded Wolf Creek has become with respect to DO concentrations, and the causes for this degradation.

The median conductivity value for all Wolf Creek sites combined (508 uohms) fell below the IQR for reference streams (Figure 11). This was true for all of the Wolf Creek sites. In our initial analysis of Stranger Creek, we found that conductivities values were similarly high compared to reference conditions. Conductivity is influenced by a number of natural factors including the surrounding geology, precipitation, and decomposition. While the values for Wolf Creek are below reference values, they are not unreasonably low and are likely not the result of pollution. Conductivity is an approximate predictor of total ion concentrations, and ion concentrations often increase, not decrease as seen in our study, in response to pollution and disturbance (Allen, 1995).

Figure 11. Box plots comparing conductivity (uohms) at Wolf Creek (all three sites combined) and reference streams. Data was also plotted from each Wolf Creek site separately in order to make comparisons between the three sites, and from Stranger Creek.



Alkalinity concentrations in Wolf Creek were lower than in the reference streams (Figure 12). The IQR for the reference streams was 194 – 250 mg/L as $CaCO_3$ and the median value from all of the Wolf Creek sites combined was 162 mg/L. Similarly, Alkalinity was higher in our 2002 analysis of Stranger Creek (IQR = 188 – 210) than in Wolf Creek. Alkalinity is a measure of the acid-neutralizing capacity of water, and is greatly influenced by the surrounding geology. Streams located in this area are naturally buffered due to high levels of bicarbonate within the surface geology, and similar to pH, these differences do not likely reflect disturbance or degradation.

In contrast to alkalinity values, there were no differences between Wolf Creek and reference streams with respect to hardness (Figure 13). The median value for all Wolf

Figure 12. Box plots comparing alkalinity (mg/L) at Wolf Creek (all three sites combined) and reference streams. Data was also plotted from each Wolf Creek site separately in order to make comparisons between the three sites, and from Stanger Creek.

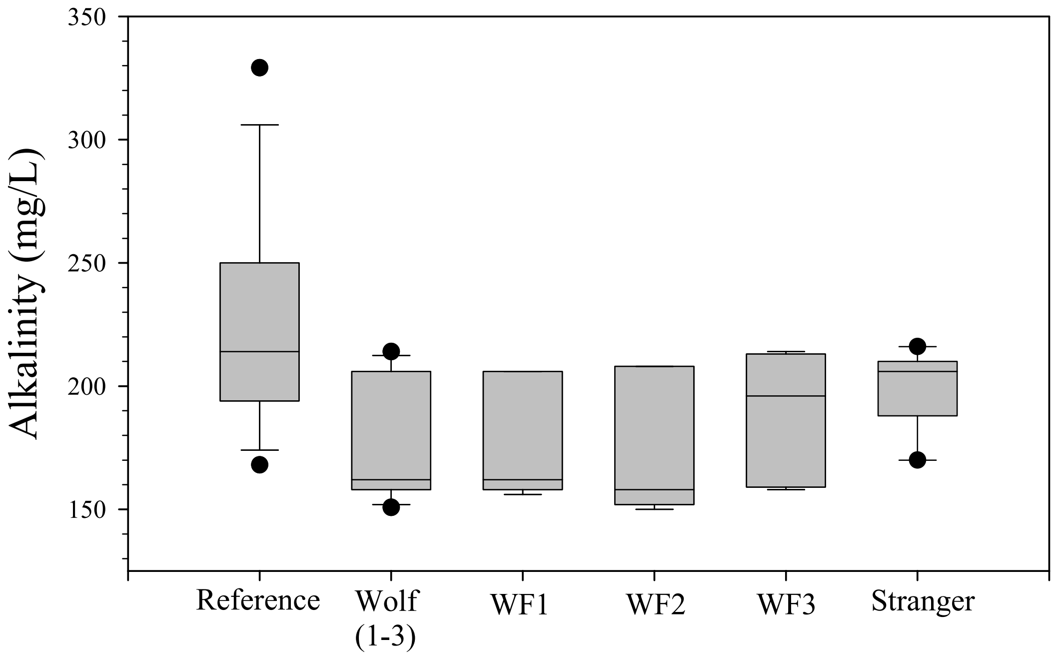
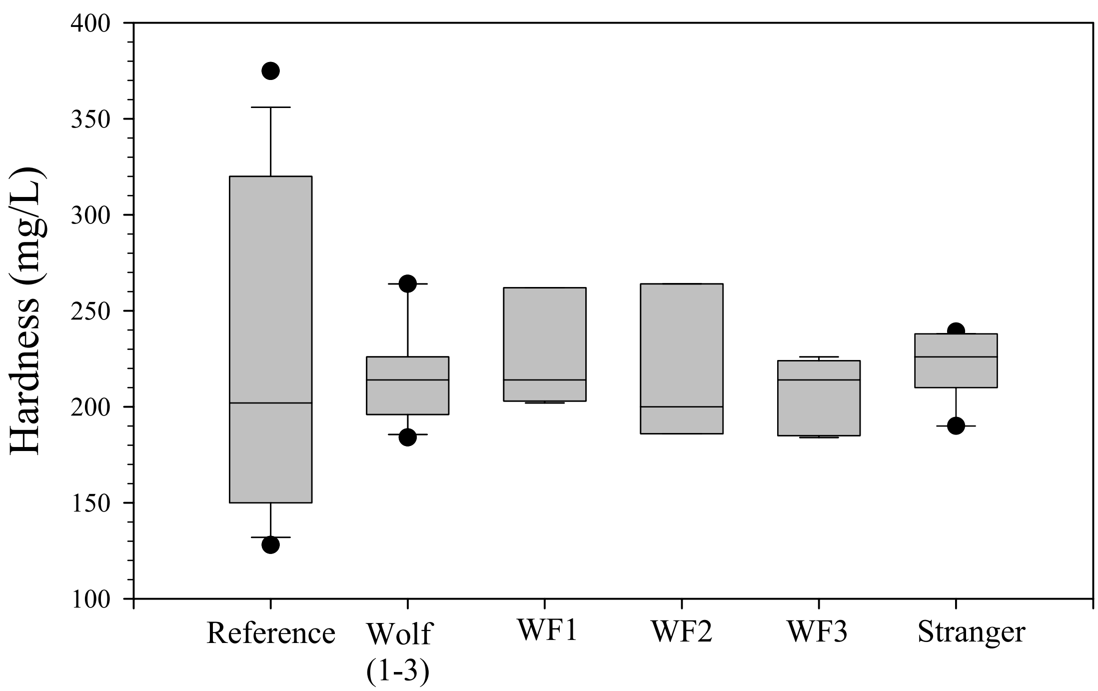


Figure 13. Box plots comparing hardness (mg/L) at Wolf Creek (all three sites combined) and reference streams. Data was also plotted from each Wolf Creek site separately in order to make comparisons between the three sites, and for Stanger Creek.



Creek sites combined (214 mg/L) fell within the IQR from reference streams (150 – 320 mg/L). Hardness is primarily a measure of the amount of calcium and magnesium salts within the water (Allen, 1995) and as with alkalinity is highly influenced by the surrounding geology.

Total nitrogen and phosphorus levels were lower in Wolf Creek than in reference streams. For example, the total nitrogen IQR for reference conditions was 1.34 mg/L – 4.44 mg/L compared to a median of 0.87 mg/L for all Wolf Creek sites combined (Figure14). Similarly, the median total phosphorus value for Wolf Creek (0.189 mg/L) was within the IQR (0.132 – 0.20 mg/L) for the reference streams (Figure 15). The total phosphorus values for Wolf Creek were also lower than the total phosphorus values for Stranger Creek collected in 2001.

Figure 14. Box plots comparing total nitrogen (mg/L) at WolfCreek (all three sites combined) and reference streams. Data was also plotted from each WolfCreek site separately in order to make comparisons between the three sites, and from Stanger Creek.

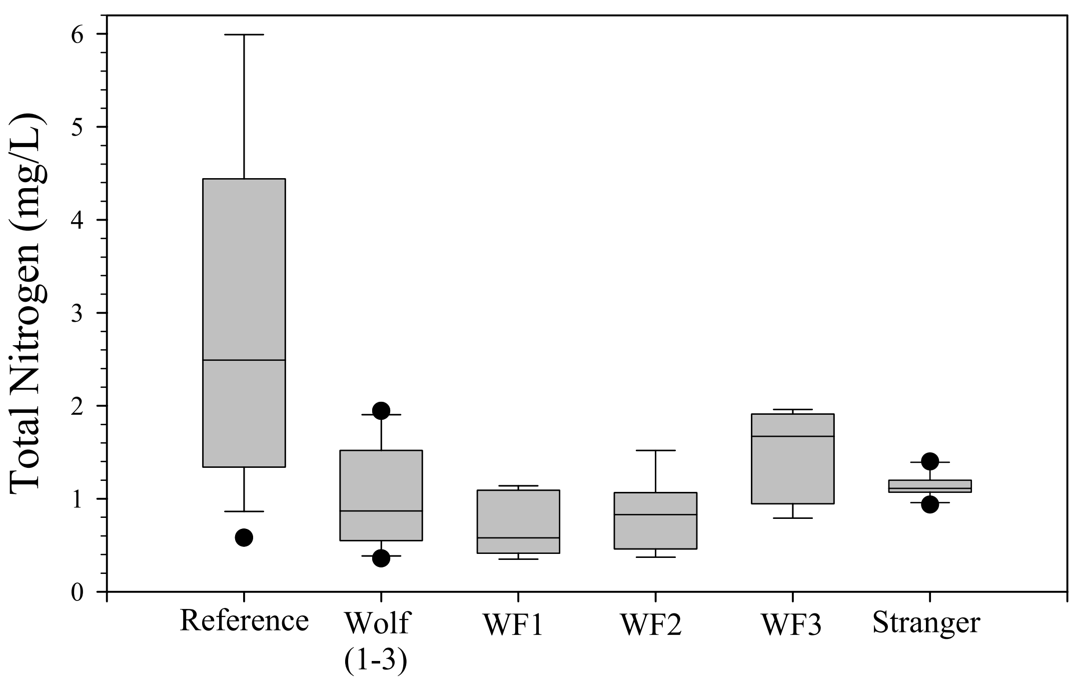
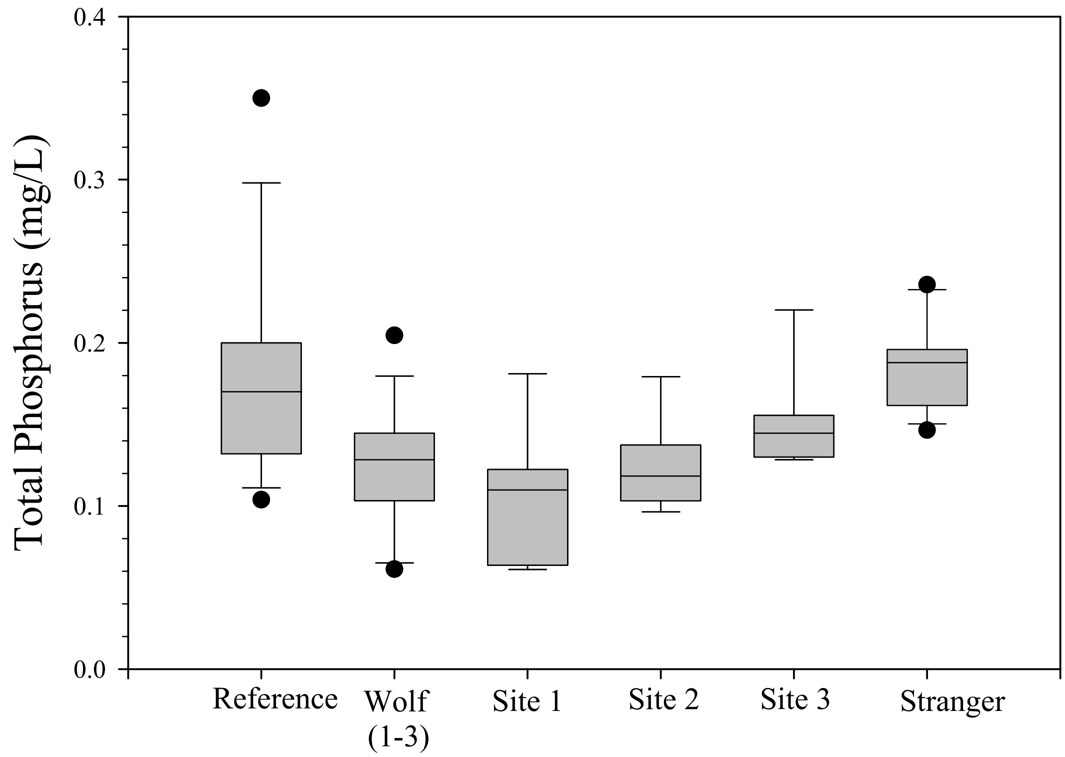


Figure 15. Box plots comparing total phosphorus (mg/L) at WolfCreek (all three sites combined) and reference streams. Data was also plotted from each WolfCreek site separately in order to make comparisons between the three sites, and from Stanger Creek.



The narrative Kansas surface water criteria for the support of aquatic life indicates that nutrient introductions shall not hamper present aquatic life nor cause the acceleration of undesirable aquatic organisms. While it is impossible to make this determination from the data collected in this study, total nitrogen and phosphorus values for Wolf Creek were lower than reference conditions. Therefore, it does not appear as though excess nutrient loads from its watershed are negatively affecting Wolf Creek.

The chemical oxygen demand (COD) at Wolf Creek was higher than at the references streams (Figure 16). For example, the median value of all of the Wolf Creek sites combined was 13.9 mg/L, which is greater than the IQR for the reference streams

(2.5 - 10.48 mg/L). This data suggest that Wolf Creek receives a large amount of organic enrichment. While this is in contrast to the low total nitrogen and total phosphorus levels observed in Wolf Creek, it may result in part from the low flow that was observed at Wolf Creek throughout the study, which resulted in the presence of isolated pools.

Atrazine is one of the most commonly used pesticides in the mid-western United States and can have detrimental effects on aquatic communities (deNoyelles *et al*., 1982). Atrazine levels at all three Wolf Creek sites combined were within the IQR for the reference streams (Figure 17). However, when looking at the three Wolf Creek sites separately it is apparent that site 2 experienced high levels of this pesticide. For example, the median atrazine value at site 2 was 1.95 ug/L which was above the IQR range of

Figure 16. Box plots comparing chemical oxygen demand (mg/L) at Wolf Creek (all three sites combined) and reference streams. Data was also plotted from each Wolf Creek site separately in order to make comparisons between the three sites, and from Stanger Creek.

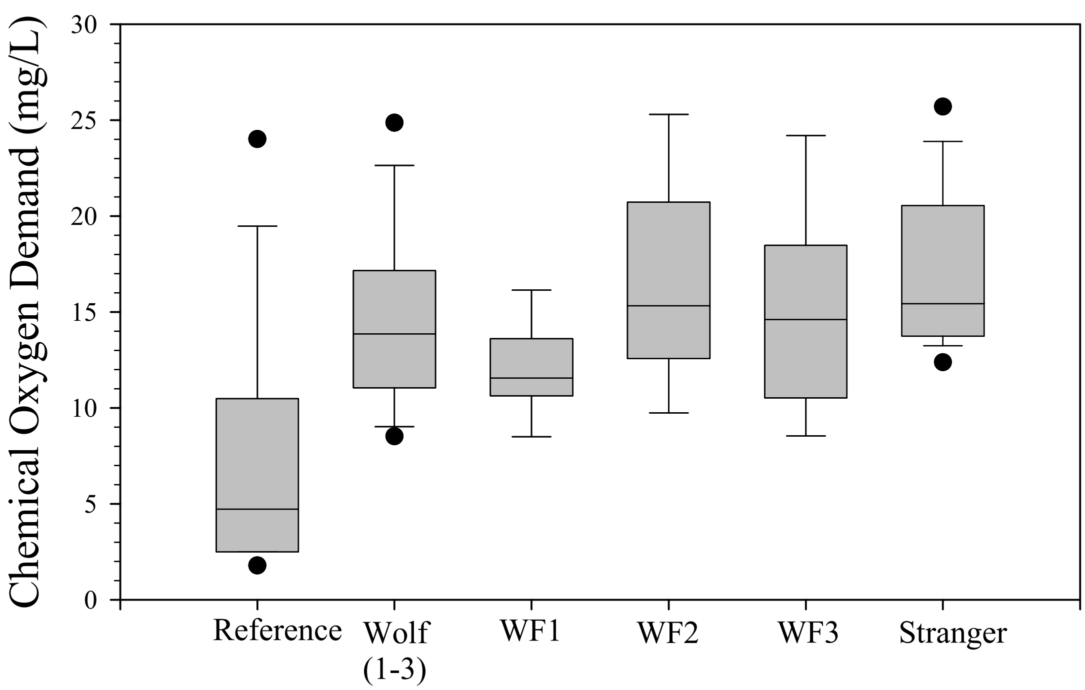
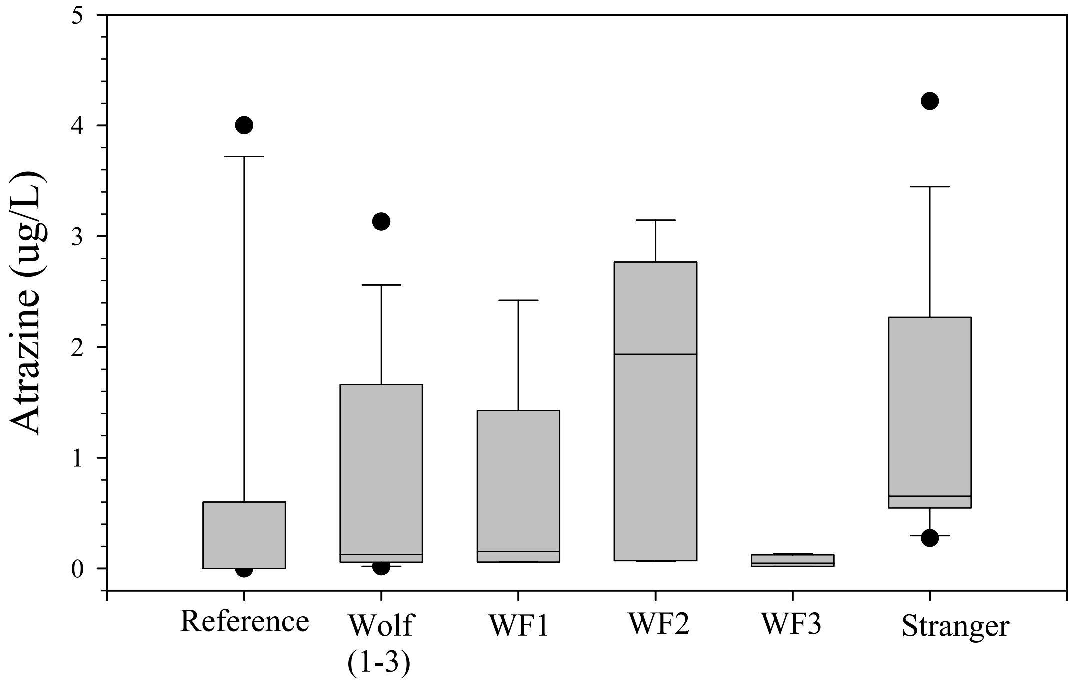


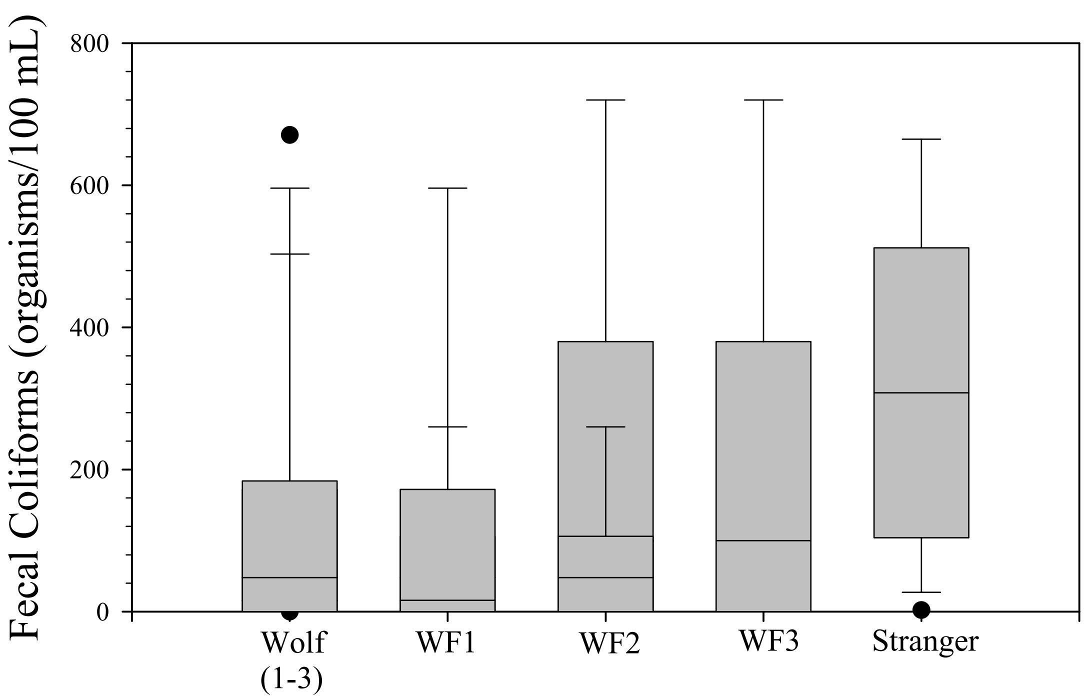
Figure 17. Box plots comparing atrazine (ug/L) at WolfCreek (all three sites combined) and reference streams. Data was also plotted from each Wolf Creek site separately in order to make comparisons between the three sites, and from Stanger Creek.



atrazine values from the reference streams (0 – 0.60 ug/L). It should be noted though, that elevated atrazine concentrations are common in Kansas during the spring (Trombley, 2001). In addition, the median values for all of the sites sampled were below the maximum allowable contamination level of 3.0 ug/L (Kansas Department of Health and Environment, 1994).

We also measured fecal coliform concentrations at each Wolf Creek site, although no comparisons were made with reference streams because similar data was unavailable. The Median fecal coliform concentration for all three Wolf Creek sites was 48 organisms per 100 mL (Figure 18). Kansas surface water criteria suggest that fecal coliform concentrations in Kansas surface water cannot exceed a geometric mean of 200 organisms per 100 mL of water for primary contact purposes. We were unable to calculate the geometric mean based on the limited number of available samples, however the median value from all sites combined did not exceeded this criteria suggesting that Wolf Creek does not have unusually high fecal coliform concentrations. When looking at each independently, site 3 had the highest median fecal coliform concentrations (100 organisms per 100 mL). In addition, fecal coliform concentrations were considerably lower in Wolf Creek than in Stranger Creek based on data from our earlier analysis. For example, the median fecal coliform concentration at Stranger Creek was 308 organisms per 100 mL.

Figure 18. Box plots comparing fecal coliform bacteria (org./100 mL) at Wolf Creek (all three sites combined) and from Stranger Creek. Data was also plotted from each WolfCreek site separately in order to make comparisons between the three sites.



Biota:

Three primary biological variables were measured at each site: periphyton, macroinvertebrates, and fish. Each of these variables is a valuable indicator of water quality (Barbour *et al*., 1999).

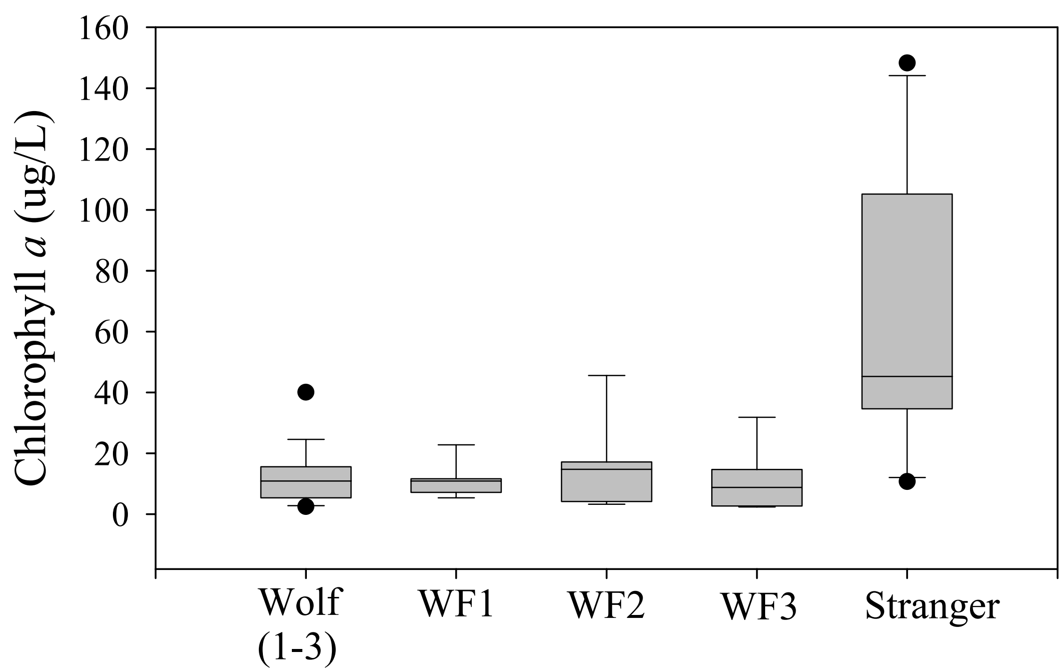
Periphyton:

Benthic algae, or periphyton, is the most important source of primary production in streams. Algal communities are strongly affected by nutrient enrichment and disturbance, and therefore are a valuable indicator of ecosystem health (Barbour *et al*., 1999). Periphyton samples were collected in triplicate from the dominant substrate type at each habitat. The substrate was isolated with a gasketed sampling tube and agitated with a brush. The dislodged material was removed by aspirating into a 40 ml collection vial. The samples were then returned to the Ecotoxicology Laboratory where concentrations of chlorophyll *a* and pheophytin *a*, two photosynthetic plant pigments, were determined fluorometrically. Periphyton was not compared to reference streams due to differences in sampling methodology. However, we did compare the three Wolf Creek sites with data collected from Stranger Creek in 2001, in order to determine if differences existed in concentrations between Wolf and Stranger Creeks.

Chlorophyll *a* concentrations did not differ significantly between the three Wolf Creek sites, and the lowest median was found at site 3 (8.78 ug/L) (Figure 19). Similar results were obtained with respect to Pheophytin *a* concentrations (data not shown). These results are in sharp contrast to the chlorophyll *a* concentrations observed at Stranger Creek in 2001. For example, the median chlorophyll *a* concentration at Stranger

Creek was 45.3 ug/L. In addition the IQR range of chlorophyll *a* values in Stranger Creek was 34.0 – 105.2 ug/L. These results suggest that nutrient enrichment has a greater impact on Stranger Creek than Wolf Creek, a finding that further supports the nutrient data (Figures 14, 15).

Figure 19. Box plots comparing chlorophyll *a* (ug/L) concentrations from the three Wolf Creek sites and Stanger Creek.



***Fish Community**:*

Samples were collected from each site for analysis of community structure. Representative portions of the available macrohabitats were individually blocked off and sampled first with seines and then electrofished with a backpack shocker. Fish samples were preserved in formalin and returned to the laboratory where they were transferred to 80% ethanol and identified to species.

We made comparisons between Wolf Creek and the reference sites; however, the results from these comparisons should be interpreted with caution since differences in stream flow and drainage basin size can affect species richness and community composition (e.g. Karr *et al*., 1986; Miller *et al*., 1988; EPA, 1996). In order to provide an assessment of the fish community at Wolf Creek we compared species richness and community structure between the three sites and reference streams.

Species Richness and abundance:

Each of the three Wolf Creek sites contained a high number of species. For example 15, 13, and 11 species were found at sites 1, 2, and 3 respectively (Table 1; Figure 20). Overall, the median richness value for Wolf Creek (13 species) was greater than the reference IQR (6 – 11.8 species). In addition, the median richness values for sites 1 and 2 were higher than the reference fish species richness IQR. We also compared the abundance of fish (individuals captured per meter of stream length) between Wolf Creek (all three sites combined) and the reference streams. Based on this comparison, we found that there was no difference in the number of individuals found at Wolf Creek and the reference streams. For example, the median number of individuals at Wolf Creek was 24.96 inds./m compared to 21.69 inds./m at the reference streams (Figure 21).

Table 1. Species lists for all fish collected from Wolf Creek throughout the course of the study.

Specie Name	**Common Name**	**Site 1**	**Site 2**	**Site 3**
Ameirus melas	Black Bullhead			X
Ameiurus natalis	Yellow Bullhead	X	X	X
Campostoma anomalum	Central Stoneroller	X	X	X
Carpoides carpio	River Carpsucker			X
Catastomus commersoni	White Sucker	X	X	
Cyprinella lutrensis	Red Shiner	X	X	X
Cyprinus carpio	Common Carp		X	
Etheostoma spectabile	Orangethroat Darter	X	X	X
Gambusia affinis	Mosquitofish	X	X	
Ictalurus punctatus	Channel Catfish	X		
Lepomis cyanellus	Green Sunfish	X	X	X
Lepomis humilis	Orangespot Sunfish	X	X	
Lepomis machrochirus	Bluegill Sunfish	X	X	X
Lepomis megalotis	Longear Sunfish	X	X	X
Lythrurus umbratilis	Redfin Shiner	X	X	X
Micropterus salmoides	Largemouth Bass	X	X	X
Moxostoma macrolepidatum	Shorthand Redhorse	X		
Notropis ludibdus	Sand Shiner	X	X	X
Noturus exilis	Slender Madton	X	X	X
Percina caprodes	Log Perch	X		
Phenacobius mirabilis	Suckermouth Minnow	X		
Pimephales notatus	Bluntnose Minnow	X	X	X
Pimephales vigilax	Bullhead Minnow	X	X	
Pomoxis annularis	White Crappie		X	X
Semotilus alromaculatus	Creek Chub	X	X	X

Community Composition:

There were similarities in the fish communities between the three Wolf Creek sites. The red shiner (*Cyprinella lutrensis*) accounted for a large proportion of the total fish biomass at each site throughout the study. For example, it accounted for 27 – 69% of the biomass at site 1, 19 – 49% of the biomass at site 2, and 7 – 25% of the biomass at site 3. *Cyprinella lutrensis* is common in Kansas and is tolerant to a variety of conditions

Figure 20. Box plots comparing average fish species richness for Wolf Creek (all three sites combined) and reference streams. Data was also plotted from each Wolf Creek site separately in order to make comparisons between the three sites, and from Stanger Creek.

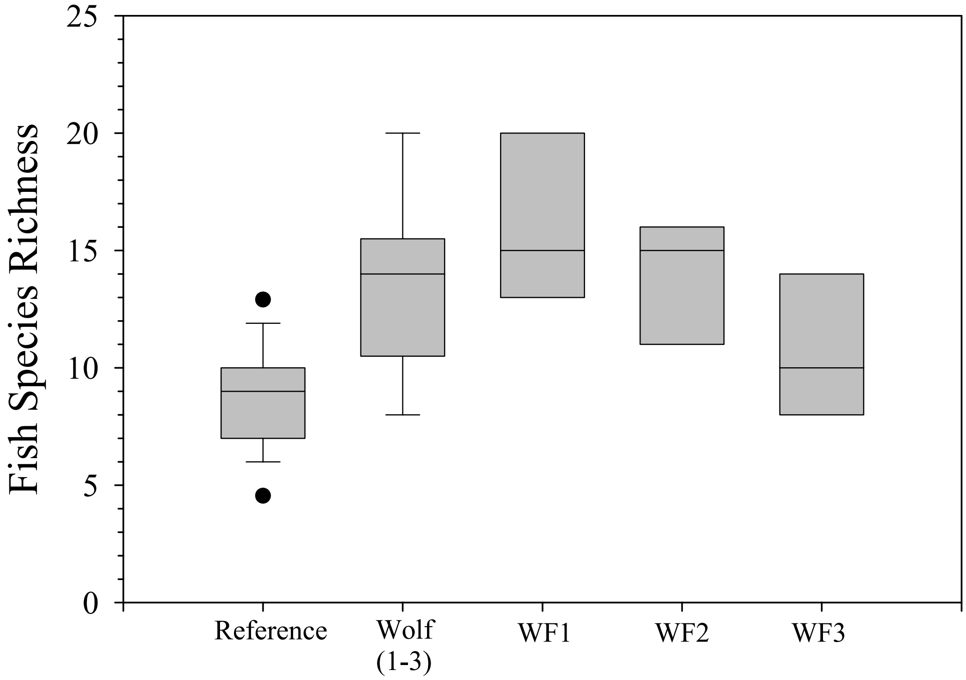
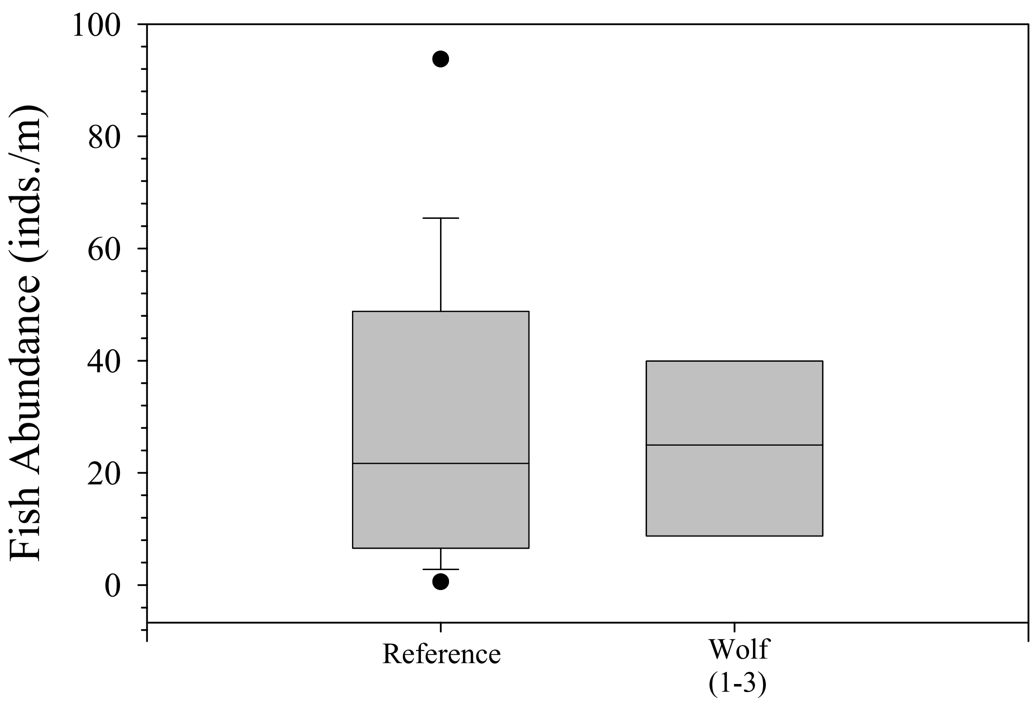


Figure 21. Box plots comparing average fish abundance (inds./m) for Wolf Creek (all three sites combined) and reference streams.



and disturbances (Cross and Collins, 1985). The red shiner also dominated fish communities at Stranger Creek in 2001 (Liechti and Dzialowski, 2001) and accounted for up to 68% of the total fish biomass in some of the reference streams.

Each site also contained a large number of individuals within the genus *Lepomis*, which was represented by several sunfish species. The largest proportion was found at site 3, where 24 – 70% of the community was comprised of *Lepomis*. Bluntnose minnows (*Pimephales notatus*), which are common in Kansas and generally occupy clear pools (Cross and Collins, 1985), were also common at each site. For example, these minnows accounted for 12 – 47% of the total biomass.

We also looked at the tolerance levels for each species that are provided by Barbour *et al*. (1999) to determine how many intolerant, intermediate, and tolerant species were present at Wolf Creek. Intolerant species are typically the first species to disappear following a disturbance and therefore are a good indicator of the health of a stream (Barbour *et al*., 1999). The fish communities at Wolf Creek were mostly dominated by intermediate and tolerant species. However, there were two intolerant species found at Wolf Creek, the slender madtom (*Notorus exilis*) and the longear sunfish (*Lepomis megalotris*). Of these two intolerant species, the longear sunfish was relatively common at all three sites comprising up to 15%, 11%, and 28% of the total biomass at sites 1, 2, and 3 respectively.

Macroinvertebrate Community:

Macroinvertebrates are used as indicators in stream bioassessement studies because they respond to a variety of disturbances, are present in a wide array of aquatic habitats, are relatively easy to sample and process, have long life histories, and are relatively sedentary (Berkman *et al*., 1986; Rosenberg and Resh, 1996; Barbour *et al*., 1999; Whiles *et al*., 2001). Disturbances of macroinvertebrate communities may result in reduced taxa richness, and/or shifts in community composition. In addition, most taxa within the orders Ephemeroptera, Plecoptera, and Tricoptera (EPT) are sensitive to slight perturbations in water quality, and their absence can be an effective indicator of disturbance (Rosenberg and Resh, 1996).

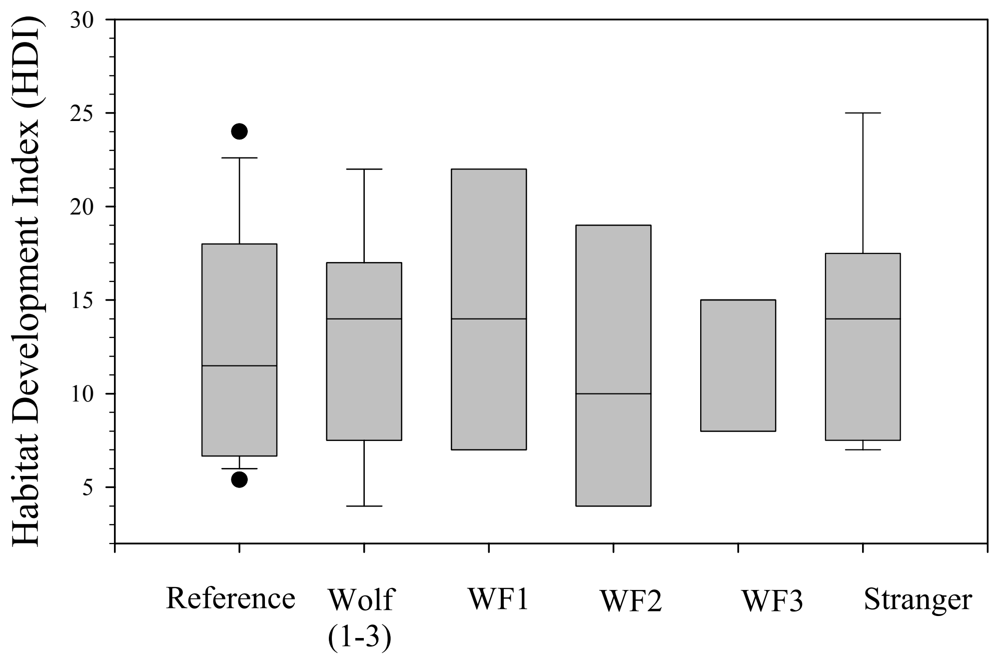
Three macroinvertebrates samples were collected at each site from the available macrohabitats (e.g. one each in riffle, run, and pool) during each sampling event. In instances where all of these macrohabitats were not present at a single site, the existing macrohabitat(s) was subdivided and a sample was collected from each of the subdivisions. For each sample the substrate was disturbed during a one-minute kick sample and a D-net was used to collect the dislodged insects. Attempts were made to sample all microhabitats capable of supporting benthic invertebrates. The macroinvertebrate samples were preserved in formalin with rose bengal and returned to the laboratory where they were sorted from the detritus and substrate and identified to family.

Macroinvertebrate Habitat:

The quality and quantity of stream habitat is an important predictor of invertebrate community composition (Huggins and Moffett, 1988; Allan, 1995). Therefore a Habitat Development Index (HDI) was calculated for each site to determine the quality of habitat at each site (Huggins and Moffett, 1988). The HDI provides a rank of quality for each macrohabitat sampled based on depth, velocity, percent cobble, percent cobble imbeddedness, presence/absence of algal masses, and densities of organic debris, macrophytes, and bank vegetation (For a detailed description see Huggins and Moffett, 1988). The higher the HDI score the greater the potential for macroinvertebrate habitat.

There was little difference in the Habitat Development Index (HDI) values calculated for Wolf Creek and the reference streams (Figure 22). For all Wolf Creek sites combined, the median HDI value was 14, which is within the reference IQR range for HDI values (6.67 – 18.0). In addition, there was no difference between the three Wolf Creek site when analyzed separately, and between Stranger Creek and the other streams.

Figure 22. Box plots comparing Habitat Development Index (HDI) at Wolf Creek (all three sites combined) and reference streams. Data was also plotted from each Wolf Creek site separately in order to make comparisons between the three sites, and from Stranger Creek.



Aquatic Invertebrates:

Several types of metrics were used to determine if macroinvertebrate communities within Wolf Creek deviated from reference conditions. Richness metrics (total taxa and EPT richness) allow for the analysis of community response to disturbance and are an important indicator or macroinvertebrate community health (Huggins and Bouchard, 2000). Abundance measures (total and EPT abundance) provide an effective tool for identifying disturbances such as nutrient loading, habitat destruction and the presence of toxic materials. Community composition measures (%EPT) highlight the presence or absence of pollution intolerant species and therefore are an effective indicator of disturbance (Huggins and Bouchard, 2000).

Family Richness:

The number of macroinvertebrate taxa collected from Wolf Creek was similar to the number of taxa collected from the streams within the reference watersheds (Table 2; Figure 23). For example, the median value for Wolf Creek was 15 families, which was within the IQR for reference watershed (11 – 15 families). When compared separately, all three Wolf Creek sites had median richness values within or above (Site 2) the reference IQR. When sampled in 2001, Stranger Creek also exhibited richness values similar to reference conditions and Wolf Creek.

With respect to EPT richness, a similar pattern was observed (Figure 24). The IQR range of EPT richness for the reference streams was 4 – 6 families. The median EPT richness for the three Wolf Creek sites combined was 4.5 families. The median EPT

Table 2. List of all macroinvertebrate families collected from Wolf Creek throughout the course of the study.

Family	**Site 1**	**Site 2**	**Site 3**
Baetidae	X	X	X
Caenidae	X	X	X
Ceratopogonidae	X	X	X
Chironomidae	X	X	X
Coenagrionidae	X	X	X
Corduliidae		X	X
Corixidae	X	X	X
Culicidae	X	X	X
Dytiscidae	X	X	X
Elmidae	X	X	X
Ephemeridae		X	X
Gerridae	X	X	
Gomphidae	X		
Gyrinidae	X		
Haliplidae	X	X	X
Helicopsychidae		X	
Heptageniidae	X	X	X
Hydrophilidae	X		
Hydropsychidae	X	X	X
Hydroptilidae	X	X	
Mesoveliidae		X	
Nepidae		X	
Oligoneuridae	X		
Sialidae	X	X	X
Simulidae	X	X	X
Stratiomyiidae			X
Tabanidae		X	
Tricorythidae	X		
Unknown *Tricophtera*	X		X
Veliidae		X	X

Figure 23. Box plots comparing family richness at Wolf Creek (all three sites combined) and reference streams. Data was also plotted from each Wolf Creek site separately in order to make comparisons between the three sites, and from Stranger Creek.

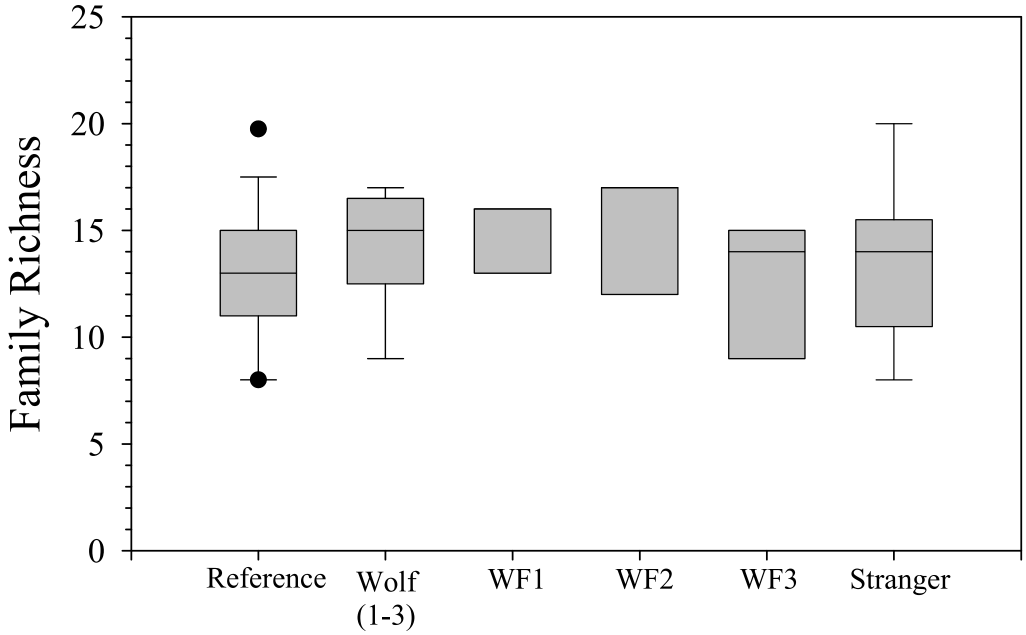
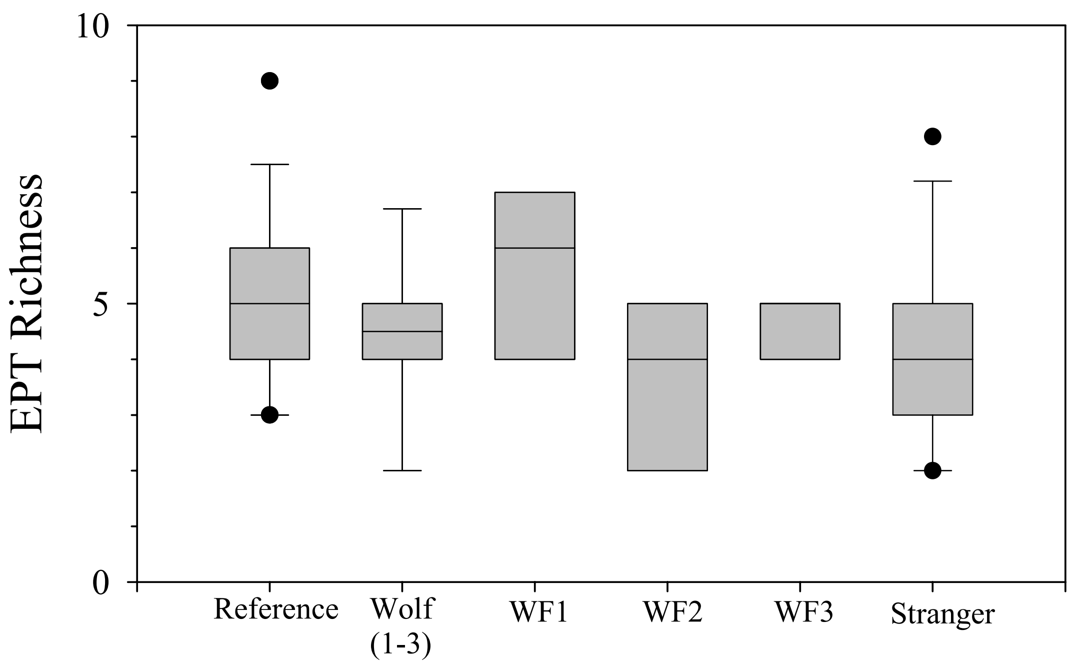


Figure 24. Box plots comparing EPT richness at Wolf Creek (all three sites combined) and reference streams. Data was also plotted from each Wolf Creek site separately in order to make comparisons between the three sites, and from Stranger Creek.



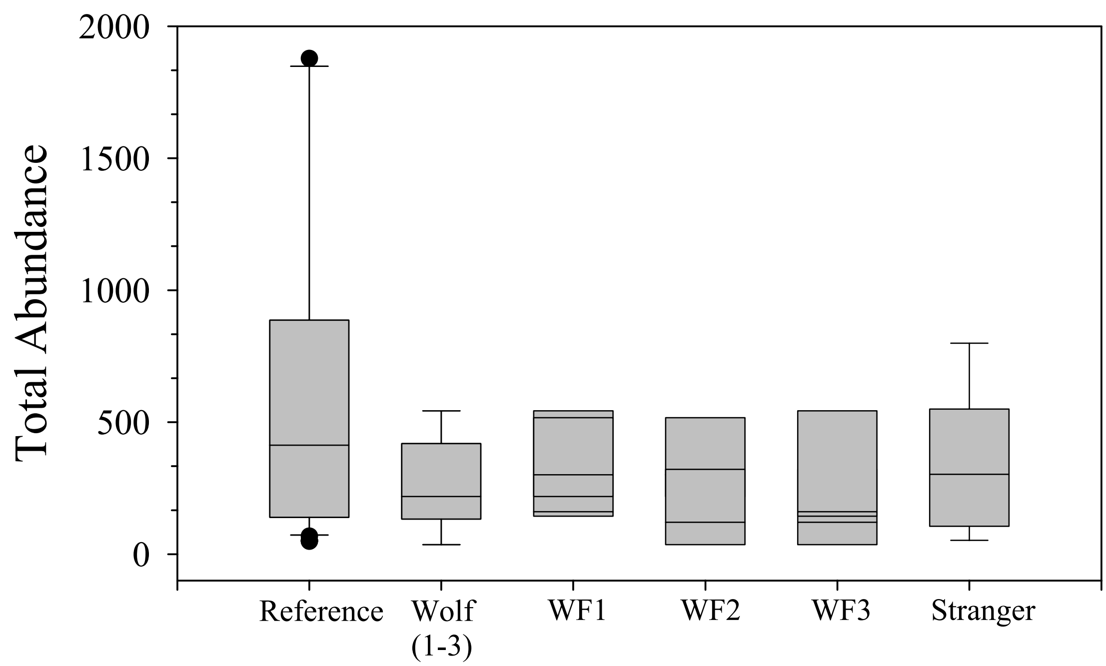
richness value for Stranger Creek was also with the reference IQR, although it was at the lower end of this range (4 families).

Abundance:

The total abundance of macroinvertebrates at Wolf Creek fell within the IQR range for reference streams (Figure 25). The median value of macroinvertebrates collected from the sites was 218 individuals, which was within the reference IQR range (140 – 887 individuals). In addition, there was not a difference in the number of individuals collected from Stranger Creek and the other sites.

Similarly, there was no difference in the abundance of EPT taxa between Wolf Creek and the reference watersheds (Figure 26). For example, the median value for all

Figure 25. Box plots comparing insect abundance at Wolf Creek (all three sites combined) and reference streams. Data was also plotted from each Wolf Creek site separately in order to make comparisons between the three sites, and from Stranger Creek.



Wolf Creek sites combined was 43 individuals compared to the IQR range from reference streams, which was 31 – 265 individuals. While there was not a difference between Wolf Creek and reference conditions, the median number of EPT taxa collected from Stranger Creek in our 2001 analysis was below both the IQR from the reference watersheds and Wolf Creek.

Figure 26. Box plots comparing EPT abundance at Wolf Creek (all three sites combined) and reference streams. Data was also plotted from each Wolf Creek site separately in order to make comparisons between the three sites, and from Stanger Creek.

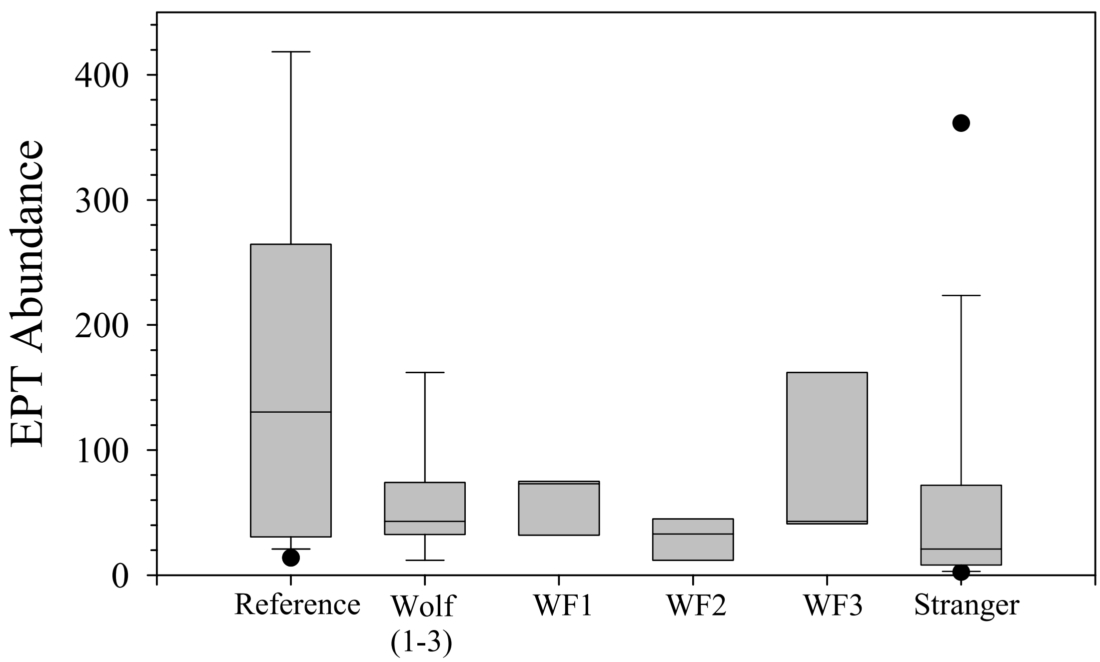
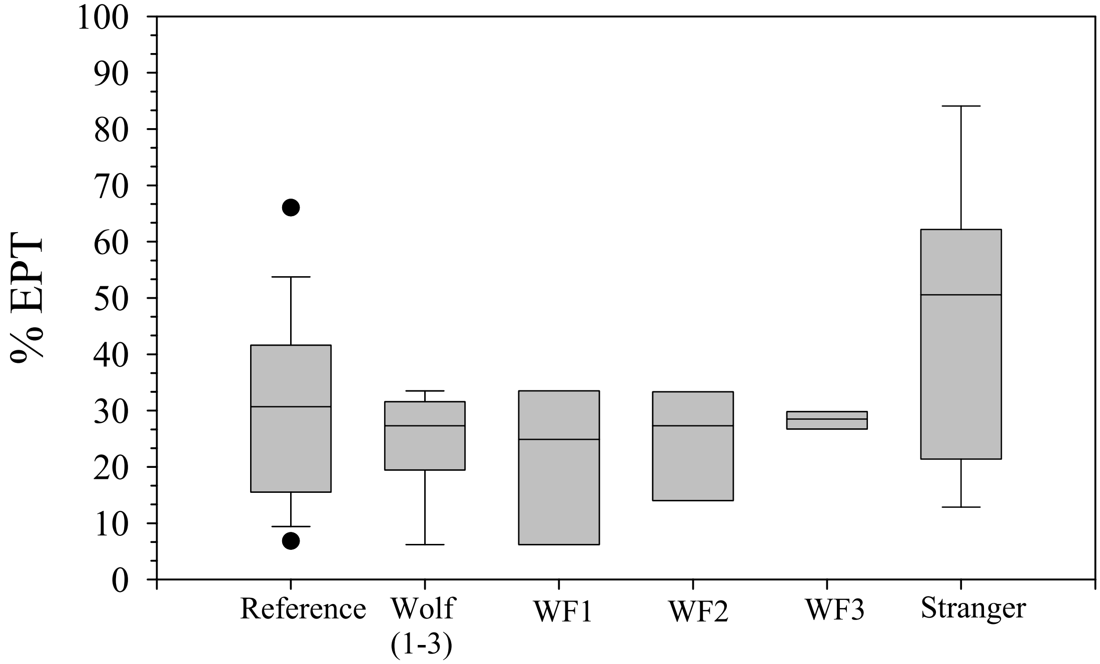


Figure 27. Box plots comparing %EPT at Wolf Creek (all three sites combined) and reference streams. Data was also plotted from each Wolf Creek site separately in order to make comparisons between the three sites, and from Stranger Creek.



Community Composition (%EPT):

In accordance with EPT abundance, the median %EPT from Wolf Creek was within the reference IQR for %EPT (Figure 27). For example, 27.3% of the invertebrate community at Wolf Creek was comprised of EPT taxa and the range for reference streams was 16.66-41.38%. In contrast to EPT abundance, the median %EPT of Stranger Creek was greater than the reference and Wolf Creek IQR's.

Conclusion: *Wolf Creek*

We conducted an ecological assessment of the physical, chemical, and biological characteristics of Wolf Creek, in Leavenworth County, Kansas. We compared data collected from three sites located along Wolf Creek during three seasons (spring, summer, and fall) to data collected from reference watersheds that were considered to have high habitat, water quality, and biological conditions. This analysis was used to determine if Wolf Creek has experienced degradation, and will be used in the development of long-term watershed management plans.

Overall, our data suggests that the ecological conditions of Wolf Creek are very similar to the ecological conditions of the reference streams. With respect to our analysis of stream habitat characteristics, Wolf Creek scored at least as good as reference streams for almost all of the measured variables. For example, the median values for riparian condition, riparian width, stream shading, and erosional area from Wolf Creek were all within the reference IQR's for these variables.

However, when we looked at each site separately there were indications that the riparian forest at site 1 has experienced some level of disturbance. A large portion of the riparian forest at this site has been removed leading to reductions in the amount of shade available, a greater amount of erosional area, and increased channel widths. It is important that the intact riparian forest along Wolf Creek is protected, and that there is development of new riparian forest where it has been removed. A healthy riparian zone will provide bank stability that reduces soil erosion and removes soil from the water as it enters the stream leading to lower turbidity concentrations (EPA, 1996; Kalff, 2002).

The majority of water quality parameters that we measured in Wolf Creek were similar to, or better then, reference conditions. For example, Wolf Creek does not appear to be experiencing excessive nutrient loads from its watershed. Wolf Creek exhibited both total nitrogen and phosphorus values that were lower (better) than reference streams. However, there were two water quality variables that scored poorer than reference streams and were close to the lower limits of the current Kansas surface water standards. These variables include turbidity, which was higher than in reference streams and dissolved oxygen, which was lower than in reference streams. While both of these variables can have significant negative impacts on the biological communities within a stream, our analysis of both macroinvertebrate and fish communities suggest that the biological communities of Wolf Creek are at least as healthy as the communities in the reference streams. It is possible that increased turbidity and low dissolved oxygen levels may negatively impact these communities in the future, and additional long-term monitoring is warranted at Wolf Creek.

We also included several biotic components of Wolf Creek in our analysis. Although we were unable to compare periphyton collected from Wolf Creek with the reference streams, we were able to compare data from Wolf Creek with similar data collected from Stranger Creek in 2001 (Liechti and Dzialowski, 2002). Benthic algal concentrations (i.e. chlorophyll *a*) did not differ between the three Wolf Creek sites. However, algal concentrations at Wolf Creek were lower than at Stranger Creek, further supporting our findings that Wolf Creek is not experiencing high nutrient loads.

Analysis of the macroinvertebrate and fish data collected at each site suggests that Wolf Creek has not deviated from reference conditions. The median values for all of the metrics used to assess these biotic communities at Wolf Creek were within, or greater than, the range of values obtained for reference streams. Therefore, these communities are diverse and represented by a number of indicator species (i.e EPT). We believe that this data suggests that the macroinvertebrate and fish communities at Wolf Creek are currently healthy. We recommend that further sampling be conducted in order to monitor any changes in these communities that may occur from future disturbances within the watershed.

Based on the overall analysis of the ecological conditions at Wolf Creek, it appears this system is relatively healthy. There is some concern of riparian loss (site 1), high turbidity levels, and low dissolved oxygen levels within Wolf Creek. However, biotic communities do not appear to be negatively affected at this time. For example, Wolf Creek does not appear to be experiencing excessive algal blooms, and both macroinvertebrate and fish communities are at least as diverse as reference in streams. Land use management and the preservation and improvement of instream habitat, in combination with continued monitoring will help to maintain the overall health of the Wolf Creek watershed.

Stranger Creek: *Background*

The KBS previously conducted an ecological assessment of Stranger Creek (Liechti and Dzialowski, 2002). Using methodology similar to that used in the assessment of Wolf Creek, we sampled three sites along the main stem of Stranger Creek during three separate sampling events in 2001. Based on this original 2001 analysis, we found that there was a high degree of site variability at Stranger Creek. For example, the inorganic substrate at sites 1 and 3 was very diverse and dominated by several substrate types including cobble, soft silt, hard clay, and sand. In contrast, site 2 was much less diverse and dominated by soft silt. Similarly, site 2 scored lower than the other two sites on most variables measuring the health of the riparian forest (Liechti and Dzialowski, 2001).

Since in-stream and near-stream variables are directly related to the health and diversity of the resulting fish communities (Allen, 1995), we were interested in determining if the conditions at sites 1 and 3, or the conditions at site 2 were more representative of the overall conditions and available habitat at Stranger Creek. Based on the placement of our original sampling sites, there is reason to believe that the overall ecological conditions of Stranger Creek are more similar to site 2. For example, while sites 1 and 3 had high fish habitat potential, they were also located directly below bridges, which provided non-natural habitat.

In our initial assessment of Stranger Creek we stated, "it is likely that the level of impairment at Stranger Creek is related to the proportion of the total stream area that is similar to each of the three sites. For example, if a large proportion of Stranger Creek has ecological conditions similar to those found at ST2, then the ecological integrity of

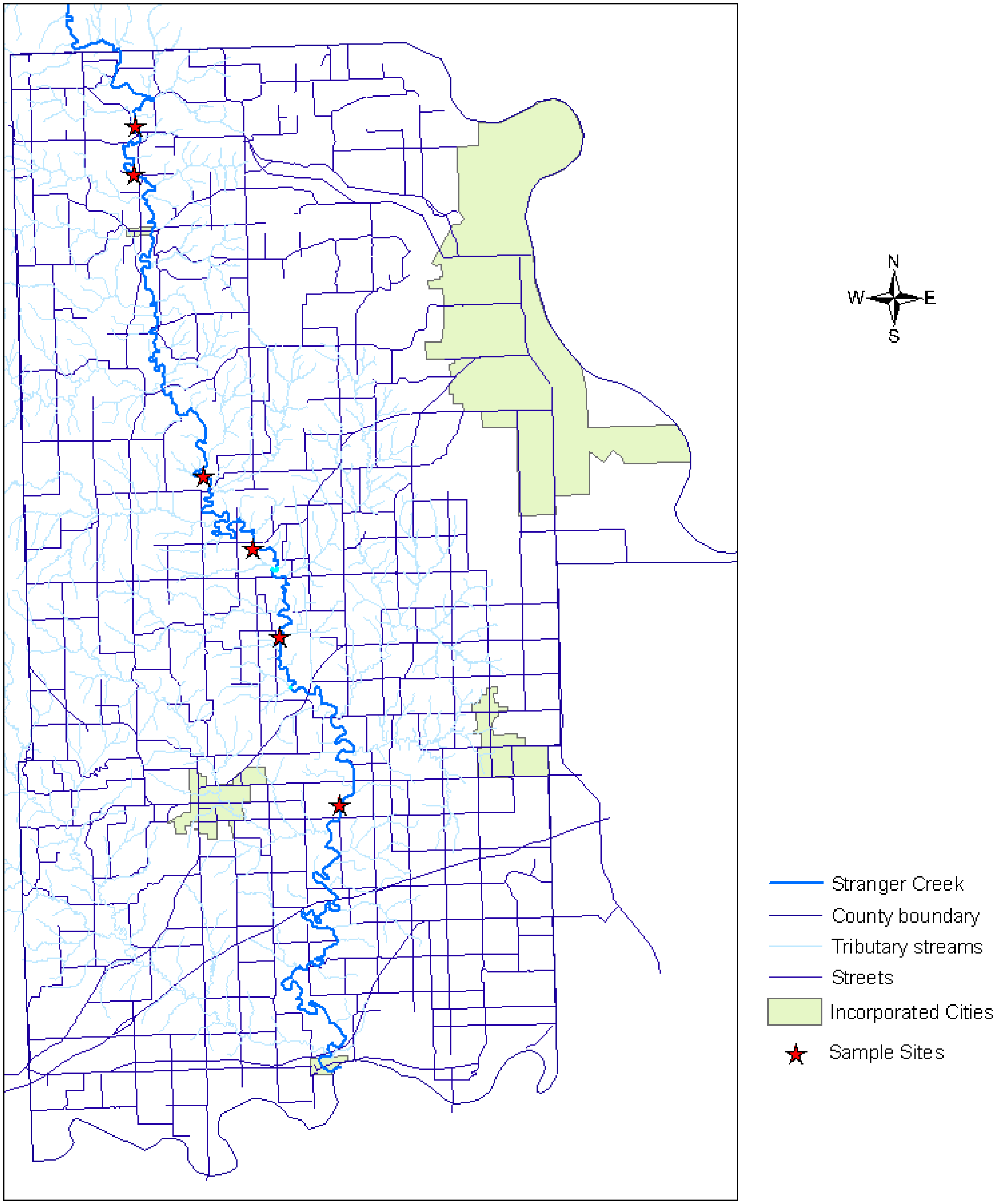
Stranger Creek has likely been severely compromised" (Liechti and Dzialowski, 2002). Therefore, we sampled several additional sites along Stranger Creek in November of 2003 in order re-asses the availability of potential fish habitat. Five new sites were selected for this analysis (Figure 28). One site was selected 100 m above our original site 1 and another site was selected 100 m above our original site 3 in order to determine the conditions outside the zone of influence associated with the bridges in these areas. Three additional sites were selected that were not directly affected by bridges, and that had relatively good riparian forests (51 – 75% of desired corridor available) as determined by the "Stranger Creek Watershed Management Plan" (Leavenworth County Planning Department, 2002). At each site a number of instream variables associated with fish habitat including inorganic substrate, areas of undercutting, areas of vegetative cover, and stream shading were measured using methodology described above for Wolf Creek.

Stranger Creek Results*: Habitat measurements*

The available inorganic habitat at the five Stranger Creek sites was dominated by soft silt (Figure 29). In addition, gravel (11%), hard clay (6%), and sand (3%) were present, but only in small quantities. Cobble, which is often considered to be an important habitat type for both fish and macroinvertebrates (Allen, 1985), was not present at any of the Stranger Creek sites sampled in 2003. In comparison with our previous analysis of the inorganic substrate availability at Stranger Creek (Liechti and Dzialowski, 2002), this data suggests that substrate conditions at our original site 2 are likely more representative of the overall conditions at Stranger Creek (Figure 30). For example, we found that soft silt comprised only 17 and 16% of the available substrate at Stranger

Figure 28

Stranger Creek
Fish Habitat Analysis Sites



Creek sites 1 and 2 in 2001. However, soft silt dominated site 2 (58%) in 2001, which is similar to what we found in the five Stranger Creek sites located away from the influence of bridges in this analysis. Therefore, it is likely that the diverse inorganic substrate observed at sites 1 and 3 in our 2001 analysis resulted from the presence of bridges at those sites, and a homogeneous substrate dominated by soft silt is more representative of the overall conditions at Stranger Creek.

Figure 29. Percent stream bottom cover for inorganic substrate occurring at five Stranger Creek sites sampled in the fall of 2003.

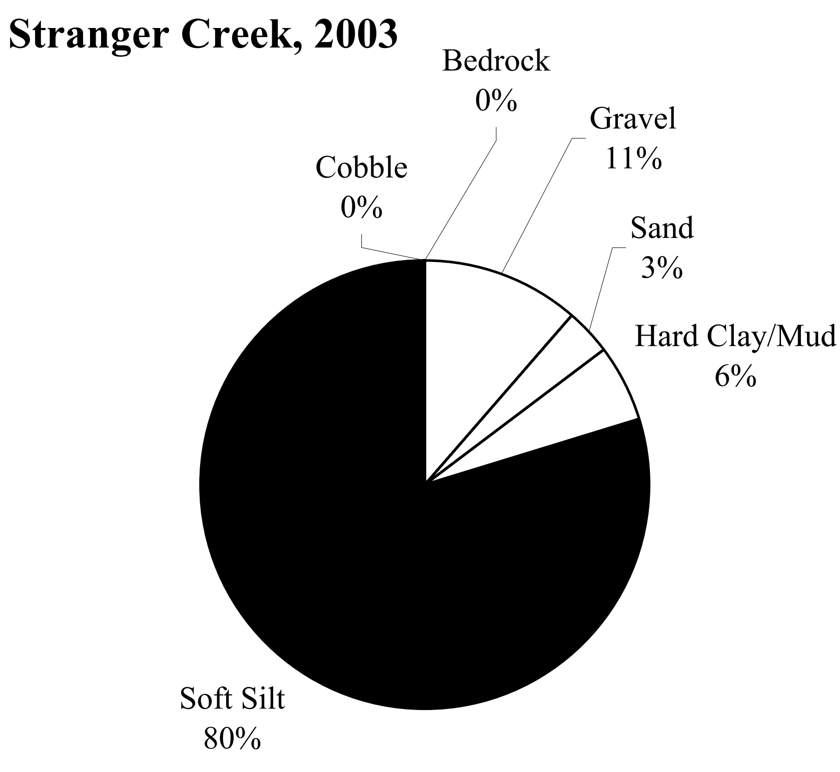
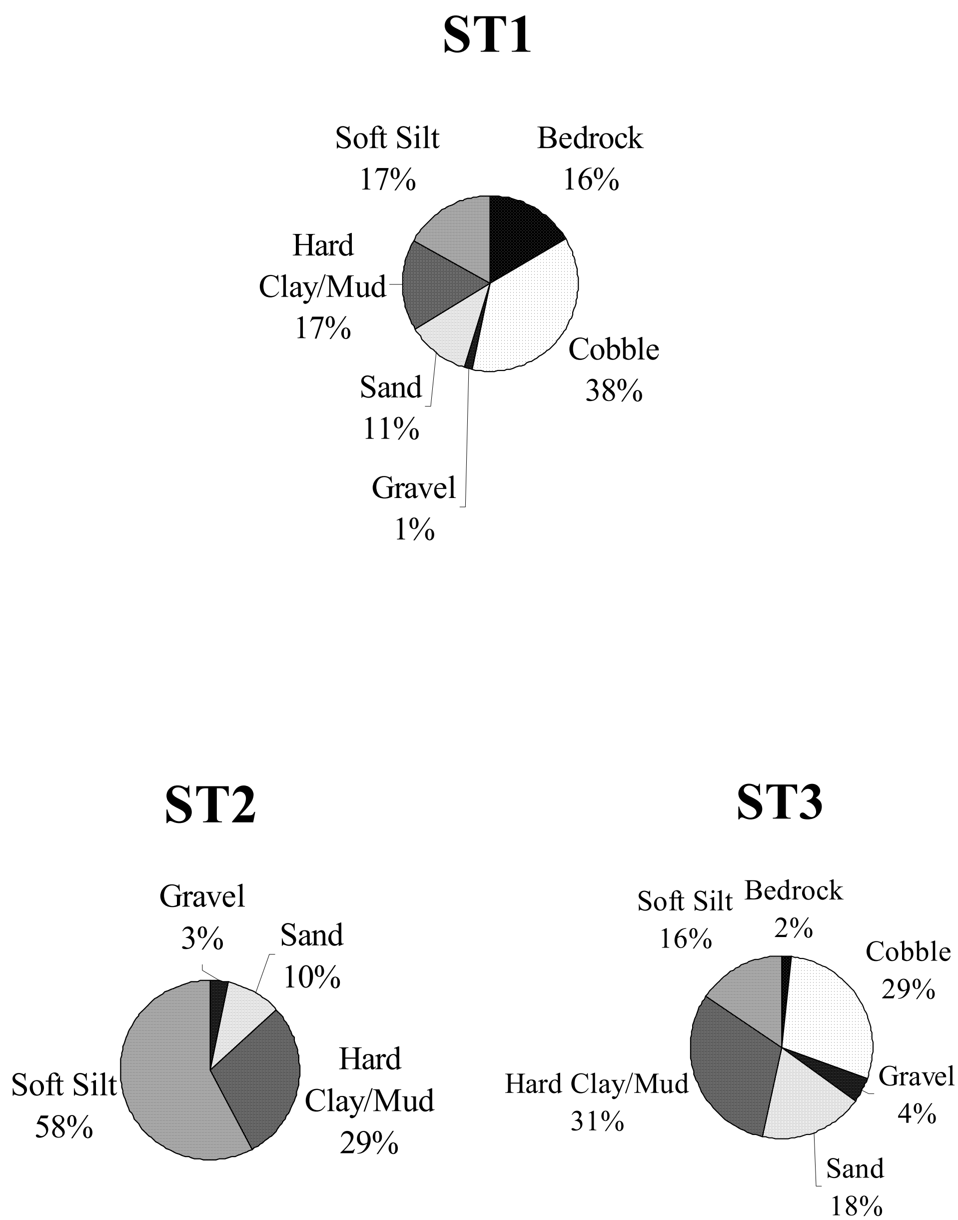
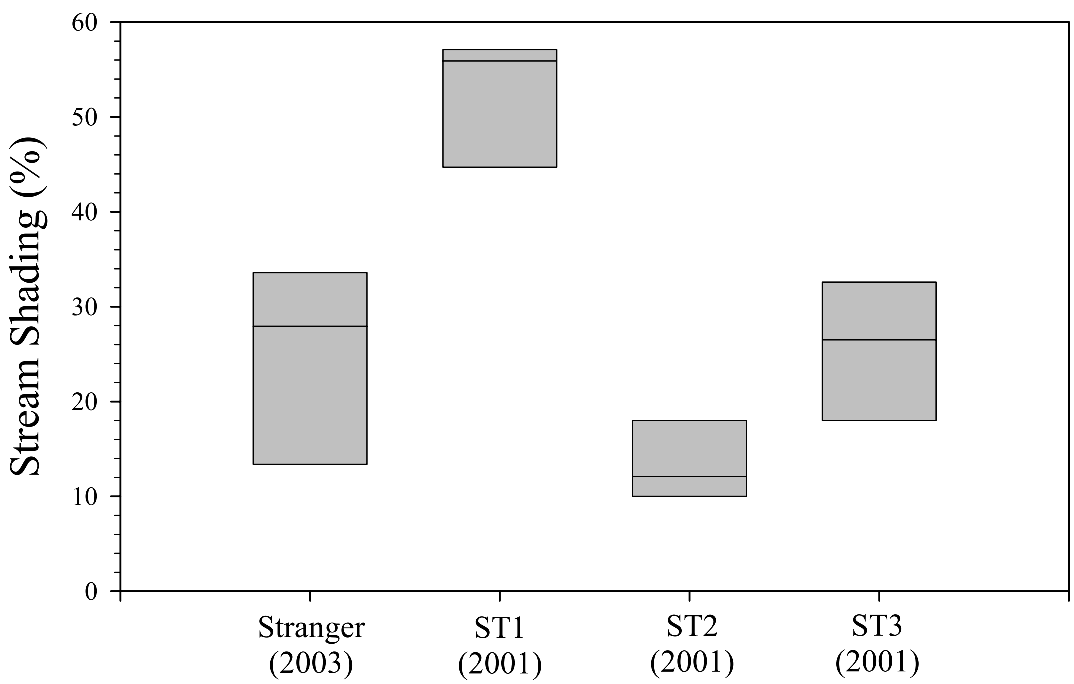


Figure 30. Percent stream bottom cover for inorganic substrate occurring at the three Stranger Creek sites in 2001 (Liechti and Dzialowski, 2002).



We did find areas of bank undercutting and vegetative overhang at several of the Stranger Creek sites sampled in 2003. While these variables represent potential fish habitat, only small areas were present. Furthermore, no major differences existed between the data collected in 2001 and 2003. For example, the median amount of bank undercutting found at the three original Stranger Creek sites sampled in 2001 was 0.70 m^3, compared to 0.99 m^3 at the five Stranger Creek sites sampled in 2003.

Figure 31. Box plots comparing stream shading (%) at the five Stranger Creek sites sampled in 2003, and the three original Stranger Creek sites sampled in 2001 (Liechti and Dzialowski, 2002).



We also measured the percent stream shading from the canopy cover at each site. Stream shading is directly related to water temperature, and the distribution of many fish species is limited by temperature. The median % stream shading for the five sites sampled in 2003 was 27.94% (Figure 31). This median value was similar to the median value observed at site 3 in 2001, but much lower than the median value observed for site 1 in 2001. These results suggest that % stream shading at Stranger Creek is similar to the results that we observed for sites 2 and 3 in 2001.

Conclusions: *Stranger Creek*

We sampled several sites along Stranger Creek in order to assess the available fish habitat. Based on our initial analysis in 2001 (Liechti and Dzialowski, 2001), it was unknown if the high habitat measures that were observed were the result of several sites being located near bridges. By looking at an additional five sites, all of which were out of the influence of bridges, we were able to assess the habitat and determine if it has been severely degraded.

We found that the inorganic substrate composition at the five Stranger Creek sites sampled in 2003 was very similar to the substrate composition at site 2, which was the only site in our initial analysis not located near a bridge. The substrate composition at site 2 was homogeneous and dominated by soft silt, which is indicative of high flow conditions, high erosion, and high levels of siltation within the watershed. Based on this analysis, we suggest that the overall fish habitat at Stranger Creek has been severely compromised and that the ecological conditions of site 2 as described in our initial assessment more accurately represent the fish habitat conditions at Stranger Creek.

Moreover, at the 3 sites located where there was relatively good riparian forest, fish habitat did not appear to be any better than at other sites where measurement were taken. The deeply incised stream channel through out the length of Stranger Creek, the consequence of altered hydrology and a thick mantel of highly erodible loess soils, may have compromised the beneficial effects of a good, intact riparian corridor along the stream banks. Future efforts to reestablish riparian vegetation along Stranger Creek may also require concurrent actions to restore a more natural hydrology to realize an improvement in the habitat available for fish in Stranger Creek.

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