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

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

Paul Liechti and Andrew Dzialowski

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Kansas Biological Survey, University of Kansas, Lawrence, Kansas

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Introduction

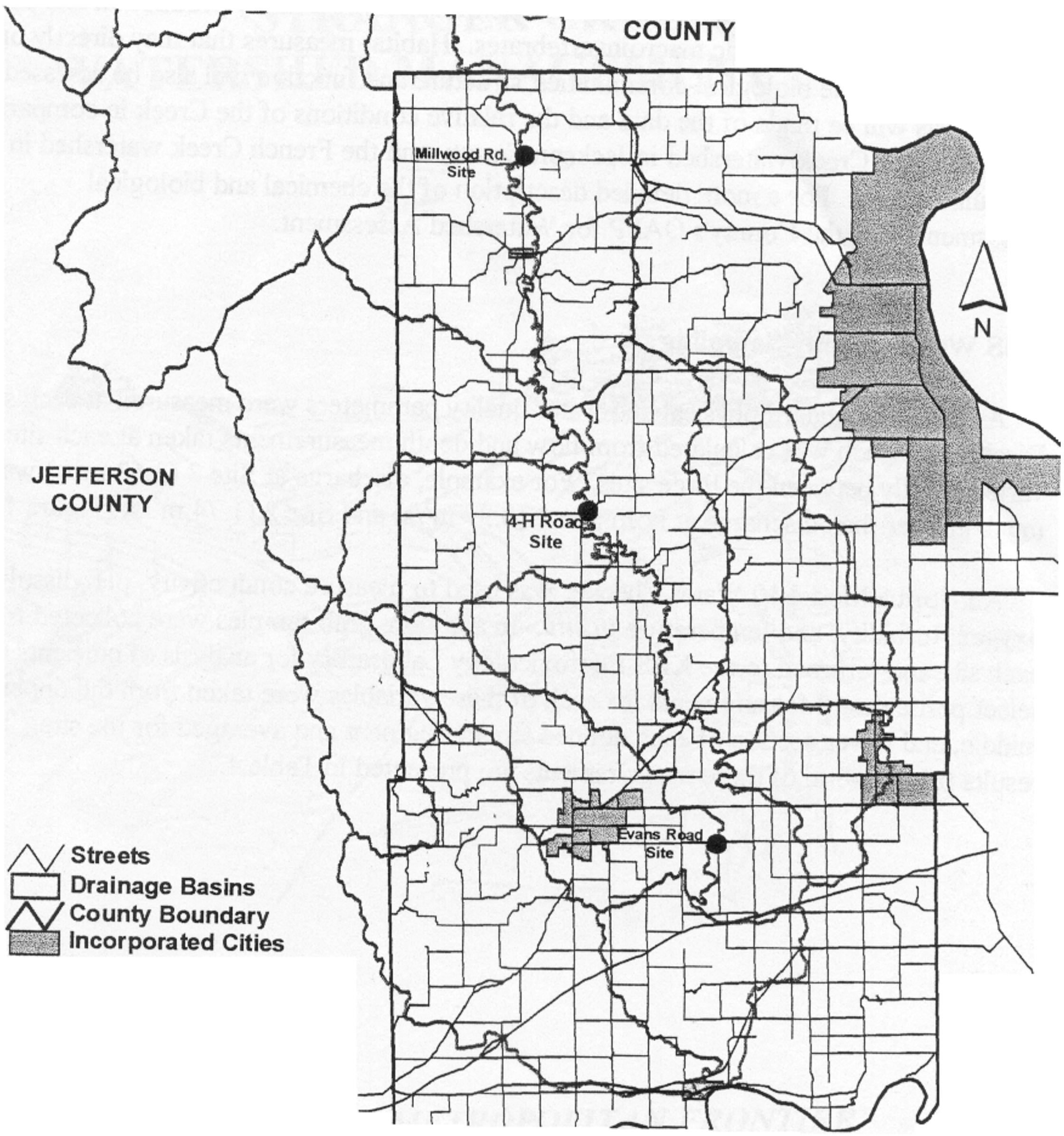
The Kansas Biological Survey conducted an investigation of the ecological integrity of Stranger Creek, Leavenworth Counties, Kansas. Three sites were selected along the main stem of Stranger Creek and sampled for a variety of physical, chemical, and biological attributes in the spring, summer, and fall of 2001. Data collected from Stranger Creek was compared to similar data collected from streams located within three reference watersheds that were previously determined to have high habitat, water quality, and biological conditions. This analysis was used to determine if Stranger Creek has deviated from reference conditions. In addition, it will help build a framework for future watershed management plans and objectives.

Watershed Descriptions:

The Stranger Creek watershed is located in northeastern Kansas in parts of Atchison, Douglas, Jefferson, and Leavenworth Counties. Roughly 2/3 of the watershed is located within Leavenworth County (Figure 1). The Stranger Creek watershed is a large (858 km^2) watershed that is composed mainly of cropland and grassland and to a lesser extent woodland (Table 1). Data collected from Stranger Creek was compared to that obtained from three reference watersheds located within the Western Corn Belt Plains (WCBP) ecoregion: 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 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)

Stranger Creek is much larger then the reference watersheds used in this study. For example, Straight, French, and North Elm encompass 60.46 km^2, 71.96 km^2, and

Figure 1. Map of Stranger Creek watershed and the three sampling sites: ST1 – Millwood Road Site; ST2 – 4-H Road Site; ST3 – Evans Road Site.



50.15 km^2 respectively. However, some similarities do exist with respect to land use patterns within the watersheds (Table 1). Cropland and grassland account for between 88% and 94% of the land cover in Stranger Creek, Straight, and French watersheds. North Elm is comprised of approximately 85% cropland and 12.3 % grassland (Table 1).

Table 1. Percent land use/land cover for Stranger Creek (Leavenworth County) and the three reference watersheds used in this study, Straight Creek (Jackson County), French Creek (Nemaha County), and North Elm (Marshall County).

Land Use/ Land Cover	**Stranger (%)**	**Straight (%)**	**French (%)**	**North Elm (%)**
Cropland	39.0	35.5	54.9	84.7
Grassland	49.0	53.0	39.8	12.3
Water	<1	<1	<1	<1
Woodland	11.0	8.4	3.8	1.6
Property/Other	<1	2.3	<1	1.2

Data Analysis:

In order to compare the physical, biological, and chemical conditions of the reference watersheds and Stranger Creek, 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 75^{th} percentile of the data set and the lower part of the box represents the 25^{th} 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 10^{th} and 90^{th} percentile of the data.

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

It should be emphasized that there were differences between Stranger 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 Stranger 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 Stranger Creek.

We also plotted the data from each of the three Stranger 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.

Sampling:

The KBS staff and Leavenworth County officials selected three sites along the main stem of Stranger Creek for analysis: a site near Millwood (ST1); a site near Springdale (ST2); and a site near Tonganoxie (ST3) (Figure 1). Each of these three sites were sampled for a variety of physical, chemical, and biological variables during three sampling events: spring (May 1-2), summer (July 7-8) and fall (September 10-11) of 2001.

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). All of these macrohabitats were not present at each site however, and in these instances the available habitat was sampled. For example, at ST1 all three macrohabitats were sampled during the first sampling event, and two distinct runs and a single riffle were sampled during the second and third sampling events. In contrast, run was the only macrohabitat present at ST2, and therefore each stream section represented a distinct run throughout the entire study period. Similarly, at ST3 we sampled 3 distinct runs during the first sampling event, and the position of the site was shifted upstream for the second and third sampling events and two distinct runs and a riffle were sampled. The physical, biological, and ecological conditions of Stranger Creek were then assessed using methodology from Platts *et al.*, (1987) and Barbour *et al*., (1999).

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 Stranger 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 Stranger Creek site was assessed based on several variables including stream shading, riparian width, and riparian condition.

Percent stream shading from the canopy cover was estimated using a concave, spherical densiometer. The median Stranger Creek values for stream shading (30.54%) fell within the reference IQR range (20.88 – 71.47%). However, there were differences in the level of stream shading at the three Stranger Creek sites (Figure 2). For example, the median percent shading at ST1 was 52.57% compared to 13.37% and 25.70% at ST2 and ST3 respectively (Figure2).

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 Stranger Creek (8.37 m) was within the reference IQR range for riparian width (7.60 – 44.65 m). As with stream shading, there were differences between the three Stranger Creek sites. The median values for ST1 and ST2 fell within the reference range, however, no riparian system was present at Site 2 (Figure 3).

Riparian condition, which is a used as an index of the health of the riparian system, was assessed along four transects at each site. 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 poor system and 4 representing a healthy system. In contrast to

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

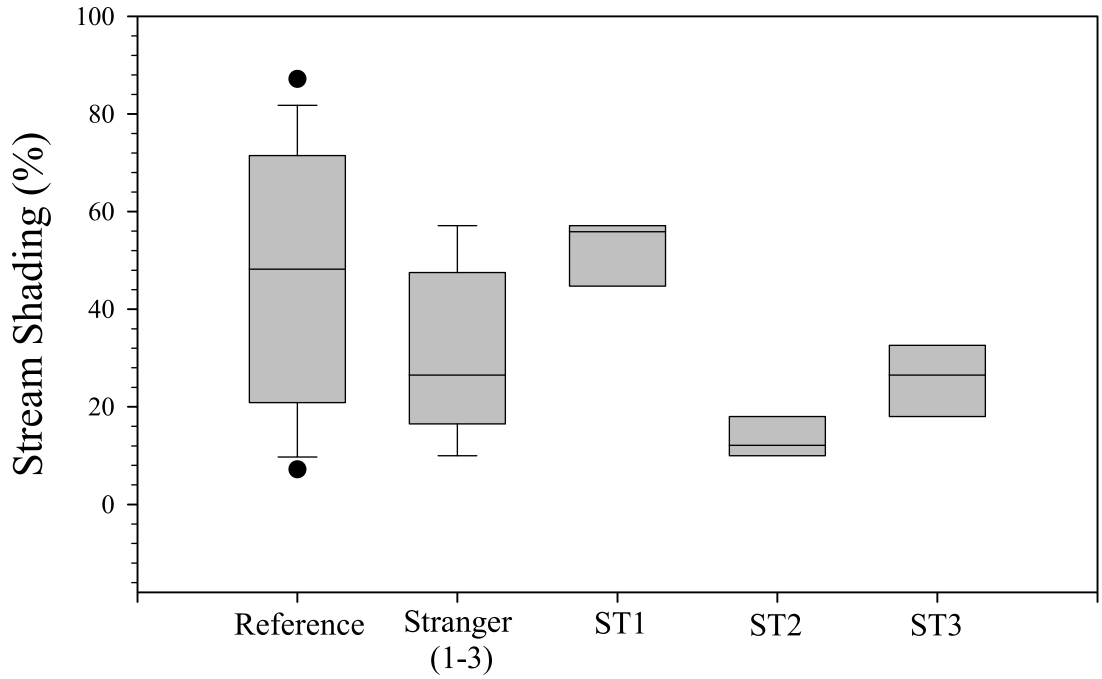
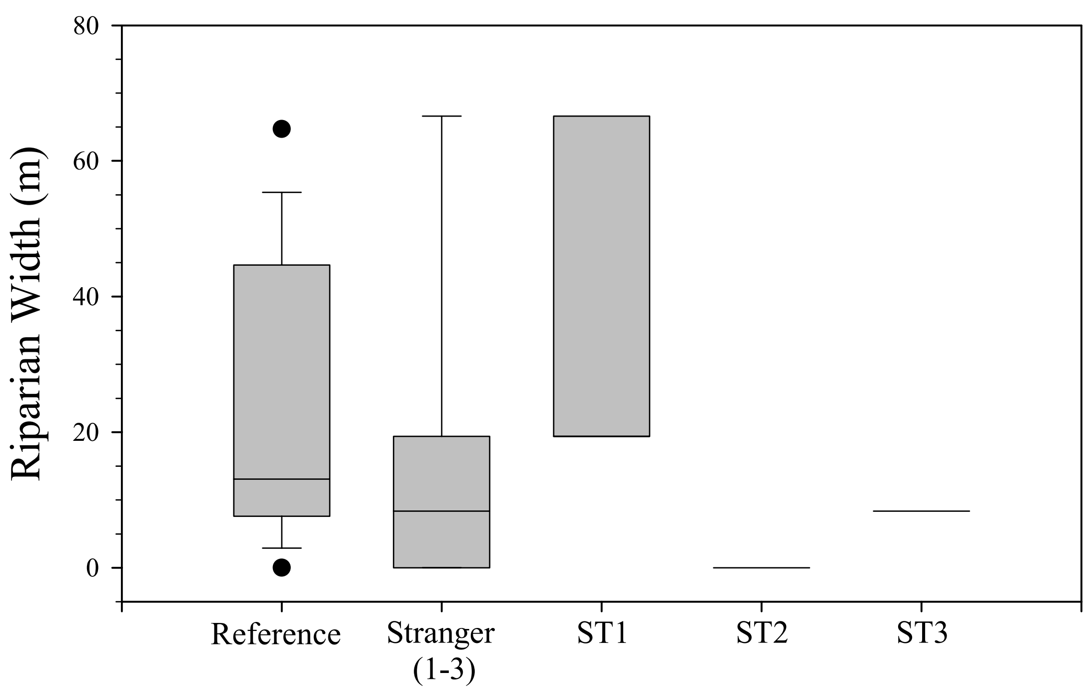


Figure 3. Box plots comparing riparian width (m) of Stranger Creek (all three sites combined) and reference streams. Data was also plotted from each Stranger Creek site separately in order to make comparisons between the three sites.



stream shading and riparian width, the riparian condition at Stranger Creek (1.77) was slightly below the reference IQR range of riparian conditions (2.00 - 3.25; Figure 4).

While stream shading and riparian width were similar between Stranger Creek and reference streams, the overall riparian condition appears to be somewhat poorer at Stranger Creek. This assessment is based on the low riparian condition values for Stranger Creek, which indicate that the available riparian forest is comprised of a thin and broken canopy and that there is low species diversity. In addition, the lack of a riparian forest at ST2 suggests that the overall riparian forest at Stranger Creek has been degraded. Removal or loss of riparian forest can result in a number of detrimental stream alterations including increased temperature, increased channel widths, reduction in habitat, increased soil erosion, and increased sedimentation (Allen, 1995).

To determine if there were differences in erosion between Stranger 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 Stranger Creek was slightly higher than at the reference streams (Figure 5). The median value for erosion area at Stranger Creek was 42.0 m^2 compared to the IQR range for reference streams which was 0 – 36.75 m^2. Looking at each site separately, erosion area was highest at ST2 (129.6 m^2). Stream bank erosion leads to direct soil loss, which results in increased turbidity. Increased turbidity in turn may result in the sedimentation of stream habitat, and the reduction of light that is available to primary producers. Concurrent with sedimentation of habitat, there is often a decrease in stream substrate heterogeneity and resulting shifts in the community composition of stream biota (Allen, 1995).

Inorganic substrate values (% cover) were recorded at each site to determine if there were differences in the substrate heterogeneity between Stranger Creek and the reference streams. Transects were established along each available macrohabitat, and the

Figure 4. Box plots comparing riparian condition of Stranger Creek (all three sites combined) and reference streams. Data was also plotted from each Stranger Creek site separately in order to make comparisons between the three sites.

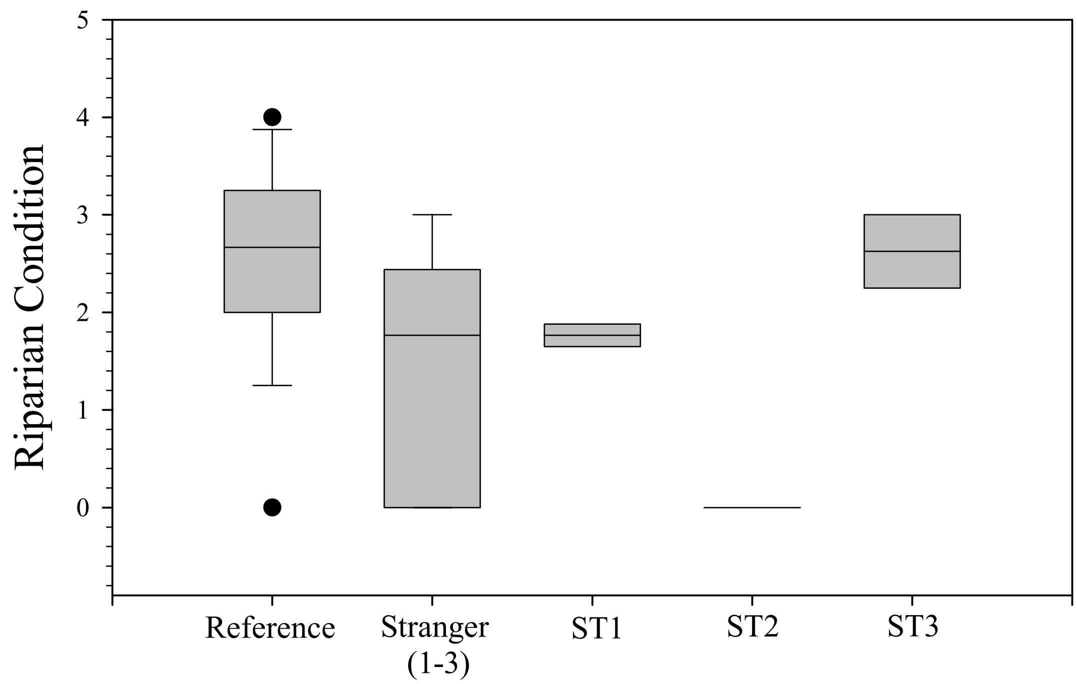
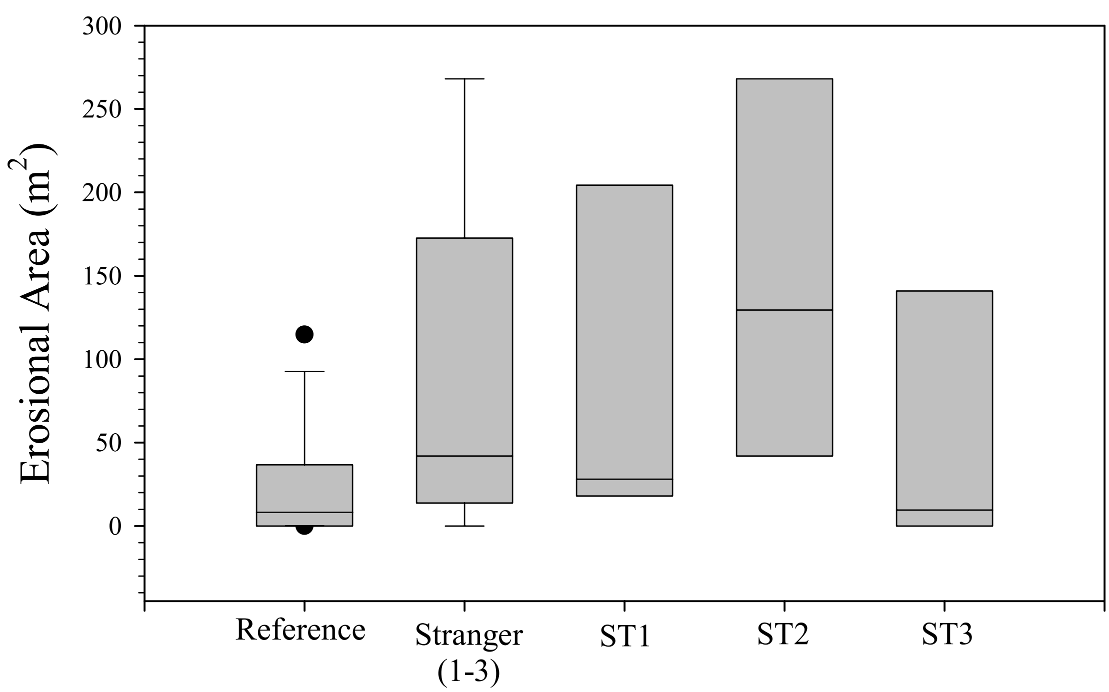


Figure 5. Box plots comparing erosion at Stranger Creek (all three sites combined) and reference streams. Data was also plotted from each Stranger Creek site separately in order to make comparisons between the three sites.



type of substrate that was present at 30 points within the section were measured. The overall inorganic substrate composition at all Stranger Creek sites combined was very diverse compared to that of the reference streams (Figure 6). The major substrate types present at Stranger Creek include cobble (22%), sand (13%), soft silt (30%), and hard clay/mud (26%) (Figure 6). 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, Stranger Creek appears to have a more diverse inorganic substrate then the reference streams. However, there were differences in the inorganic substrate composition between the three Stranger Creek sites. The inorganic substrate at ST1 and ST2 was much more diverse than the inorganic substrate at ST2 (Figure 6). For example, the dominant inorganic substrate type at both ST1 (38%) and ST3 (29%) was cobble. In addition, soft silt, hard clay, and sand all made up greater than 10% of the inorganic substrate composition at each of these two sites. In comparison, cobble was not present at ST2 and the dominated substrate types were soft silt (58%), hard clay (29%), and sand (10%). These differences in habitat heterogeneity likely effect the biotic community of Stranger Creek, as substrate heterogeneity is directly related to biotic diversity (Allen, 1995).

Discharge was calculated at for each site from depth and velocity measurements. A transect was established across the stream and at least ten measurements of depth and velocity were recorded along it. Discharge values increased downstream, as expected (Figure 7). The average discharge at ST1 was 0.73 m^3/s compared to 0.97 m^3/s at ST2 and 1.80 m^3/s at ST3.

Figure 6. Percent stream bottom cover for inorganic substrate occurring at Stranger Creek (all three sites combined). Data was also plotted from each Stranger Creek site separately in order to make comparisons between the three sites.

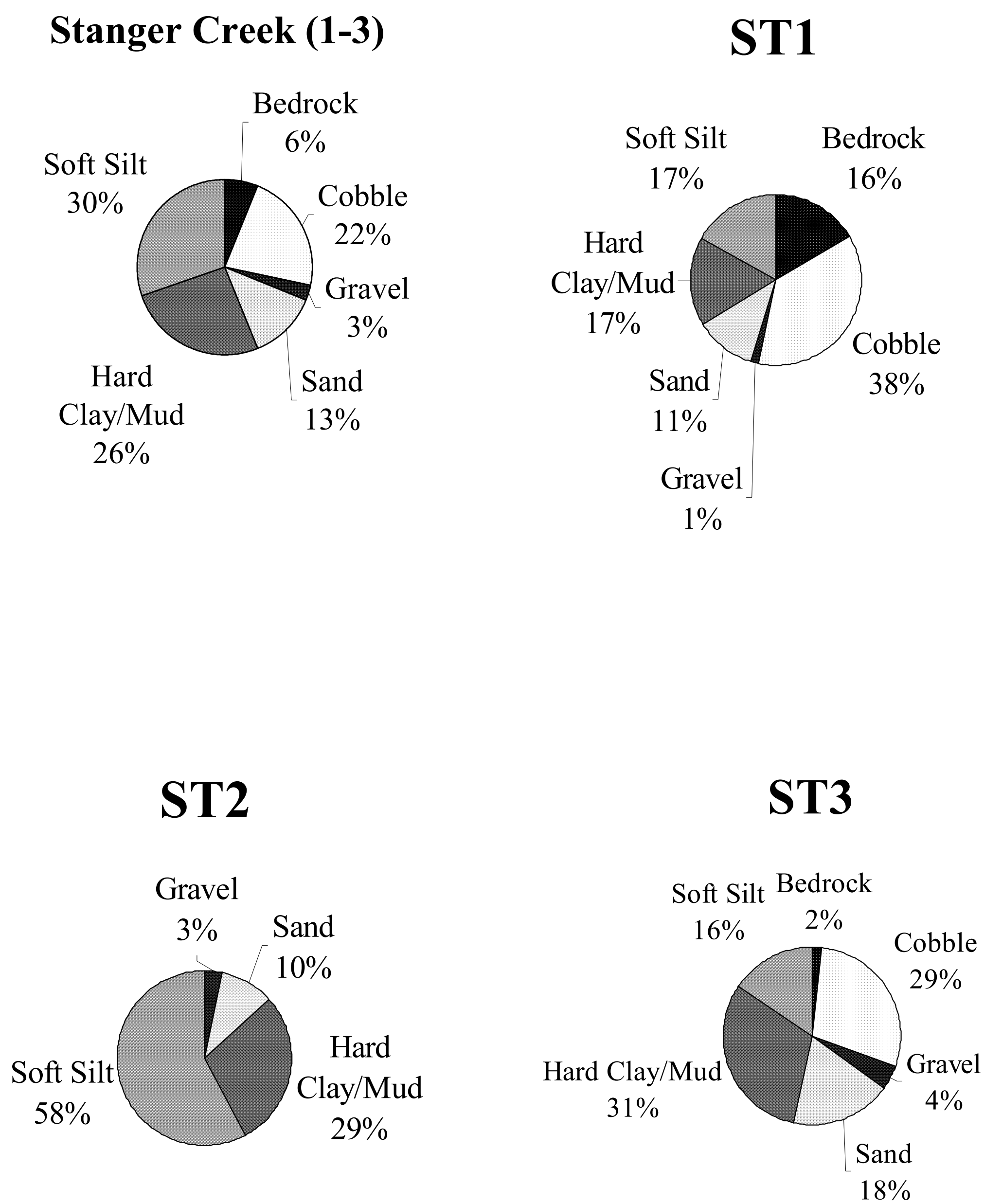
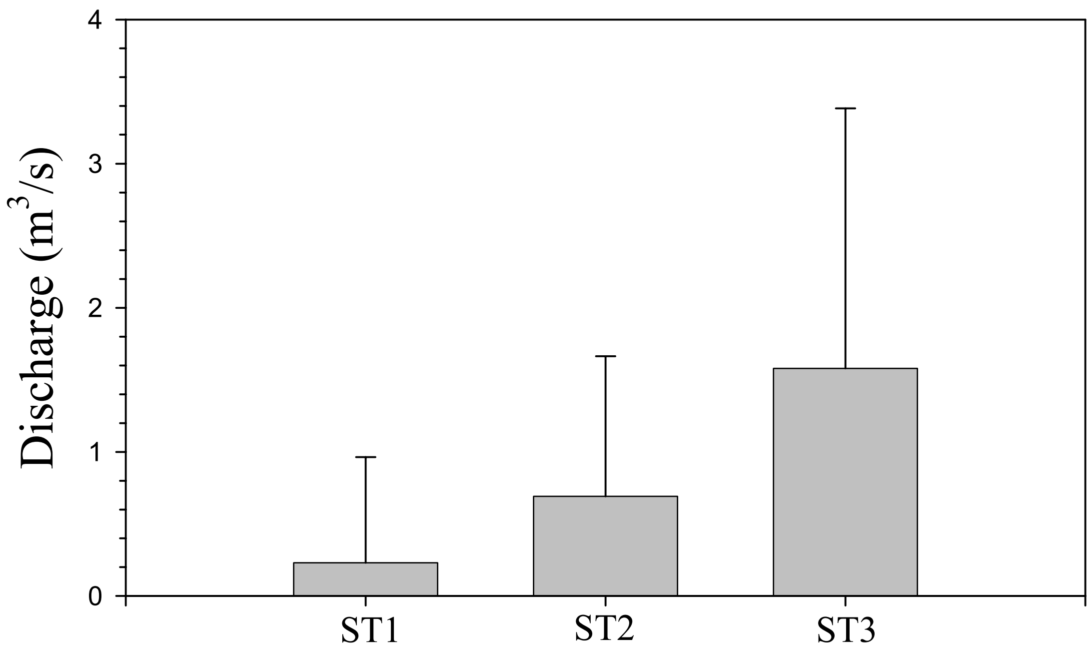


Figure 7. Stream discharge values for each Stranger Creek site. Data was averaged over the course of the study.



A number of additional habitat variables including animal access, vegetative cover, and undercut vegetation were measured at Stranger Creek. Animal access was determined to be insignificant at the three Stranger Creek sites as there was no evidence of livestock browsing, trailing, or waste deposits. Similarly, vegetative overhang was not present at any of the Stranger Creek sites, and undercut vegetation was present at ST1 in only small areas. Therefore, while all of these variables can have profound effects on the stream habitat and biota, it is unlikely that they greatly effect the ecological conditions at Stranger Creek.

Water Quality:

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 where they were analyzed for total phosphorus and nitrogen, alkalinity, hardness, chemical oxygen demand, and atrazine, a pesticide that is commonly used in this ecoregion. In addition, water samples were taken back to the local laboratory facilities for fecal coliform analysis. During each grab sample event, we also used an Horiba H_20 multi-probe water quality analyzer to record *in situ* measurements of temperature (°C), dissolved oxygen (mg/l), pH, turbidity (NTU) and conductivity (uohms).

The median pH value (8.34) for the three Stranger Creek sites was higher than the pH IQR range for the reference streams (7.9 – 8.1). In addition, there appeared to be differences between the median values of the three Stranger Creek sites (Figure 8), which were 8.22, 8.34, and 8.49 respectively. These median values are very close to the upper limit of the Kansas surface water criteria for maintenance of aquatic life (6.50 - 8.50). However, it is difficult to determine a definite cause for variations in pH values as natural factors such as geology effect pH concentrations. Therefore, it is unlikely that the observed increased pH values at Stranger Creek, are the result of pollution or degradation, but instead represent natural fluctuations.

Turbidity values were higher in Stranger Creek than in reference streams (Figure 9). The overall Stranger Creek median turbidity value, as well as the median turbidity values for each individual site were higher than the IQR of the reference streams (7 – 50 NTU). The median turbidity value for all Stranger Creek sites combined was 81 NTU and the median values for ST1, ST2, and ST3 were 71.0, 128.0, and 151.0 respectively (Figure 9). The Kansas surface water quality standards for turbidity and suspended solids maintain that artificially imposed suspended solid levels shall not impair the behavior, reproduction, physical habitat or any other factors related to any organism utilizing

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

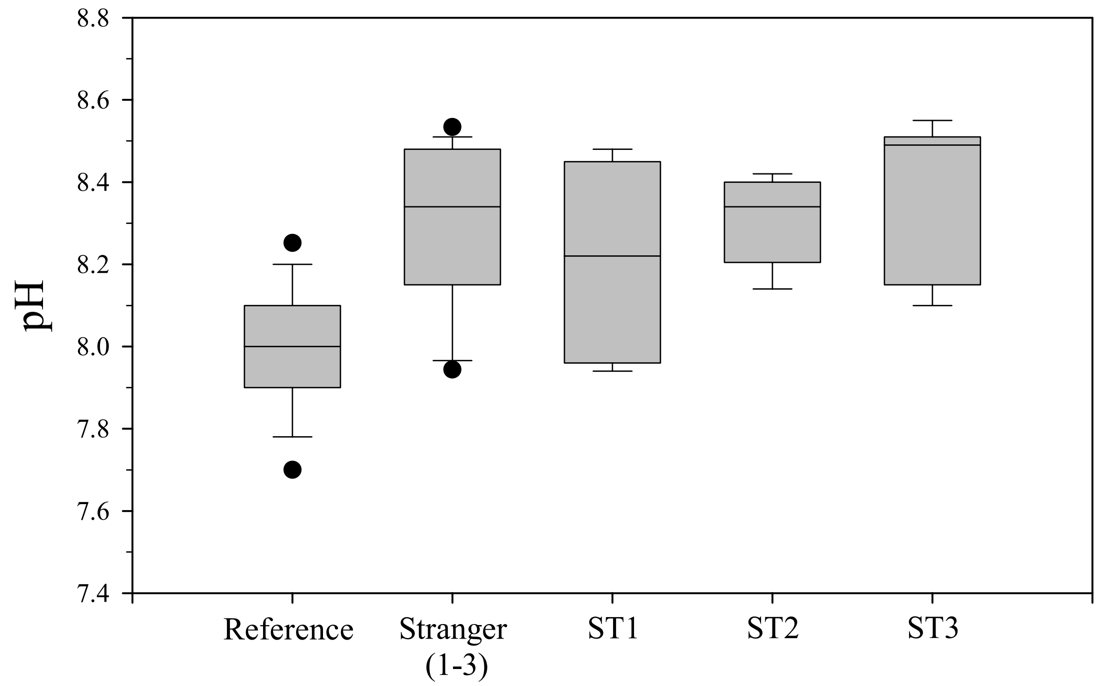
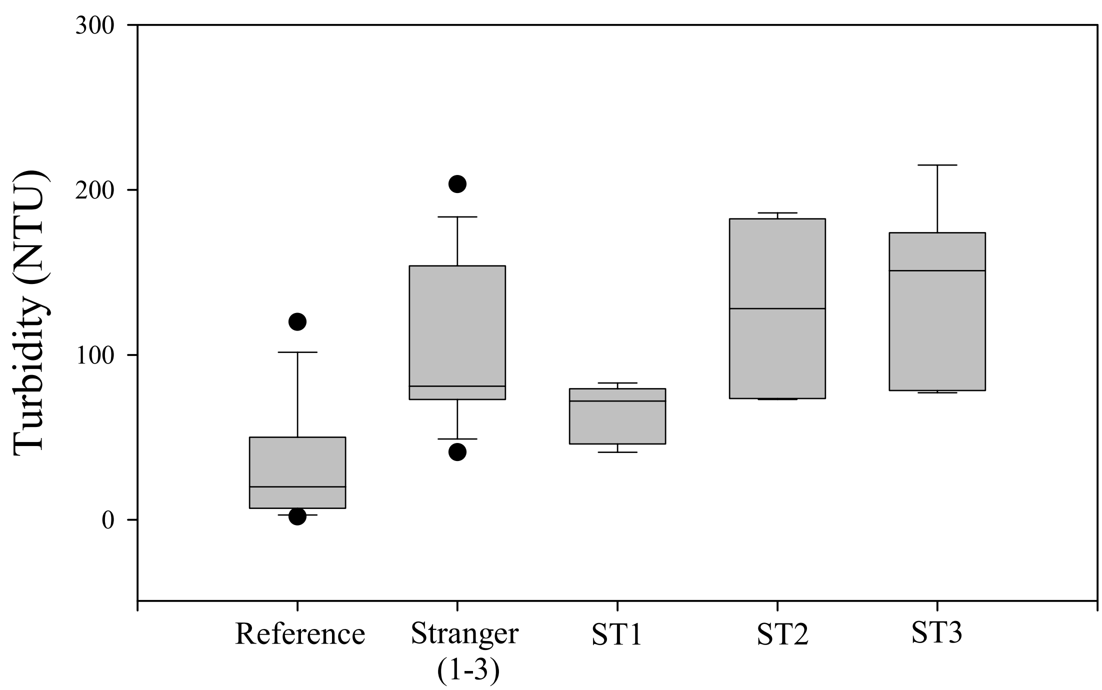


Figure 9. Box plots comparing turbidity at Stranger Creek (all three sites combined) and reference streams. Data was also plotted from each Stranger Creek site separately in order to make comparisons between the three sites.



surface water systems. While more data is needed from Stranger Creek to make this determination, turbidity was higher at Stranger Creek than in reference streams suggesting that this system has experienced some degradation. 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).

In comparison to reference conditions, dissolved oxygen (DO) concentrations were lower in Stranger Creek (Figure 10). The IQR for DO in reference streams was 8.30 mg/L to 10.7 mg/L. The Stranger Creek median value was 6.0 mg/L, which is well below the reference IQR. Dissolved oxygen levels were particularly low at ST1, where the median concentration (4.81 mg/L) was slightly below the Kansas surface water standard, which is set at 5.0 mg/L. The observed low DO levels in Stranger Creek may be the result of low primary productivity as a result of light limitation caused by increased turbidity. Turbidity induced light limitation of primary producers occurs in many mid-western agricultural streams (Munn *et al*., 1989). In addition, low DO levels may be the result of increased decomposition due to high inputs of organic matter from the watershed. While it is difficult to determine the actual causes of the observed low DO values at Stranger Creek, the recorded values were below reference values and near the lower limit of the Kansas surface water standards. Therefore, further monitoring is necessary to determine how degraded Stranger Creek has become with respect to DO concentrations, and the causes for this degradation.

The median conductivity value for all Stranger Creek sites combined (460 uohms) fell below the IQR for reference streams (Figure 11). This was true for all of the Stranger Creek sites. Conductivity is influenced by a number of natural factors including the surrounding geology, precipitation, and decomposition. While the values for Stranger 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,

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

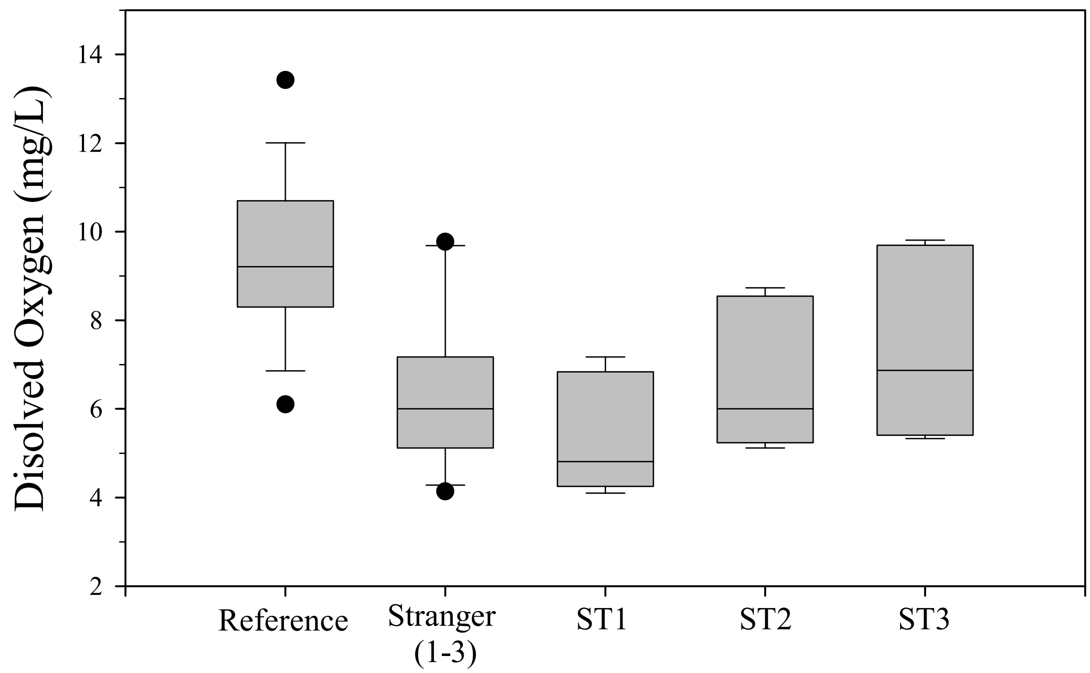
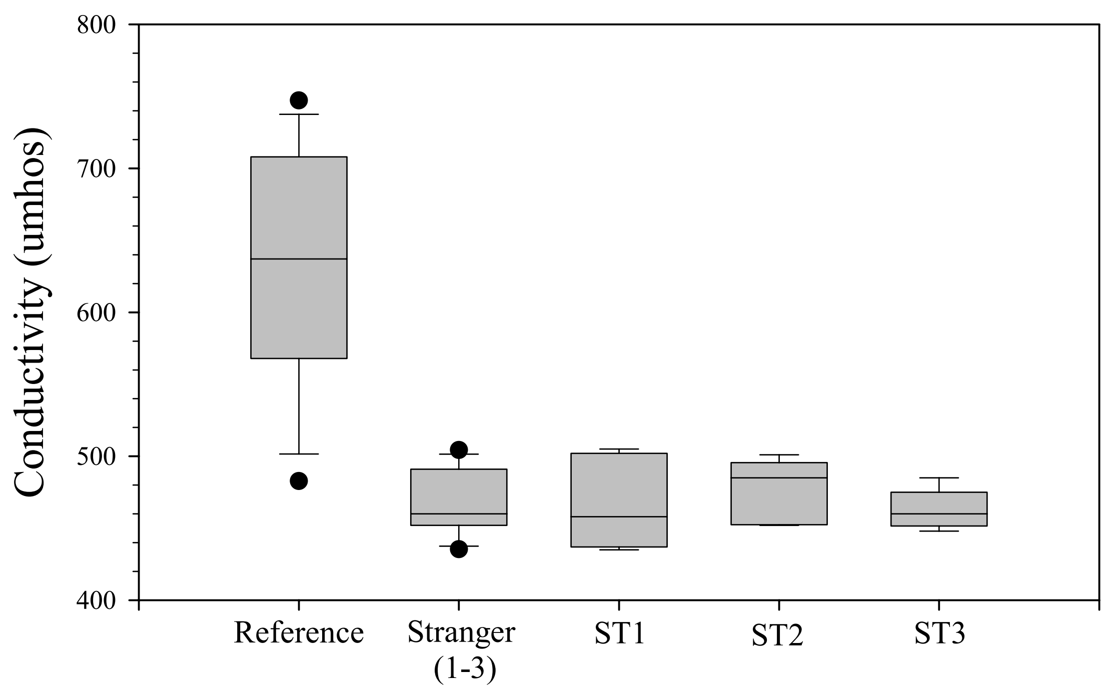


Figure 11. Box plots comparing conductivity (uohms) at Stranger Creek (all three sites combined) and reference streams. Data was also plotted from each Stranger Creek site separately in order to make comparisons between the three sites.



and ion concentrations often increase, not decrease as seen in our study, in response to pollution and disturbance (Allen, 1995).

There were no apparent differences between the alkalinity concentrations in Stranger Creek and in reference streams (Figure 12). The IQR of reference streams was 194 – 250 mg/L as $CaCO_3$ and the median value from all Stranger Creek sites combined was 206 mg/L. There were no differences between the three Stranger Creek sites. 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.

Similarly, there were no differences between Stranger Creek and reference streams with respect to hardness (Figure 13). The median value for all Stranger Creek sites combined (226 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 levels were lower in Stranger Creek than in reference conditions. The IQR of reference conditions was 1.34 mg/L to 4.44 mg/L compared to a median of 1.11 mg/L for all Stranger Creek sites combined (Figure14). Between the three sites, our results suggest that ST1 (1.21 mg/L) had the highest median level of total nitrogen, however this value was also below the reference IQR. With respect to total phosphorus, the median value for Stranger Creek (0.189 mg/L) was within the IQR (0.132 – 0.20 mg/L) for the reference streams (Figure 15). In contrast to total nitrogen concentrations however, ST1 had lower median total phosphorus (0.159 mg/L) than the other two sites.

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 the nutrient and biological data from this study are not extensive enough to make this determination, nutrient values were either lower

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

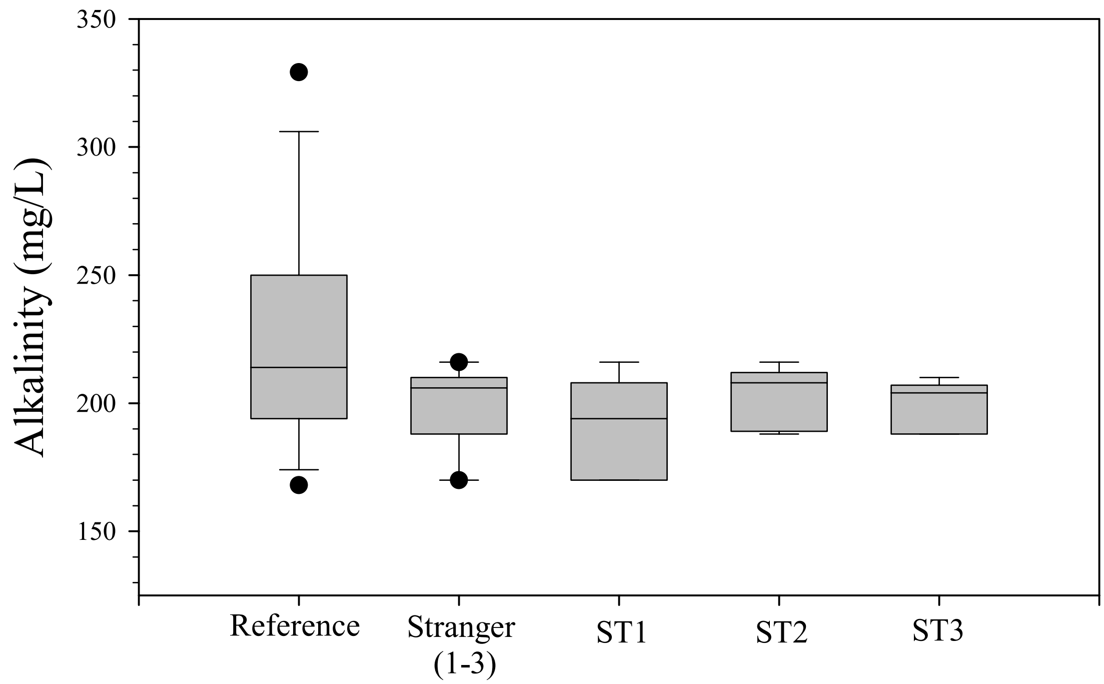
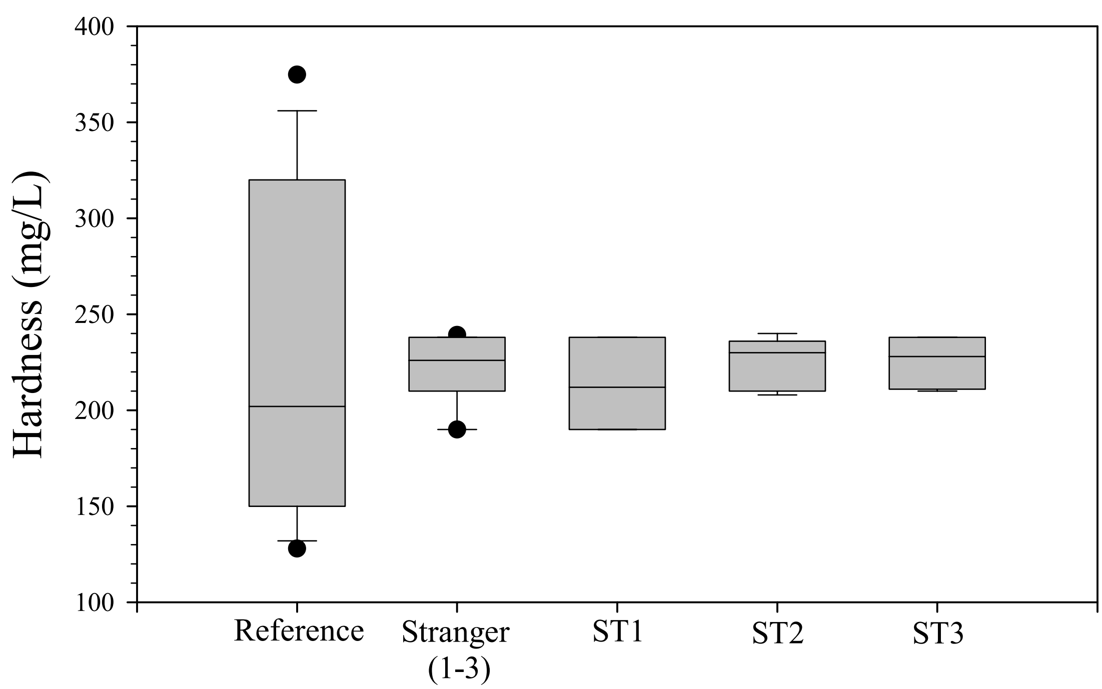


Figure 13. Box plots comparing hardness (mg/L) at Stranger Creek (all three sites combined) and reference streams. Data was also plotted from each Stranger Creek site separately in order to make comparisons between the three sites.



(total nitrogen) than or within (total phosphorus) reference streams ranges. Therefore, it does not appear that Stranger Creek is being impacted by elevated nutrient levels.

The chemical oxygen demand (COD) at Stranger Creek was higher than at the references streams (Figure 16). For example, the median value of all of the Stranger Creek sites combined was 16.76 mg/L, which is greater than the IQR for the reference streams (2.5 - 10.48 mg/L). In addition, all three Stranger Creek sites had COD values that were higher then the reference streams. These results suggest that Stranger Creek has a large amount of organic enrichment. However, these results are in contrast to total nitrogen and total phosphorus levels and further analysis is needed to determine the cause of elevated COD values at Stranger Creek.

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

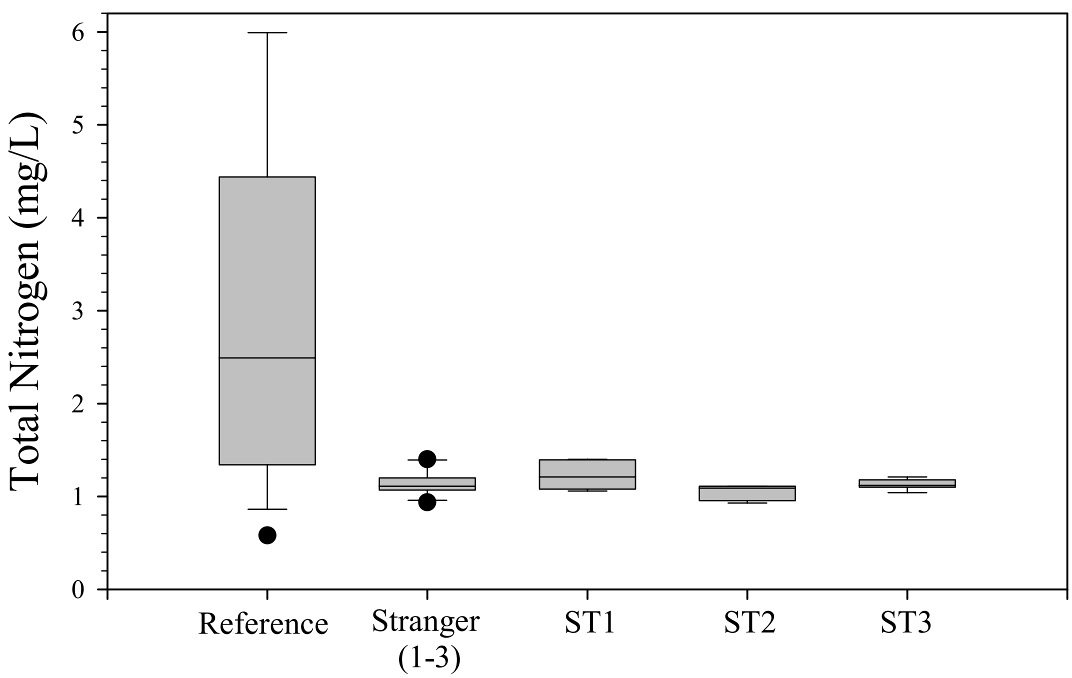


Figure 15. Box plots comparing total phosphorus (mg/L) at Stranger Creek (all three sites combined) and reference streams. Data was also plotted from each Stranger Creek site separately in order to make comparisons between the three sites.

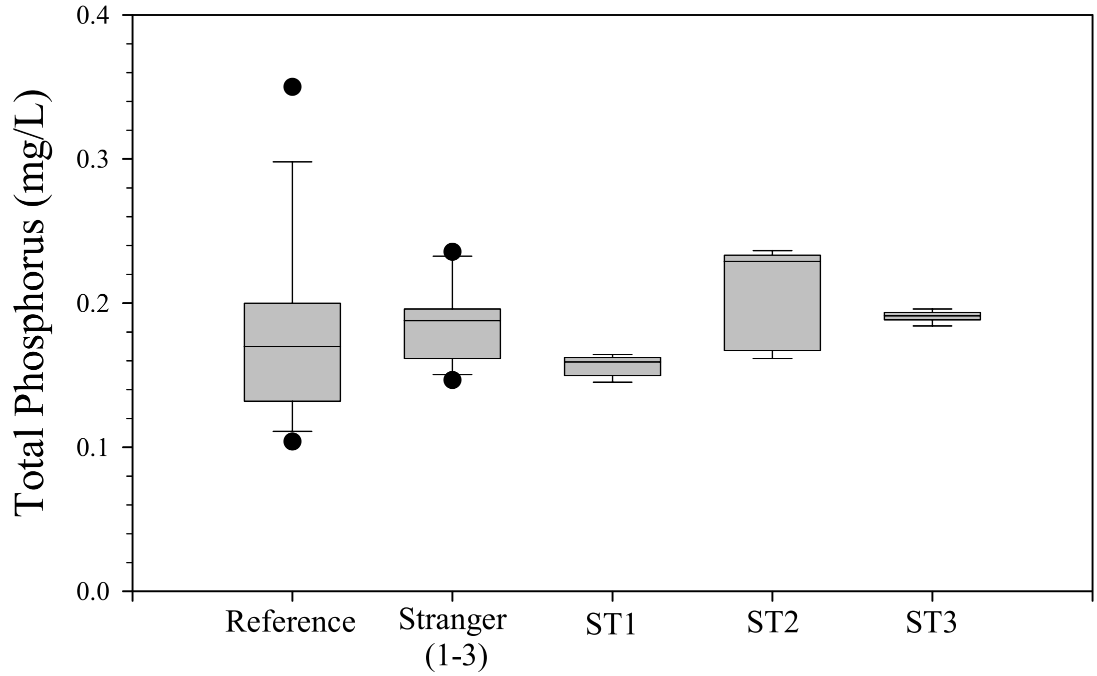
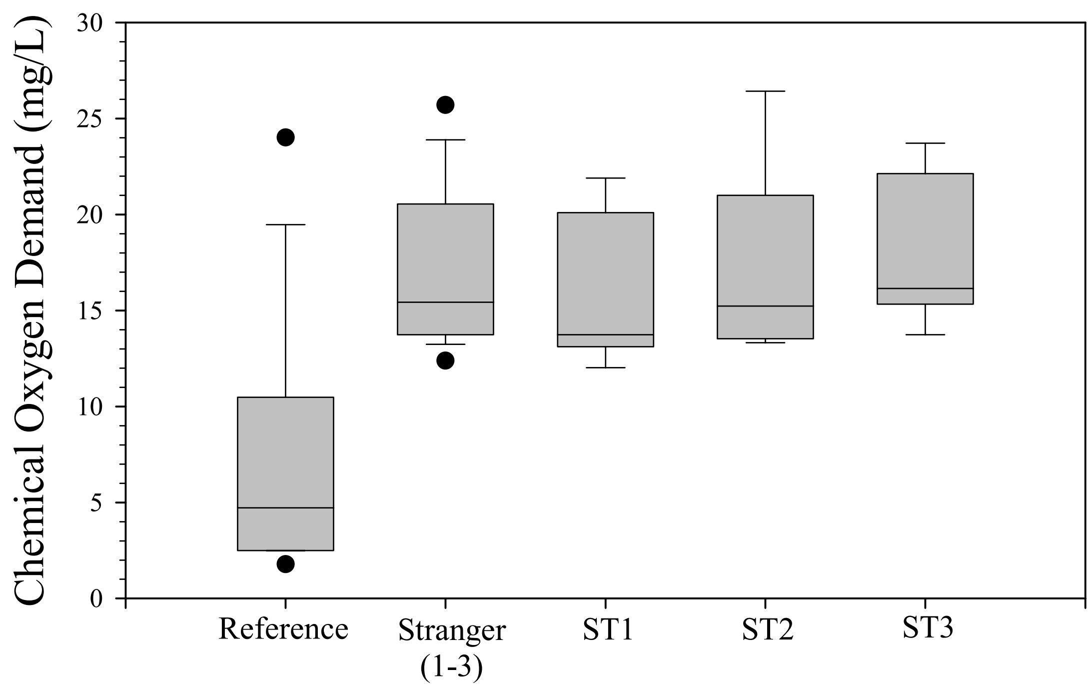


Figure 16. Box plots comparing chemical oxygen demand (mg/L) at Stranger Creek (all three sites combined) and reference streams. Data was also plotted from each Stranger Creek site separately in order to make comparisons between the three sites.



Atrazine levels at Stranger Creek were slightly higher than in reference streams (Figure 17). For example the median concentration for the Stranger Creek sites was 0.654 ug/L. This value is only slightly higher than the IQR range of atrazine values from the reference streams (0 – 0.60 ug/L) and well below the maximum contamination levels of 3.0 ug/L (Kansas Department of Health and Environment, 1994). It should be noted that concentrations greater than this maximum contamination level were observed at ST1 during the spring sampling event, however elevated atrazine concentrations are common in Kansas during this time (Trombley, 2001). 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).

Median fecal coliform concentrations at Stranger Creek were 504 organisms per 100 mL at ST1, 272 organisms per 100 mL at ST2, and 232 organisms per 100 mL at ST3 (Figure 18). While we were unable to compare these values to fecal coliform concentrations in reference streams, we did compare them to Kansas surface water criteria. 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 each site exceeded this criteria suggesting that Stranger Creek has elevated fecal coliform concentrations. In addition, the Kansas Department of Health and Environment (KDHE) conducted a Total Maximum Daily Load (TMDL) for Stranger Creek, and found that fecal coliform concentrations exceeded these set limits for 36% of the samples collected within the watershed. As a result, Stranger Creek has been labeled a high priority watershed for water quality improvement implemenation. The TMDL suggests that the cause of elevated fecal coliform levels are the result of non-point pollution sources, and that activities to reduce fecal contamination should be directed at smaller, unpermitted livestock operations and rural homesteads and farmsteads within the watershed.

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

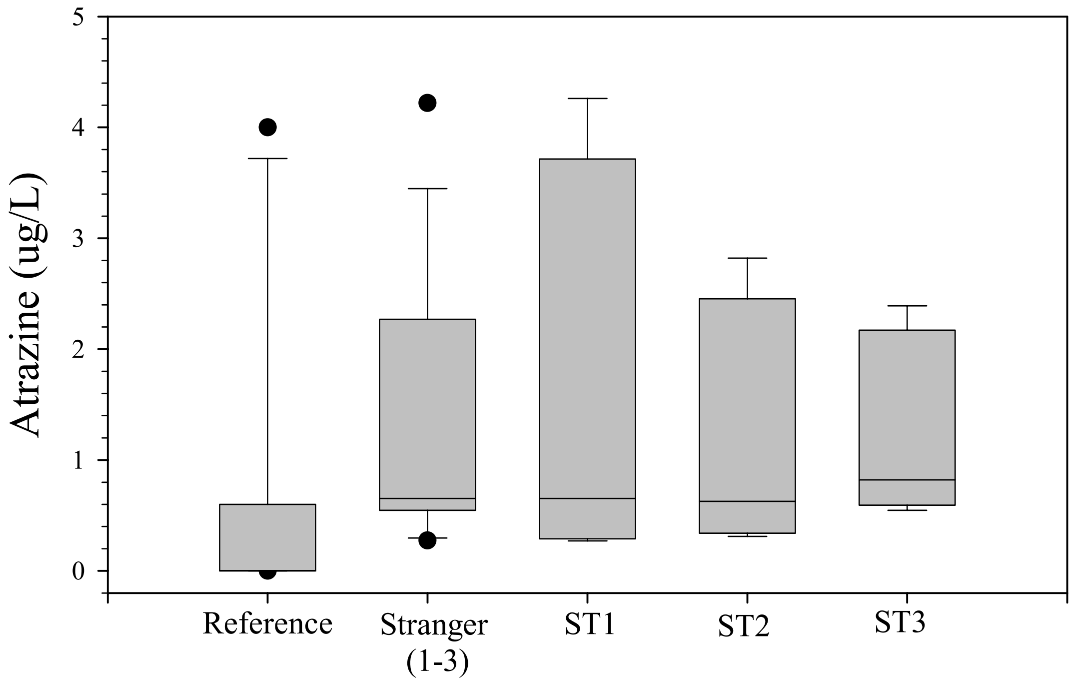
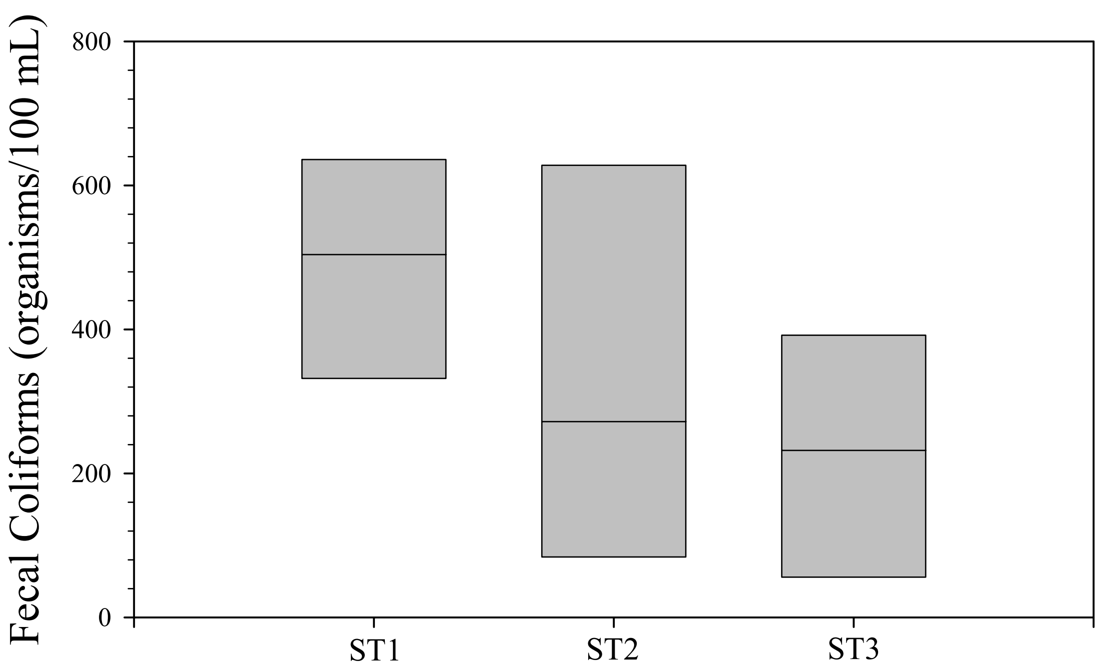


Figure 18. Box plots comparing fecal coliform bacteria (org./100 mL) at Stranger Creek (all three sites combined) and reference streams. Data was also plotted from each Stranger Creek site separately in order to make comparisons between the three sites.



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. Periphyton communities are strongly effected by 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. We did compare the three Stranger Creek sites however, to determine if differences existed in periphyton concentrations.

Chlorophyll *a* concentrations did not differ significantly between the three Stranger Creek sites. The median values for each site are very similar (Figure 19), and there is considerable overlap between the range of values from each site. Similar results were obtained with respect to Pheophytin *a* concentrations, which did not differ significantly between the three sites (Figure 20). For example, the median value at ST1 was 14.5 ug/L compared to 15.9 ug/L at ST2 and 18.6ug/L at ST3.

Figure 19. Box plots comparing chlorophyll *a* (ug/L) concentrations at the three Stranger Creek sites.

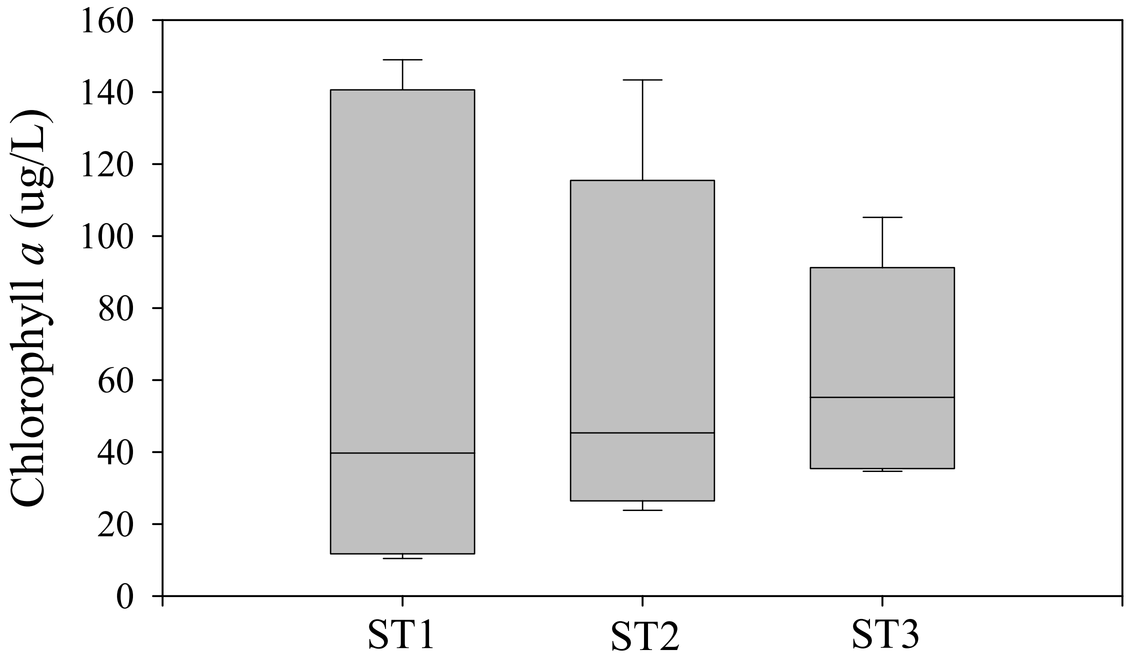
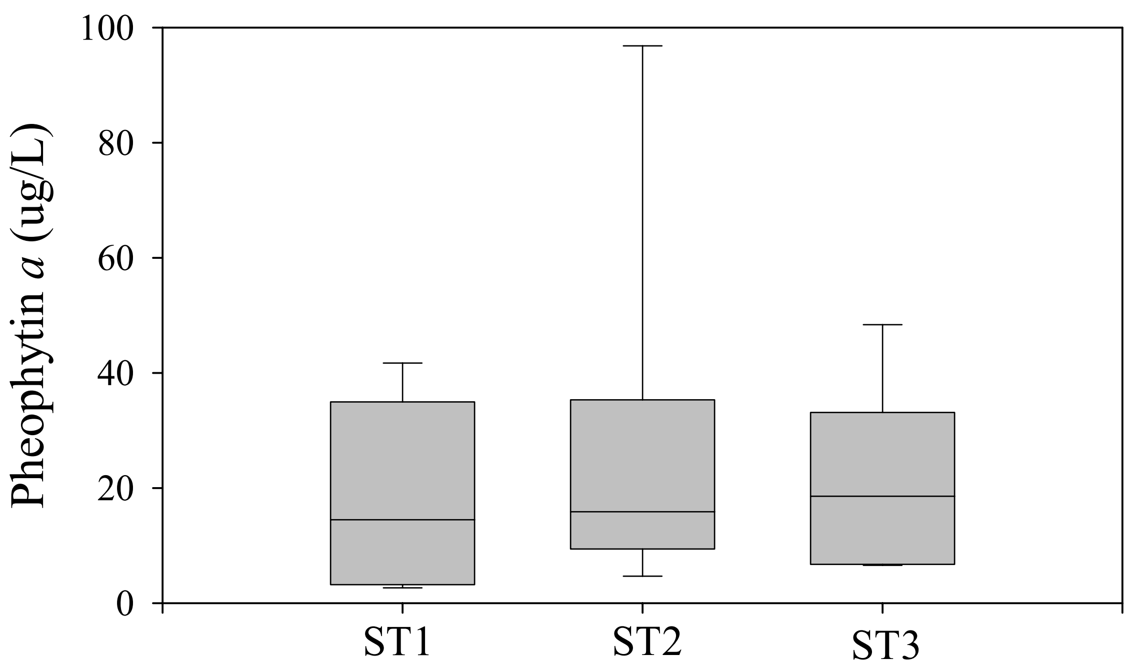


Figure 20. Box plots comparing pheophytin *a* (ug/L) concentrations at the three Stranger Creek sites.



Overall there do not appear to be differences in chlorophyll *a* and pheophytin *a* concentrations between the three Stranger Creek sites, however there was a great deal of variation between sampling dates. Therefore, we plotted time series data for chlorophyll *a* and pheophytin *a* concentrations, to look at differences over time. For both measurements, there was a sharp increase during the summer sampling event at each site (Figure 21, 22). This observed peak in periphyton production is likely related to a variety of factors including nutrient concentrations, stream shdaing, and turbidity, however based on the available number of samples, it is difficult to determine the responsible mechanisms.

Figure 21. Box plots comparing chlorophyll *a* (ug/L) concentrations at Stranger Creek over the course of the study.

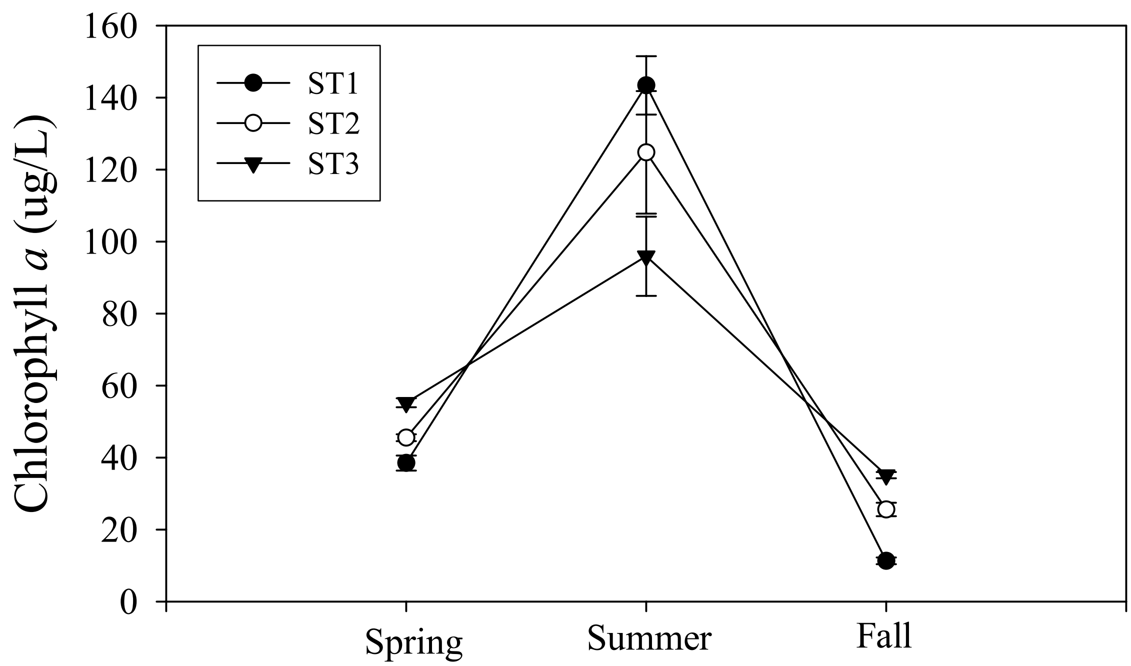
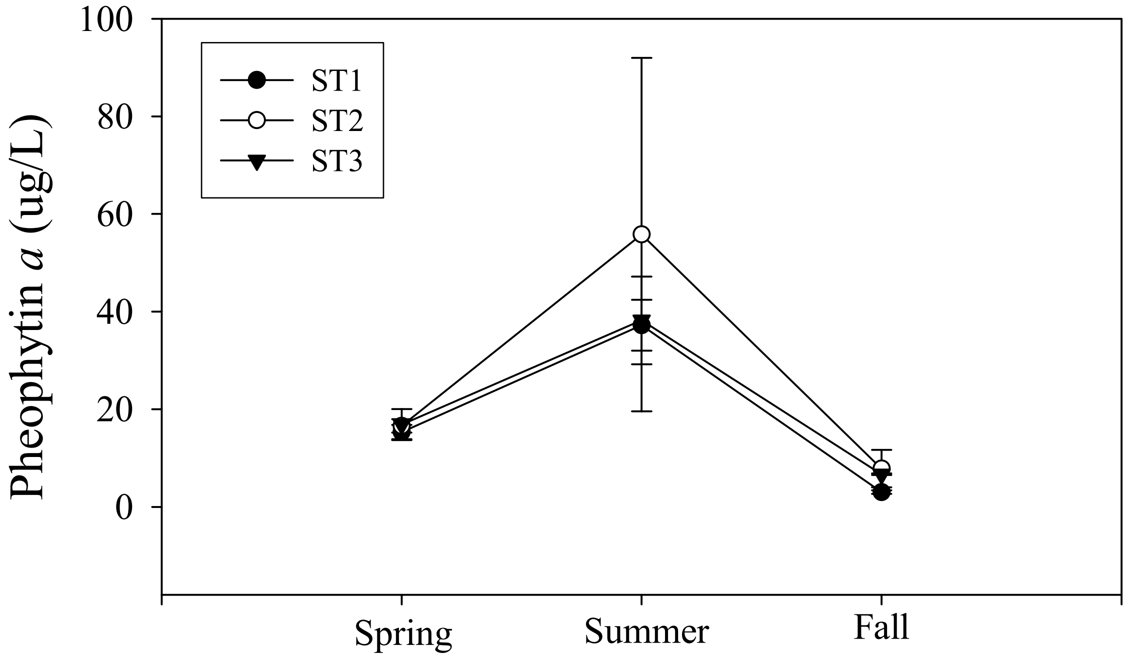


Figure 22. Box plots comparing pheophytin *a* (ug/L) concentrations at Stranger Creek over the course of the study.



Fish Community*:*

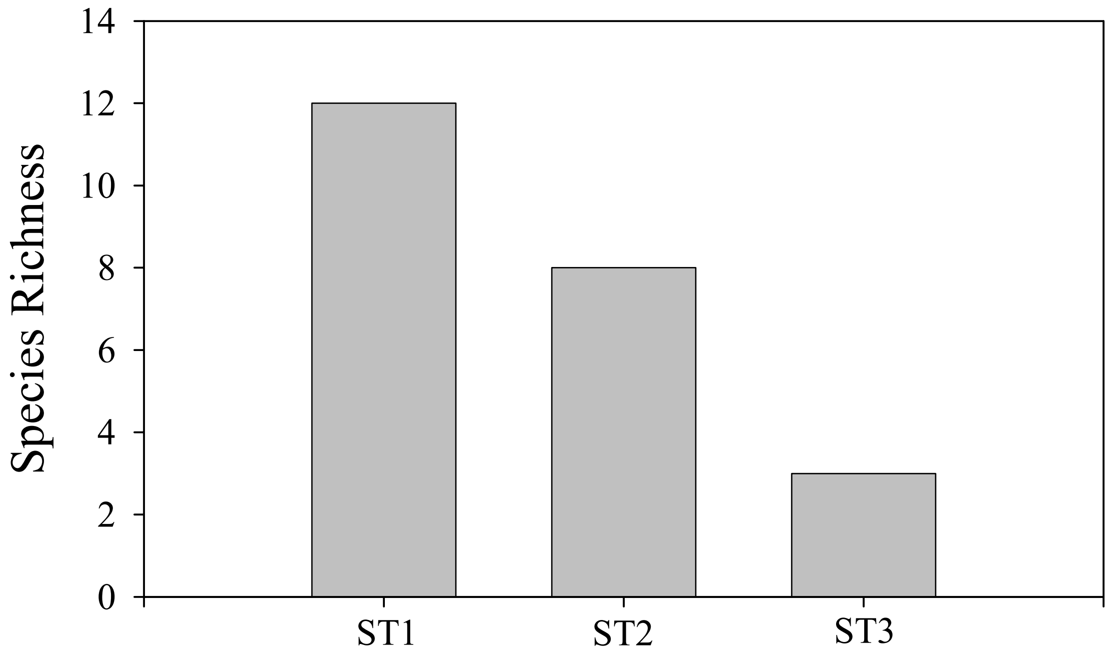
Samples were collected from each site for analysis of fish community structure. Representative portions of the available macrohabitats were individually blocked off and sampled first with seines and then electrofished with a backpack shocker. Fish samples were preserved in formalin and returned to the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

We did not make comparisons between Stranger Creek and the reference sites because of differences in stream flow and the size of the drainage basins, both of which effect species richness and community composition (e.g. Karr *et al*., 1986; Miller *et al*., 1988; EPA, 1996). In addition, sampling effort at Stranger Creek was based on the number of available macrohabitats and therefore varied between the three sites. For example, fish were collected from ST1 during all three sampling events. However, due to elevated flow, we only collected samples from ST2 during the spring and fall sampling events and from ST3 during the fall sampling event. Therefore, there were differences in the sampling effort between sites, and comparisons should be interpreted with caution. In order to provide an initial assessment of the fish community at Stranger Creek we compared species richness and community structure between the three sites.

Species Richness:

Species richness varied between the three Stranger Creek sites (Figure 23). A total of 12 species were collected from ST1, compared to only 8 species from ST2, and 5 species from ST3 (Figure). The species that occurred at ST 1 but not at ST2 and ST3 include *Carpiodes carpio, Moxostoma macrolepidtum, Notorus flavus, Polydictis* *olivaris*, and *Etheostoma spectabile* (Table 2). There was also one species, *Pimephales vigilax*, which was found only at ST2 and ST3. *Percina phoxocephala* was found exclusively at ST2, and *Aplodinotus grunniens* was found exclusively at ST3 (Table 2).

Figure 23. Comparison of fish species richness at the three Stranger Creek sites.



Community Composition:

While species richness varied between the three sites, there were similarities in the relative species density (Table 3). For example, the red shiner (*Cyprinella lutrensis*) was the most abundant species at all three sites. *Cyprinella lutrensis* accounted for approxiametely 82-92% of the total fish community at ST1, 59-93% of the fish community at ST2, and 72% of the fish community at ST3. *Cyprinella lutrensis* is common in Kansas and is tolerant to unstable conditions caused by irregular flow, turbid

Table 2. Total fish abundance data for each Stranger Creek site over the course of the study. Fish were sampled in the spring (5/5/01), summer (7/9/01), and fall (9/11/01) of 2001. Total stream length sampled varied between sites.

	ST1			ST2			ST3		
	5/5/01	7/9/01	9/11/01	5/5/01	7/9/01	9/11/01	5/5/01	7/9/01	9/11/01
Cyprinidae									
Cyprinella lutrensis	585	1431	953	281	na	139	na	na	58
Notropus ludibundus	6	21	1	6	na	0	na	na	0
Phenacobius mirabilis	0	0	0	0	na	0	na	na	2
Pimephales notatus	75	69	78	11	na	17	na	na	0
Pimephales vigilax	0	0	0	0	na	6	na	na	4
Catostomidae									
Carpiodes carpio	0	1	0	0	na	0	na	na	0
Moxostoma macrolepidotum	1	0	0	0	na	0	na	na	0
Ictaluridae									
Ictalurus punctatus	7	56	0	1	na	72	na	na	16
Notorus flavus	1	0	0	0	na	0	na	na	0
Polydictis olivaris	2	3	0	0	na	0	na	na	0
Centrarchidae									
Lepomis cyanellus	32	1	0	1	na	0	na	na	0
Lepomis macrochirus	3	36	3	1	na	0	na	na	0
Percidae									
Aplodinotus grunniens	0	0	0	0	na	0	na	na	1
Percina caprodes	2	2	1	0	na	0	na	na	0
Percina phoxocephala	0	0	0	0	na	2	na	na	0
Etheostoma spectabile	1	6	2	0	na	0	na	na	0
TOTAL	**715**	**1626**	**1038**	**301**	**--**	**236**	**--**	**--**	**81**

Table 3. Relative fish abundance data for each Stranger Creek site over the course of the study. Fish were sampled in the spring (5/5/01), summer (7/9/01), and fall (9/11/01) of 2001. Total stream length sampled varied between sites.

	ST1			ST2			ST3		
	5/5/01	7/9/01	9/11/01	5/5/01	7/9/01	9/11/01	5/5/01	7/9/01	9/11/01
Cyprinidae									
Cyprinella lutrensis	81.8	88.0	91.8	93.36		58.9			71.60
Notropus ludibundus	0.84	1.29	0.09	1.99		0			0
Phenacobius mirabilis	0	0	0	0		0			2.47
Pimephales notatus	10.49	4.24	7.51	3.65		7.20			0
Pimephales vigilax	0	0	0	0		2.54			4.94
Catostomidae									
Carpiodes carpio	0	0.06	0	0		0			0
Moxostoma macrolepidotum	0.14	0	0	0		0			0
Ictaluridae									
Ictalurus punctatus	0.98	3.44	0	0.33		30.51			19.75
Notorus flavus	0.14	0	0	0		0			0
Polydictis olivaris	0.28	0.18	0	0		0			0
Centrarchidae									
Lepomis cyanellus	4.47	0.06	0	0.33		0			0
Lepomis macrochirus	0.42	2.21	0.29	0.33		0			0
Percidae									
Aplodinotus grunniens	0	0	0	0		0			1.23
Percina caprodes	0.28	0.12	0.09	0		0			0
Percina phoxocephala	0	0	0	0		0.85			0
Etheostoma spectabile	0.14	0.37	0.19	0		0			0
TOTAL	**100%**	**100%**	**100%**	**100%**		**100%**			**100%**

water, and pollution (Cross and Collins, 1995). At St2 (fall sampling event) and ST3, *Ictalurus punctatus*, which is also a common species that does well in turbid water (Cross and Collins, 1995), accounted for a larger percentage (20-30%) of the population. The large abundance of *Ictalurus punctatus* at ST2 during the fall sampling event (30.5%) is somewhat surprising due to the homogeneous instream habitat at this site (Figure 6). This species is often found in the greatest abundance in streams with habitat dominated by sandy or rocky bottoms (Cross and Collins, 1995), both of which were not present at ST2

We also used tolerant levels provided by Barbour *et al*. (1999) to determine how many intolerant, intermediate, and tolerant species were detected at Stranger Creek. Of the 16 total species detected at Stranger Creek, 10 were intermediate species and 4 were tolerant species. The stonecat (*Notorus flavus*) and the slenderhead darter (*Percina phoxocephala*) were the only two intolerant species present at Stranger Creek, and they were both present in small densities (Table 2). Intolerant species are typically the first species to disappear following a disturbance (Barbour *et al*., 1999).

This initial analysis of fish communities at Stranger Creek suggests that species richness is greater at ST1 than it is at ST2 and ST3 (Figure 23). Similarities do exist however with respect to community composition, as red shiner (*Cyprinella lutrensis*) dominated the fish community at each site (Table 2, 3). In addition, tolerant and intermediate species dominate the fish communities in Stranger Creek. Habitat structure plays an important role in fish community structure (Gorman and Karr, 1978) and it is therefore likely that the reduced habitat diversity at ST2 negatively effects community structure. Based on the limited number of samples and the differences in sampling effort between the three sites however, it is difficult to make definite conclusions about the health of the fish community in Stranger Creek. Therefore, while data suggests that there are between site differences, more sampling is needed to determine to what degree the fish community varies between sites, and to determine to what degree the fish community has been degraded overall in Stranger Creek.

Macroinvertebrate Community:

Macroinvertebrate communities are often used 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). Degradation of the macroinvertebrate community 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).

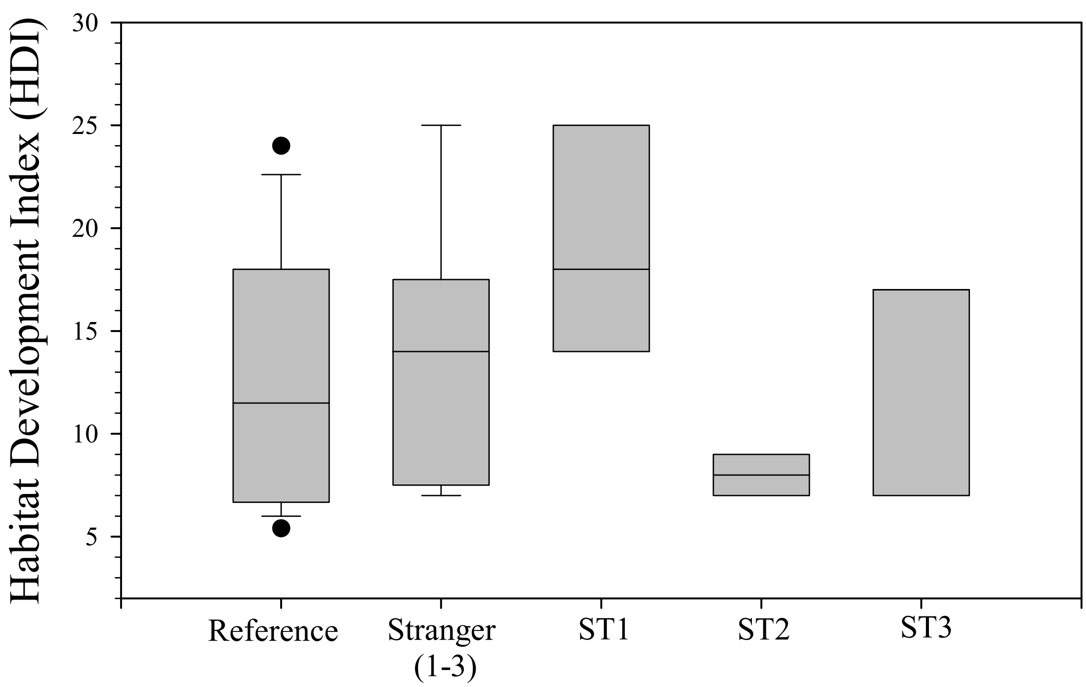
Three macroinvertebrates samples were collected at each site from the available macrohabitats (e.g. one each in riffle, run, and pool) during each sampling event. In instances where all of these macrohabitats were not present at a single site, the existing macrohabitat(s) was subdivided and a sample 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.

The Habitat Development Index (HDI) values calculated for Stranger Creek were similar to those from the reference streams (Figure 24). For all Stranger Creek sites combined, the median HDI value was 14, which is within the reference IQR range for HDI values (6.67 – 18.0). The median HDI value from ST2 (8) however, was lower then the median HDI values from ST1 (17) and ST3 (18). This data suggests that the habitat at ST2 is more homogeneous then at ST1 and ST3, and that the habitat at ST1 and ST3 is potentially capable of supporting a more diverse community of macroinvertebrates.

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



Aquatic Invertebrates:

Several types of metrics were used to determine if macroinvertebrate communities within Stranger 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. Diversity indices (Shannon Diversity) are often incorporated in bioassessment studies because they incorporate both richness and evenness (the proportion of individuals in each taxa) into a single value. High values often indicate the presence of diverse, stable communities (Washington, 1984).

Taxa Richness:

Taxa richness did not deviate between Stranger Creek and the reference watersheds (Figure 25). The IQR for reference watershed was 11 – 15 families compared to a median of 14 families for Stranger Creek. In comparing the three Stranger Creek sites separately however, our data suggests that family richness was slightly lower at ST2 where the median value was 10 families, which is below the reference range. A similar pattern was observed with respect to EPT richness (Figure 26). The median EPT richness for the three Stranger Creek sites was 4 families. The IQR range of EPT richness for the reference stream was 4 – 6 families. The median EPT richness at ST2 (3 families) was slightly lower then the reference IQR. These results suggest that for both overall richness and richness of sensitive taxa, ST2 exhibits conditions below that of reference streams. It is likely that this reduction is in part the result of reduced habitat heterogeneity at ST2 (Figure 6, 24)

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

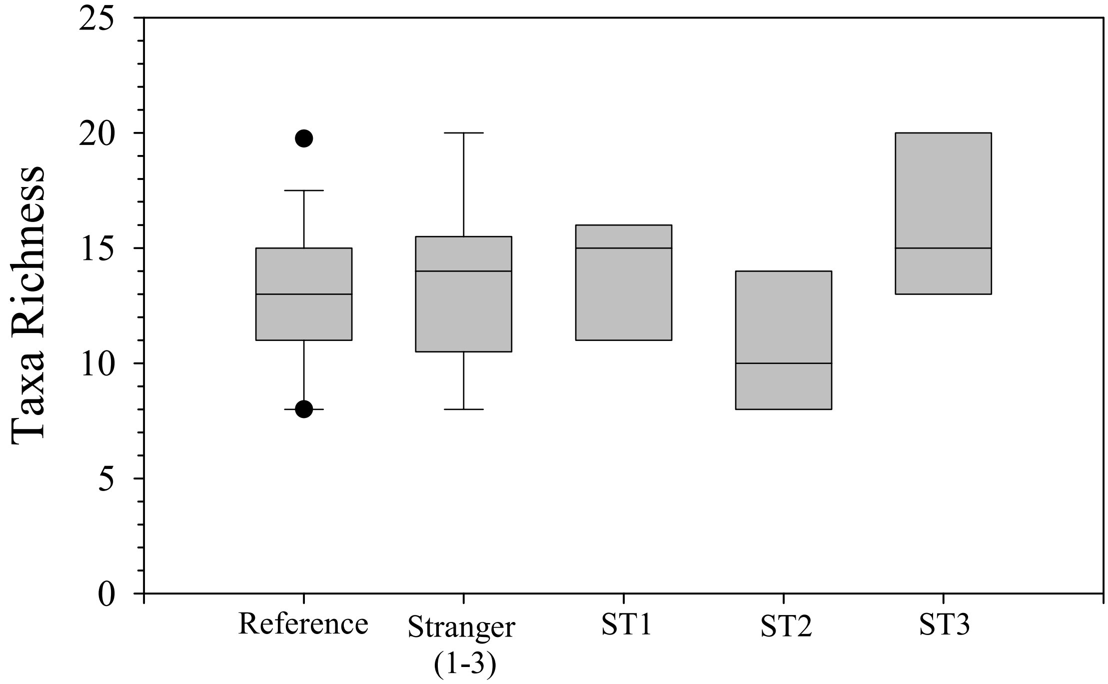
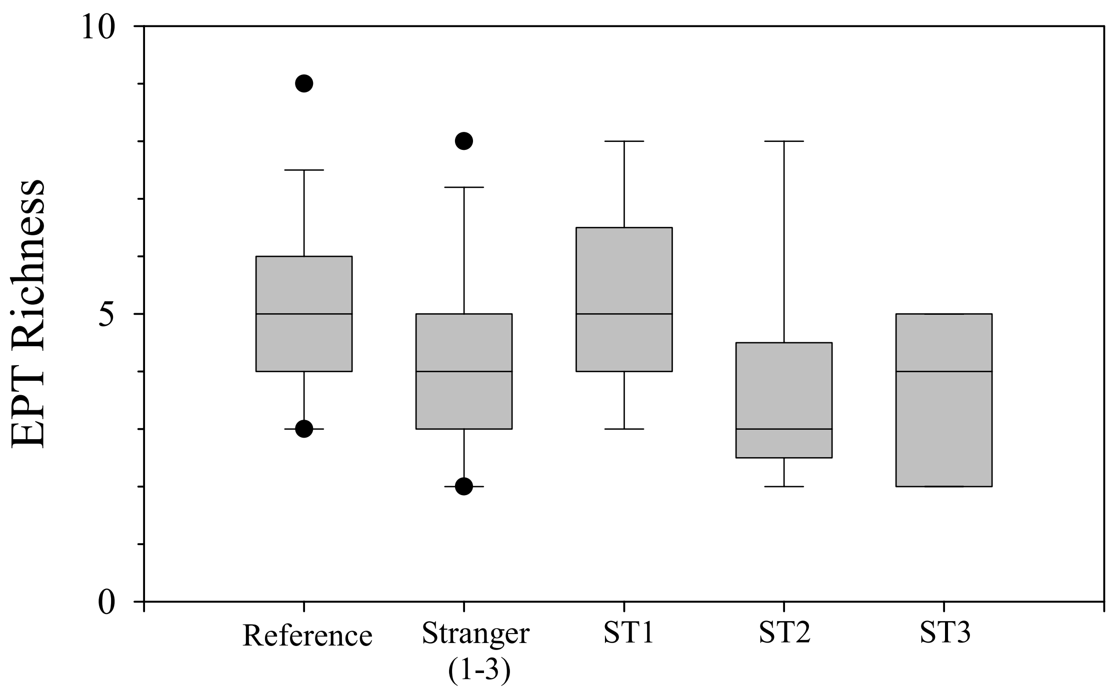


Figure 26. Box plots comparing EPT richness at Stranger Creek (all three sites combined) and reference streams. Data was also plotted from each Stranger Creek site separately in order to make comparisons between the three sites.



Abundance:

Total abundance for macroinvertebrates at Stranger Creek fell within the IQR range for reference streams (Figure 27). The abundance of EPT taxa however, was lower in Stranger Creek (Figure 28). For example, the median value for all Stranger Creek sites combined was 21 individuals compared to the IQR range from reference streams, which was 30 – 265 individuals. Only at ST1 did the median EPT abundance (72 individuals) value fall within the reference IQR range. The EPT abundance values at ST2 (8 individuals) and ST3 (18 individuals) fell below the reference IQR range. These results suggest that there is some deviation from reference conditions at Stranger Creek with respect to macroinvertebrate communities and further sampling and monitoring is warranted.

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

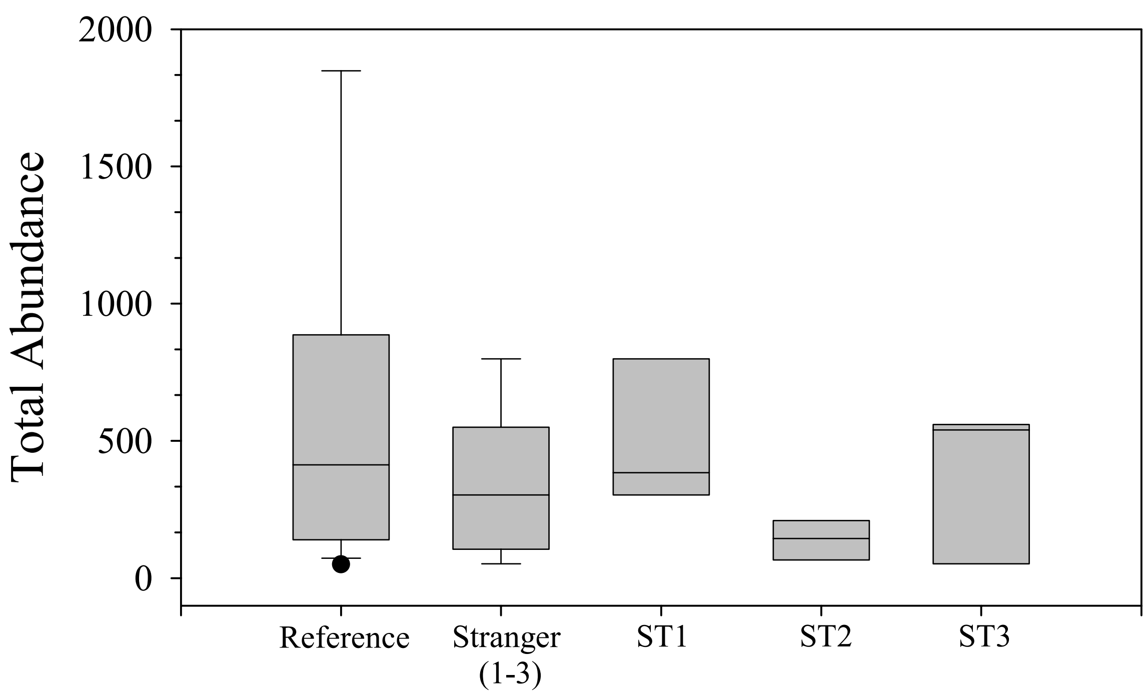
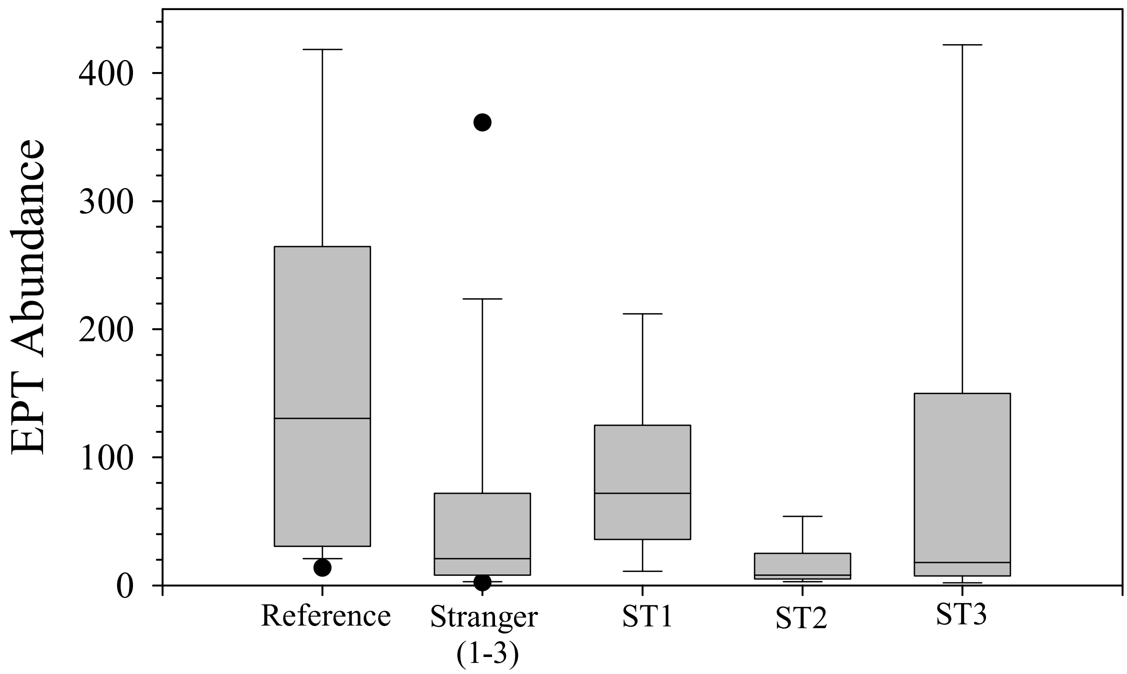


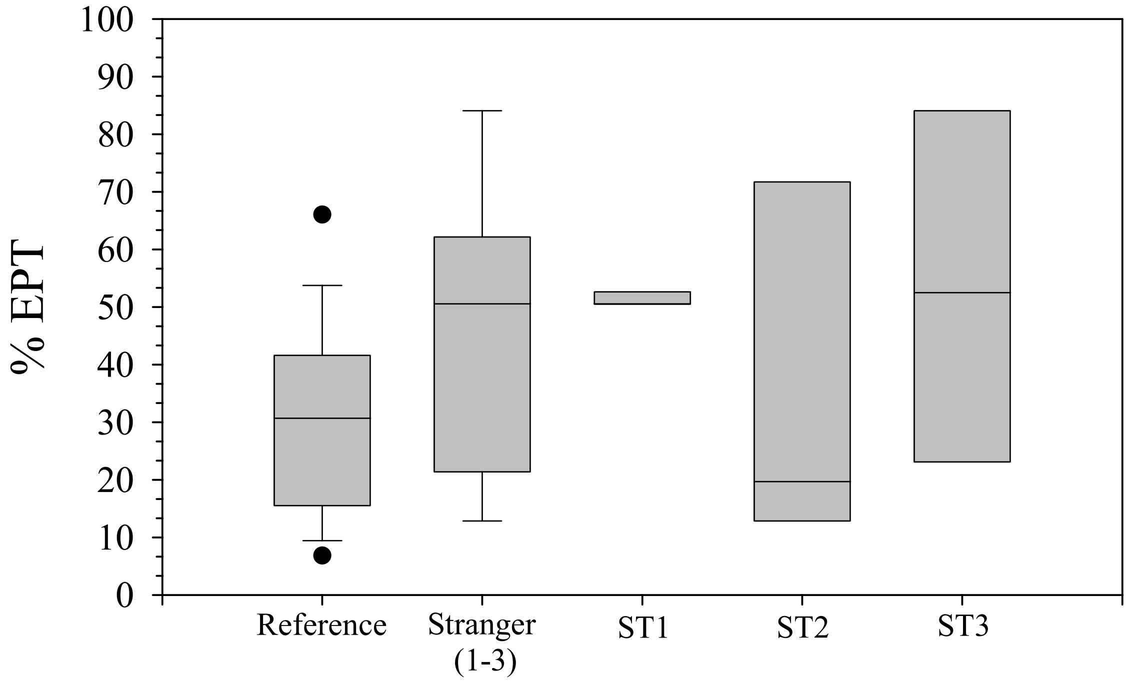
Figure 28. Box plots comparing EPT abundance at Stranger Creek (all three sites combined) and reference streams. Data was also plotted from each Stranger Creek site separately in order to make comparisons between the three sites.



Community Composition (%EPT):

In contrast to EPT abundance, the median %EPT from Stranger Creek was greater then the reference IQR for %EPT (Figure 29). For example, 50.56% of the invertebrate community at Stranger Creek was comprised of EPT taxa. In contrast, the range for reference streams was 16.66-41.38%. As with the other metrics used to assess the invertebrate community at Stranger Creek however, the median %EPT value for ST2 (19.7) was considerably lower then the medians for ST1 and ST3. This data further suggests that while the three sites combined are similar to reference conditions, the conditions at ST2 have deviated from reference conditions.

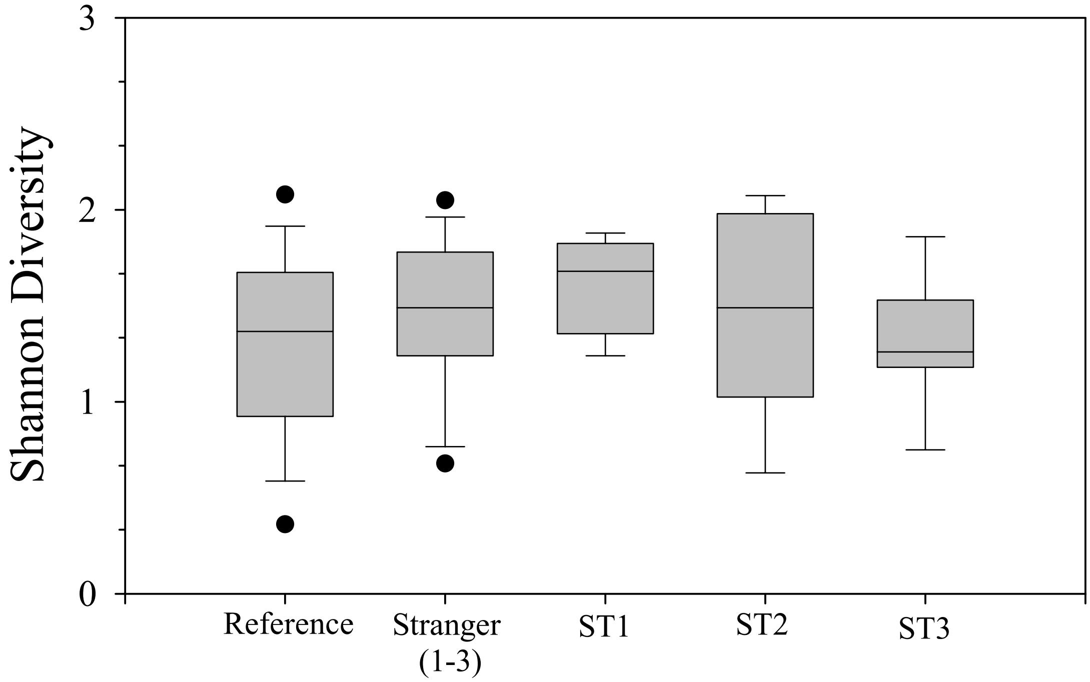
Figure 29. Box plots comparing %EPT at Stranger Creek (all three sites combined) and reference streams. Data was also plotted from each Stranger Creek site separately in order to make comparisons between the three sites.



Diversity Index:

There were no significant differences in Shannon Diversity between Stranger Creek and the reference streams (Figure 30). For example, the IQR range for reference streams was 0.92 – 1.67, and the medians for each of the three Stranger Creek sites were 1.68, 1.49, and 1.26. Contrary to the other metrics used to assess macroinvertebrate communities, there were no differences between the three sites. These results suggest that with respect to Shannon Diversity, Stranger Creek has not deviated from reference conditions.

Figure 30. Box plots comparing Shannon Diversity at Stranger Creek (all three sites combined) and reference streams. Data was also plotted from each Stranger Creek site separately in order to make comparisons between the three sites.



KBS Oversight Responsibilities:

An additional component of this project involved interaction with three Leavenworth High School teachers who have been sampling Stranger Creek tributaries. We have been in close contact with the three teachers throughout the project (the third teacher recently joined the project). Two of the teachers and their classes have observed multiple KBS sampling events. In January 2002 we will meet with the teachers and participate in a hands-on training session. This session will demonstrate the procedures that are used to measure various physical, biological, and chemical variables of water quality. The teachers can then take this information, with help from the KBS staff, and present it to their students. As the teachers begin to sample with their classes in the spring, KBS staff will participate and help lead sampling events.

We have also worked on the implementation of several new procedures that will allow the teachers and students to gain additional experience in the analyses of water quality variables. For example, we have tested the accuracy of a new method for detecting pollution in stream water. This technique detects the presence of optical brightners, a compound found in all major brands of laundry detergents, in stream water. It is a relatively easy procedure that can be effectively utilized by high school students to detect source of pollution within the watershed. We hope that the high school classes will utilize this technology in the near future.

***Conclusion**:*

The purpose of this study was to provide a general assessment of the physical, chemical, and biological conditions at Stranger Creek, Leavenworth County, Kansas. Data was collected from three sites located along the main stem of Stranger Creek during three seasons (spring, summer, and fall). This data was then compared to data collected from reference watersheds that were considered to have "good" habitat and water quality, and biological conditions.

According to the habitat analysis, Stranger Creek scored below reference streams for several near stream and instream variables. For example, the low riparian condition values at Stranger Creek and the absence of a riparian forest at ST2 raise concerns about habitat degradation. This degradation is likely the result of agricultural activity, which leads to the removal of forest to the stream edge in order to maximize the amount of land available for cultivation. In addition, erosional area was greater at Stranger Creek, likely resulting from agricultural mediated losses of riparian habitat, and increase flow due to stream channelization. As erosion increases, excess sediment loads may cause homogenization of stream sediment, which appears to be evident at ST2. In comparison to ST1 and ST3, the inorganic habitat at ST2 was much less diverse. The maintenance of intact riparian habitat, and the development of new riparian forest along the banks of Stranger Creek will provide stability that reduces soil erosion and removes soil from the water that enters the stream from the watershed (EPA, 1996; Kalff, 2002). In addition land management practices such as terracing, minimum tillage, increased bank stabilization, buffer strips, streamside fencing to prevent cattle access, and rotational grazing, could potentially improve the habitat characteristics of Stranger Creek (Huggins and Bouchard, 2000).

Several of the water quality parameters collected from Stranger Creek were similar to, or better then, reference conditions. These variables include alkalinity, hardness, total nitrogen, total phosphorus, and atrazine. However, there were several water quality variables including turbidity, dissolved oxygen, and fecal coliform bacteria that scored poorer than reference streams and were close to, or below current Kansa surface water standards. As a result these variables may be compromising the ecological integrity of Stranger Creek.

Turbidity values were higher at Stranger Creek than in reference watersheds likely resulting from increased erosion and excess sediment inputs from the watershed. Dissolved oxygen values were lower at Stranger Creek than at reference streams. Low DO levels may be the result of increased decomposition, or decreased primary productivity due to excessive sediment loads, although it is difficult to determine the exact cause for this degradation. With respect to fecal coliform bacteria, we were unable to make comparisons with reference streams, however existing data supports our findings that fecal coliform levels are elevated above recreational use criteria within Stranger Creek. As suggested in the TMDL report, these elevated bacteria levels likely result from non-point pollution sources, and activities to reduce fecal contamination should be directed at smaller, unpermitted livestock operations and rural homesteads and farmsteads within the watershed.

Based on the limited number of samples, and the lack of comparisons with reference streams, it is difficult to make a definitive assessment of the periphyton and fish communities at Stranger Creek. However, our initial analysis suggests that periphyton communities are similar between sites, and that there were extremely elevated levels during the summer sampling event. With respect to the fish community in Stranger Creek, species richness was highest at ST1, although community composition was similar between sites. The most abundant species at each site was a tolerant species that does well in unstable conditions caused by irregular flow, turbid water, and pollution. These results suggest that the integrity of Stranger Creek may have been compromised, and more data is needed to determine if and how far fish communities have deviated from reference streams.

Macroinvertebrate data further suggests that Stranger Creek has deviated from reference conditions. As with other habitat variables used in this study, the Habitat Development Index (HDI) indicates that habitat heterogeneity was greater at ST1 and ST3 than at ST2. This finding suggests that macroinvertebrate communities should be poorer at ST2. All of the metrics used to assess the macroinvertebrate community, with the exception of total abundance of sensitive taxa (EPT) were similar to reference conditions. In addition, % EPT at Stranger Creek surpassed reference streams. However, when each Stranger Creek site was examined by itself, it was found that ST2 scored below reference conditions for most metrics. Therefore, while our data suggests that the overall macroinvertebrate community at Stranger Creek is similar to reference conditions, between site comparisons suggest that macroinvertebrate communities at ST2 have deviated from reference conditions. Further sampling is needed to determine to what degree this system has become impaired with respect to macroinvertebrate communities.

Based on the overall analysis of the ecological conditions at Stranger Creek, it appears as though the ecological integrity of this system has been compromised. In particular several habitat (riparian forest, erosion), water quality (turbidity, dissolved oxygen, and fecal coliform), and biological conditions (EPT abundance) scored lower than reference conditions. In addition, ST2 scored lower then the other two Stranger Creek sites for several habitat variables and macroinvertebrate metrics. Therefore, 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. Land use management and improvement of instream habitat, in combination with continued monitoring will likely improve and maintain the overall health of the Stranger Creek watershed.

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