FINAL ASSESSMENT OF THE ECOLOGICAL INTEGRITY OF SOLDIER CREEK IN THE PRAIRIE BAND POTAWATOMI NATION RESERVATION (JACKSON CO., KANSAS)

Final report for the investigation of biological, water quality and land use parameters in the Soldier Creek watershed

A RESEARCH PROJECT COMPLETED IN COLLABORATION WITH THE PRAIRIE BAND POTAWATOMI NATION RESERVATION IN JACKSON CO., KANSAS

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Introduction

The investigation of Soldier Creek, Jackson County, Kansas was conducted by the Kansas Biological Survey in spring 1996-1997 and summer and fall 1997. The purpose of the study was to assess general ecological conditions of Soldier Creek in the river reach that flows through the Prairie Band Potawatomi Nation Reservation. The ecological assessment was approached through the identification and evaluation of select water quality, biological and habitat parameters. The data on physical, chemical, and biological parameters in Soldier Creek was evaluated through comparisons of similar data sets collected in Soldier Creek by the Kansas Department of Health and Environment from 1978 to 1983. The historic Soldier Creek data set provided a frame work to examine potential changes in the stream system over a time span of almost 20 years. In addition, the current data for Soldier Creek was compared to water quality, habitat and biological data collected from two reference watersheds by the Kansas Biological Survey from 1992 to 1994. These preselected reference watersheds, French Creek (Nemaha County, Kansas) and Straight Creek (Jackson County, Kansas) are representative of the "least impacted" condition within the ecoregion. Documented stream and riparian conditions from the French and Straight Creek watersheds were selected to serve as reference conditions for comparison with current conditions in Soldier Creek.

Description of Study Areas

The Soldier Creek Watershed is located in northeast Kansas in Nemaha, Jackson, and Shawnee Counties (Figure 1). The 406 km^2 watershed is linear in form with basin widths ranging from 4.8 to 11.3 km. This long narrow watershed tends to produce broad crested runoff hydrographs along the 84.8 km of stream length that contribute extended flow after surface runoff events. The mean rainfall in Soldier is 88.52 cm, with temperatures ranging from -31 to 52 °C and a mean of 12 °C.

The reference watersheds, French and Straight Creeks, were located in Nemaha County, Kansas, and the Jackson County, Kansas, respectively. French and Straight Creeks are smaller watersheds than Soldier Creek (67 and 60 km2), and are much more elliptoid in shape than Soldier. The mean rainfall in French is 87.5 cm and the mean temperature is 11.9 °C. The mean rainfall in Straight is 89.6 cm with the mean temperature at 15.2 °C.

The general land use/land cover of Soldier Creek was assessed using the land cover database produced by the Kansas Applied Remote Sensing Program, University of Kansas (KARS 1995). The land use/land cover

Figure 1: Map of the Soldier Creek watershed with study sites labeled. Site 1, Site 3, and Site 7 are located on Soldier Creek; Site 5a (Crow Creek), Site 6 (Southbranch Creek), and Site 9 (James Creek) are local tributaries flowing into Soldier.

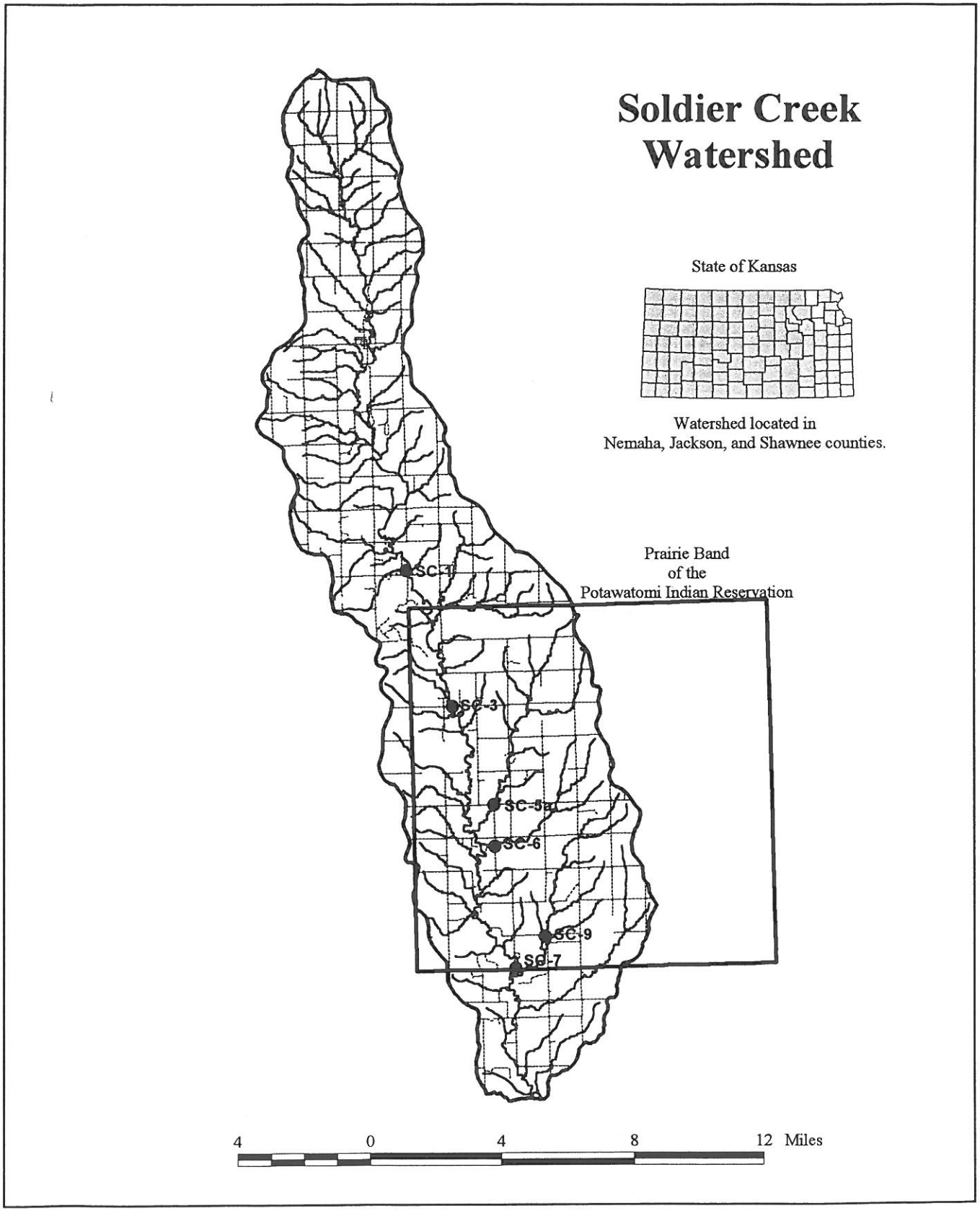


Figure 2: Map of the land use/ land cover for the Soldier Creek watershed.

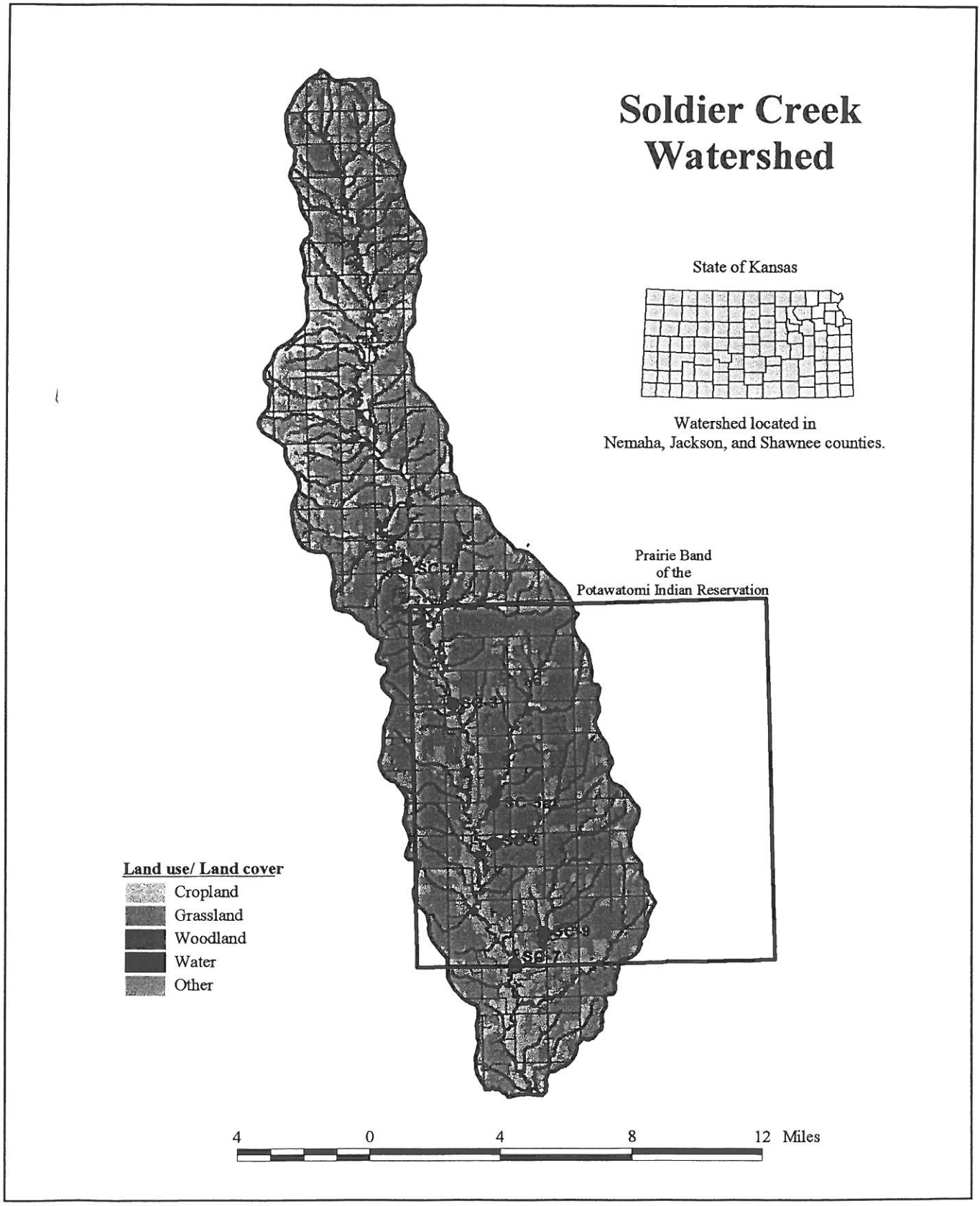


Table 1. Total area and percent land use/land cover in Soldier Creek (Jackson County), French Creek (Nemaha County), and Straight Creek (Jackson County).

LU/LC	Soldier Area (km^2)	Soldier %	French Area (km^2)	French %	Straight Area (km^2)	Straight %
Cropland	153.92	32.04	37.13	54.89	21.47	35.46
Grassland	297.46	61.91	26.89	39.75	32.06	52.96
Water	1.13	0.24	0.32	0.47	0.54	0.89
Woodland	27.85	5.80	2.62	3.87	5.07	8.37
Property/Other	0.09	0.02	0.68	1.01	1.40	2.31
Total Area	480.45		67.64		60.54	

(LU/LC) characteristics of Soldier Creek are similar to the reference watersheds (Table 1) with a higher percentage of the watershed remaining in grassland (e.g. pastures, hay meadows, range land). In that portion of the watershed contained within the boundaries of the reservation, the LU/LC is predominately grasslands with most cropland occurring in the floodplain of Soldier Creek or its larger tributaries (Figure 2). While Soldier Creek is nearly eight times larger than the reference streams, general similarities do exist. Soldier and Straight Creeks have similar percentages of cropland and grassland, which combined comprise over 85% of the land use in both watersheds. French Creek contains a greater portion of cropland and lesser portions of grassland than do Soldier or Straight.

The current study sites for Soldier Creek were selected near previous sites which were part of a larger Kansas Department of Health and Environment Study undertaken in 1978 (KDHE 1984). Comparisons of past and current conditions can be made by revisiting this study of almost 20 years ago. The current study sites were located approximately two miles down stream of SC298 (Site 1), at SC299 (Site 3) and at SC100 (Site 7) (Figure 1). The current Site numbers (i.e. 1, 3, 7) were the same as those used by the U.S.G.S. in their water quality study for this same time period (i.e. summer 1996). Additionally, 1997 macroinvertebrate and fish collections incorporated three additional study sites on Southbranch Creek (SC6), Crow Creek (SC5A) and James Creek (SC9) in order to provide data on the status of local tributaries flowing into Soldier (Figure 1).

The French and Straight watersheds were selected as reference watersheds for comparison purposes based on a 1992-1994 KBS study indicating that French and Straight Creeks generally had higher habitat, water quality and

biological conditions than the streams of 14 other watersheds examined in the ecoregion (Kansas, Nebraska, and Iowa).

Results

Various stream and riparian variables for Soldier Creek and the reference streams were graphed as box plots to facilitate comparisons between past and current Soldier Creek conditions and reference stream conditions. Box plots are a powerful graphic analysis technique that allows investigators to examine and compare the median value of a data set along with the distribution of the data around this central value. In the form used for this study, the median value of a variable is located at the most constricted point in the notch that separates the box into a upper and lower portion (e.g. Figure 3). The upper portion of the box represents the 75^{th} percentile of the data while the lower portion represents the 25^{th} percentile. Thus, the total height of the box represents the interquartile range or IQR (Lee and Maykovich 1995).

We have selected this modified box plot, or notched box plot, to assist in making comparisons among the distributions of several different data series (e.g. pH values between different streams or stream sites). The notched box plots were constructed using the following formula:

$$\text{median value} \pm 1.57 \frac{(IQR)}{\sqrt{n}}$$

If the notches in the box plots do not overlap, then it may be assumed that the medians are significantly different for the different data series (NCSS 1995). This approach provides an informal test of whether two or more populations (data populations) are potentially different and allows the assessment of how far a population may have deviated from reference conditions. This technique has been used successfully by several researchers and agencies involving bioassessments and water pollution studies (e.g. Karr et al. 1986, Ohio EPA 1987, Plafkin et al. 1989, US EPA 1996).

Comparisons were made using the box plot of the reference stream values combined as a benchmark for judged as "good" for an attribute of parameter. The comparison criteria used for Soldier Creek were that median values in data sets must fall within the 25^{th} to 75^{th} percentile of the reference box plot to accept the assumption that stream or site conditions were similar. For example, if the median value of the current riparian width data for Soldier

Creek fall within the 25 to 75 % range of the reference streams' riparian width (i.e. French and Straight Creeks), potential similarities between streams may exist (Figure 3). Conversely, median values for Soldier that fall outside the reference streams indicate potential differences (see Figure 4).

The same criteria were applied to the examination of current and historic conditions in Soldier Creek. In these box plots, outliers were represented by a filled circle. Certain parameters were available for current Soldier Creek data that were not available in the historic Soldier or reference stream data sets. These parameters were graphed individually as bar or line charts for each site in the current Soldier Creek study.

The box plots were constructed based on a varying number of samples for habitat and water quality measures. Data for the three current Soldier Creek sites consisted of three samples (collected June 1996) for habitat parameters and nine samples for the water quality parameters (the biology within Soldier Creek was sampled more extensively; see fish and macroinvertebrate sections). The historic water quality data for Soldier Creek was available for six sample sites for a total sample size of six individual measures. Each of these six values represented the mean value of a varying number of samples (depending on the parameter) collected over the study period between July, 1978 and April, 1983. The French and Straight Creek data set was represented by a sample size of 20 samples for habitat variables and 60 samples for water quality parameters distributed through the watershed for two sample periods (July of 1992 and 1993). Box plots incorporating only three data values are suspect and care must be exercised in interpreting these results.

It is important to note differences in data collection between data sets. The historic Soldier Creek data was available only as averages of numerous data values collected over long temporal spans. The historic water chemistry data set also includes data from sites outside the current study area in Soldier Creek, which may explain some of the differences seen between the different studies. The current Soldier Creek water chemistry and habitat data were composed of a relatively small number of values for a single summer sampling event. The combined French/Straight Creek box plots were based on a large number of values representing summer sampling events over a two year period. In summary, assumptions used in making box plot comparisons were that French and Straight Creek were reference streams exhibiting above average conditions, that the limited number of samples in the current study of Soldier Creek accurately characterize the habitat and that the averaged values for water quality parameters measured in the historic Soldier Creek Study adequately represented historical conditions in the stream.

Habitat

The box plots for habitat data in Soldier Creek versus reference streams (Straight and French) are displayed in Figures 3 - 9. Livestock disturbance, bank undercutting and near-stream vegetative overhang did not occur in these Soldier Creek sites. Livestock access to stream segments can result in near-stream and in-stream deposits of fecal materials, extensive browse damage, and can contribute to bank erosion. Bank undercutting provides habitat for certain fish species, but can also collapse adding to erosion problems in a stream system. Vegetative overhang is measured as vegetation occurring over the stream surface and within 30 cm of the water. Vegetative overhang can provide shading and fish habitat and the bank vegetation itself may also function to stabilize stream banks. The absence of these conditions at the current sampling sites are an indication that such factors may be somewhat limited in this general reach of the stream. It is unlikely that such conditions prevail throughout Soldier Creek.

Riparian width is the measurement of the riparian corridor along five transects on each bank within a stream sampling segment. The median value of 5.5 m for riparian width in Soldier Creek falls just within the 25-75% range of the reference streams. However, riparian width values exhibit a much larger range (10 to 50m) in reference streams and are skewed towards higher values (Figure 3). Riparian condition was used as an index of health of the riparian system and is scored from a low of 0 to a high of 4. Riparian condition is generally poorer in Soldier Creek than in reference streams, with the median value around 1.25 versus the reference range of 2.5 to 3.75 (Figure 4). Median stream shading values for Soldier (10%) also fell well outside the reference range of 40 to 75% (Figure 5). In addition, channel widths were greater in Soldier than in reference streams with the median value of around 25.5 m falling well outside the 75% of 16 m in reference streams (Figure 6). Both the reduced stream shading and greater channel widths associated with these Soldier Creek sites were mostly a reflection of the large stream size in this reach (e.g. 5^{th} order stream) versus the reference streams (i.e. 4^{th} order streams).

Riparian widths appear to be similar in Soldier Creek and the reference streams, however, the condition of the riparian zone is poorer in Soldier Creek, as is evidenced by low riparian condition scores and low stream shading scores. Low riparian conditions reflect areas that are comprised of a thin and broken canopy, low species richness and poor cover conditions associated with the understory community.

Stream shading can provide some indication of potential temperature fluctuations in the system as well as the amount of light available to primary producers. Low stream shading values may be attributed to low riparian conditions, but may also be due to the wider stream channels in this reach of Soldier Creek.

The Debris Loading Index (DLI) is an indirect measure of potential fish and macroinvertebrate habitat as well as a potential energy source (i.e. organic matter). The median DLI value for Soldier Creek exceeded the 75th percentile for reference values (Figure 7). Reference DLI values fell between 11 and 18, while the median value for Soldier Creek was about 23. In this instance, higher DLI conditions in Soldier Creek in comparison to reference stream DLI values is not a sign of impairment, but rather is an indication of above average habitat conditions.

Figure 3. Box plots of riparian widths (m) for Soldier Creek sites (3) versus reference stream sites (10).

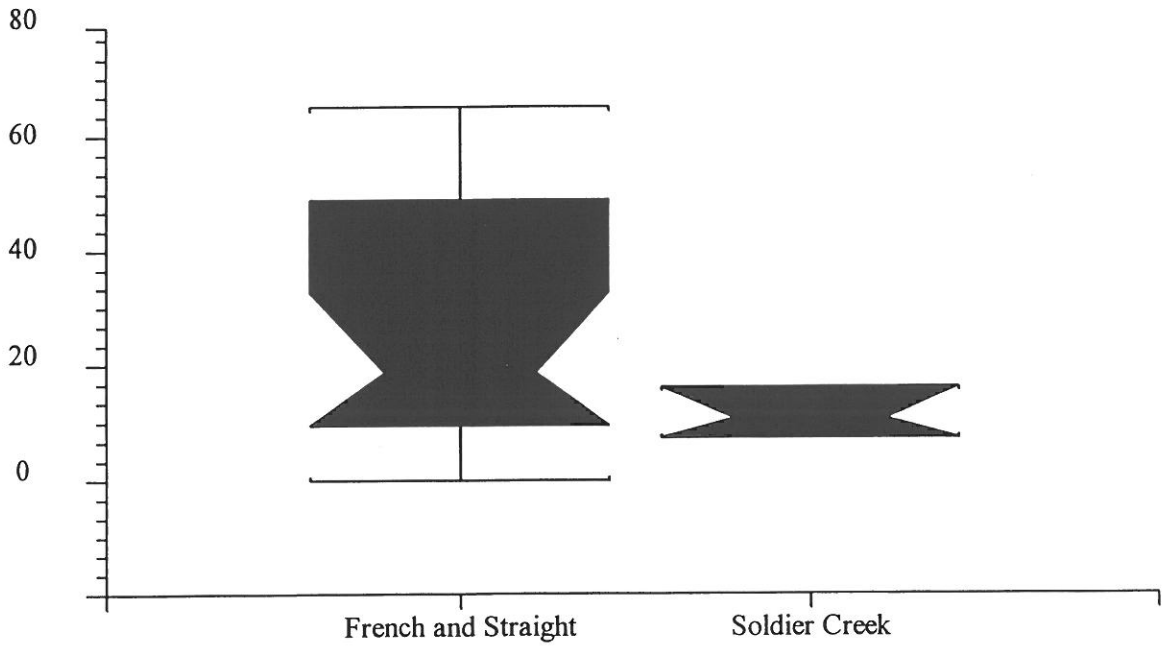


Figure 4. Box plots of riparian condition for Soldier Creek sites (3) versus reference stream sites (10).

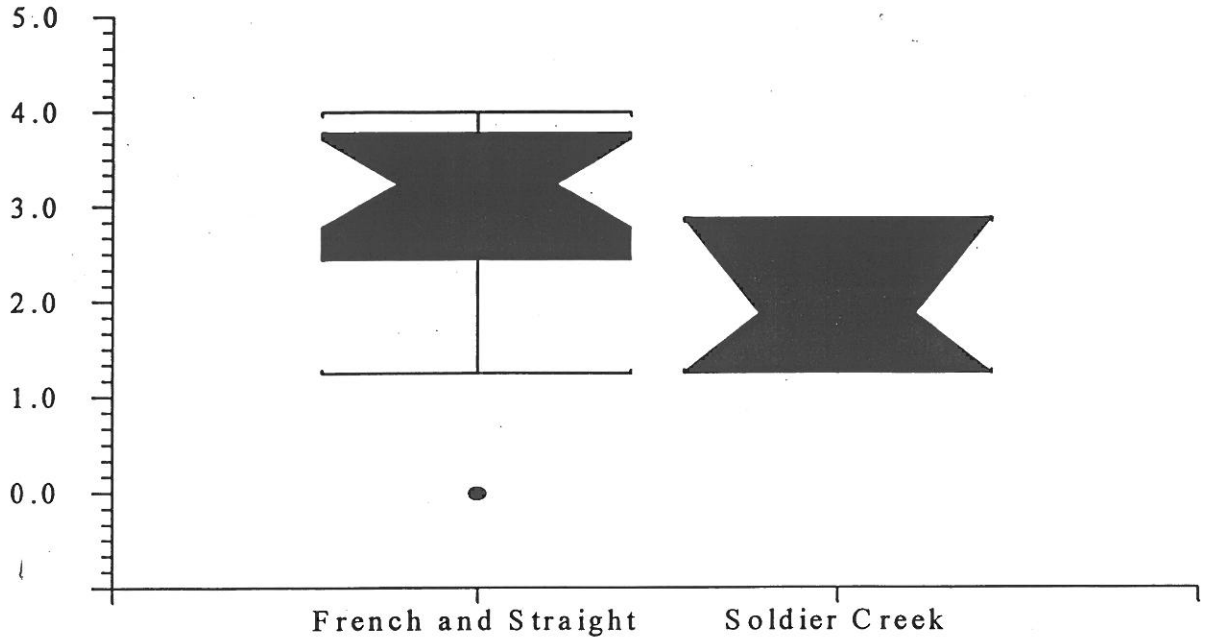


Figure 5. Box plots of % stream shading for Soldier Creek sites (3) versus reference stream sites (10).

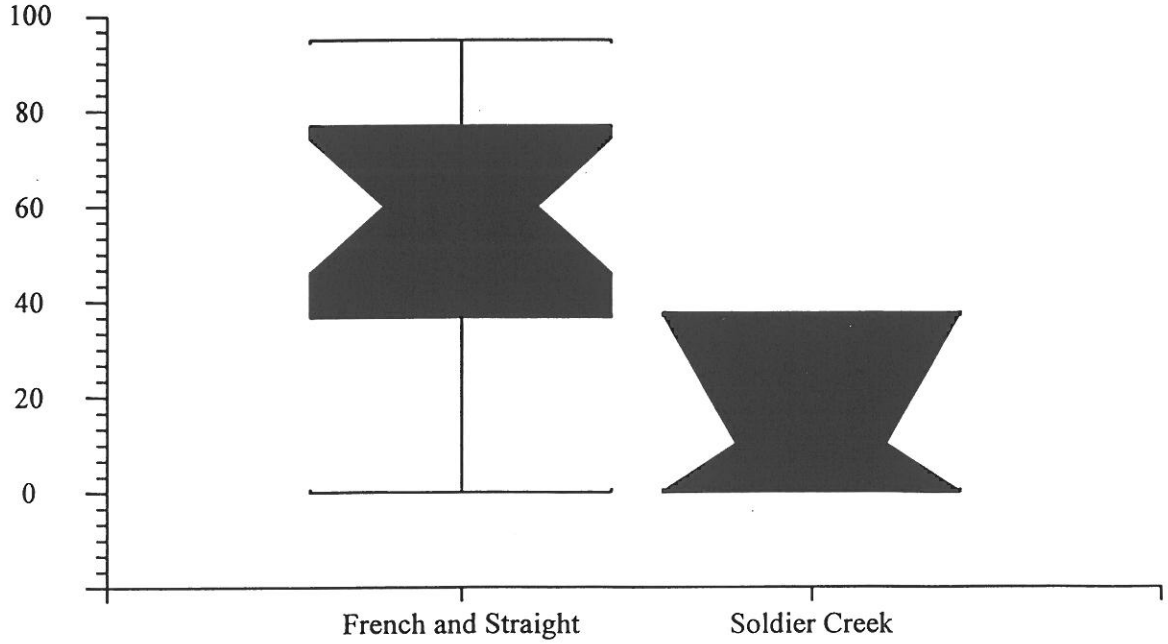
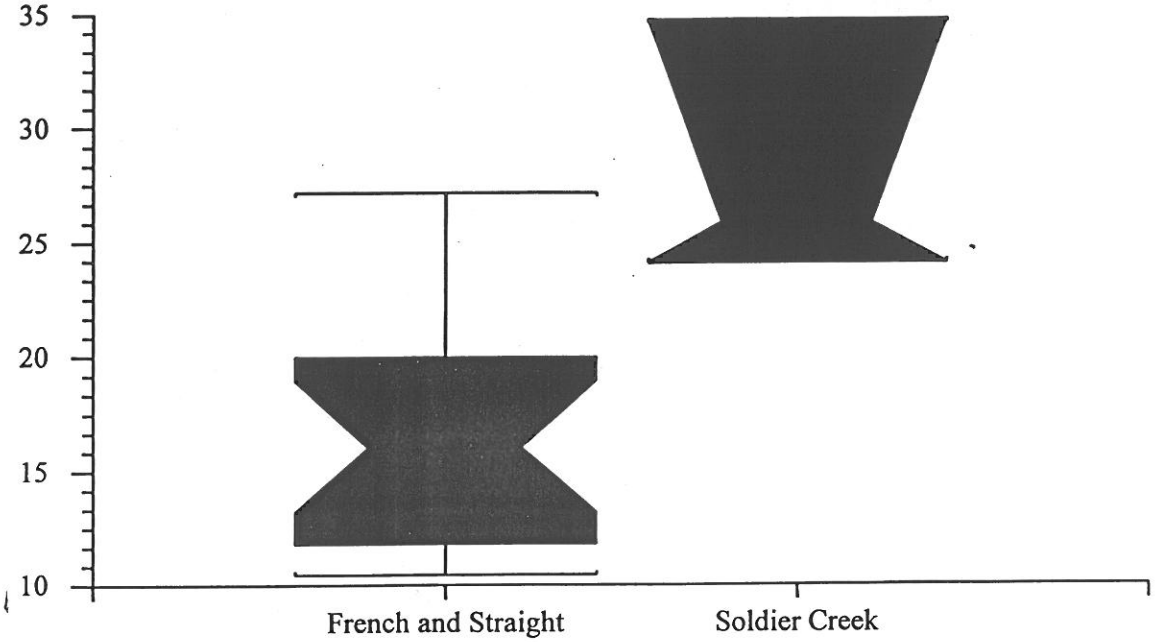


Figure 6. Box plots of channel widths (m) for Soldier Creek sites (3) versus reference stream sites (10).



Stream bank erosion results in direct soil loss but can also indirectly influence the stream community through increased turbidity and the sedimentation of habitat, which can have varied effects on stream biota. The amount of eroding stream bank in Soldier Creek far exceeded reference conditions, with a range of values from 0 to 40 m^2 of erosional area occurring in the IQR for reference streams compared to a median value of 160 m^2 for Soldier Creek (Figure 8).

The Habitat Richness Index (HRI) scores the diversity of the organic and inorganic substrates based on presence/absence of various substrates within a site. Organic substrates include algal mats, fine and course particulate organic matter and macrophytes. Inorganic substrates scored in the HRI were bedrock, cobble, gravel, sand, hard clay and soft silts. The median HRI score of 14 for Soldier Creek was much greater than the 4.5-5.5 range associated with the reference streams (Figure 9). For the most part, reference streams were sand bottom streams composed almost exclusively of sand substrates, with minor occurrences of gravel and hard clay substrates. While the Soldier Creek HRI values were greater than those of reference streams, the potential maximum score for the HRI is 45, indicating that stream conditions were well below potential habitat richness values.

Stream flow (discharge), inorganic and organic substrate values for each of the three sites examined in the present study of Soldier Creek are shown in Figures 10-12. Discharge values followed an obvious downstream trend, with lower discharge values at the upper sites (0.3 m^3/s at SC1) increasing to nearly 0.6 m^3/s at SC7 nearer the lower portion of the watershed (Figure 10). Inorganic substrate values (% cover) for each site showed a shift in major substrate classes from the upper to lower portion of the watershed in the study area (Figure 11) .The dominant classes at SC1 were hard clay (41.92%), soft silt (17.57%) and sand (17.04%). Inorganic substrates at Site SC3 were primarily composed of soft silt (35.20%) and sand (27.25%), with gravel occurring in smaller portions (18.34%). The stream bed substrate of Site SC7 was composed mostly of soft silt (39.82%) and to a lesser degree cobble (26.06%), which occurred predominantly in the riffle areas.

In general, organic substrates displayed a similar downstream trend in occurrence (Figure 12). Macrophytes were absent in all sites, while algal mats decreased in percent cover from the top site to the bottom site, (48.77%, 8.29%, and 3.75% for SC1, SC3, and SC7 respectively). Fine particulate organic matter (FPOM) increased from SC1 (51.23%) to SC3 (79.97%), and then dropped markedly at SC7 (23.82%). Course particulate organic matter was absent at SC1, occurred in small portions of SC3 (11.74%), and was associated with most of the stream bottom at SC7 (72.43%).

Figure 7. Box plots of woody debris loading index values for Soldier Creek sites (3) versus reference stream sites (10).

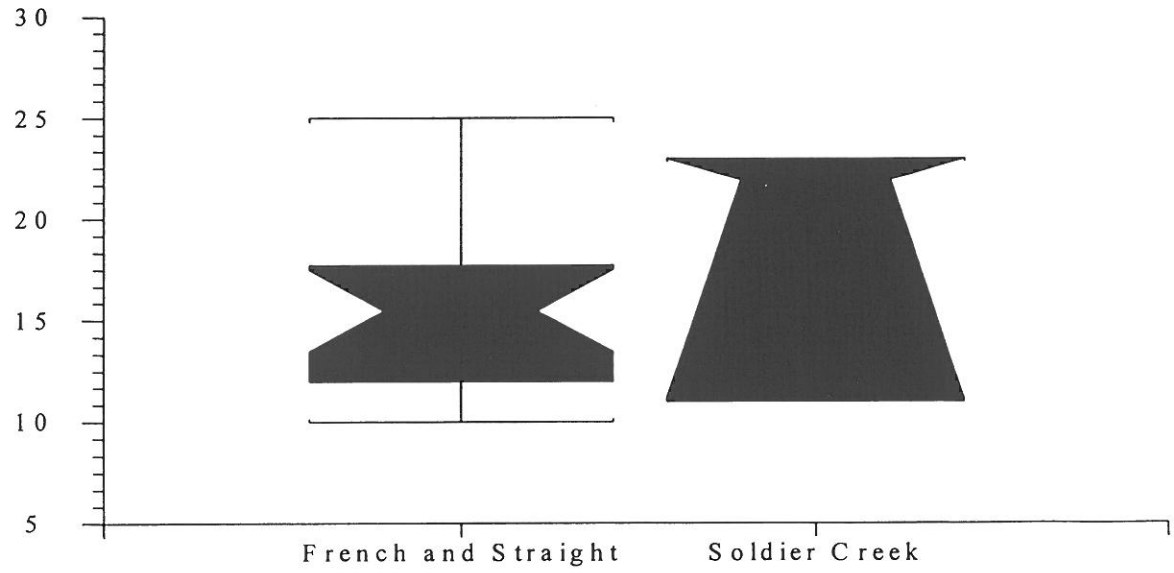


Figure 8. Box plots of erosional areas (m2) for Soldier Creek sites (3) versus reference stream sites (10).

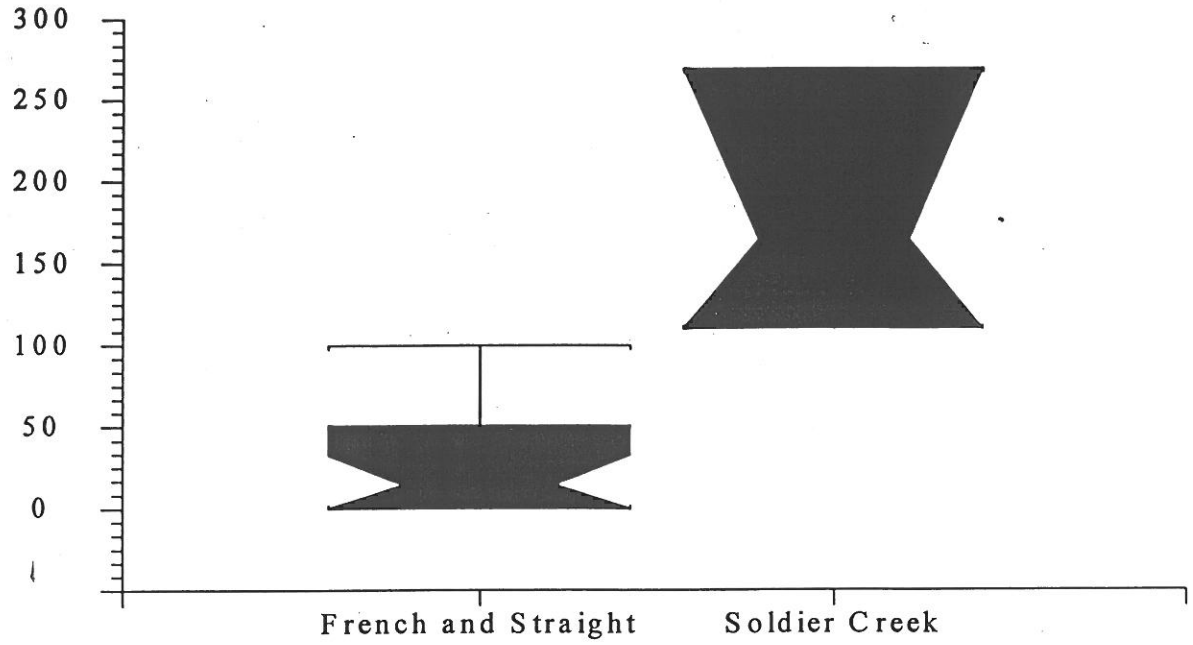


Figure 9. Box plots of habitat richness values for Soldier Creek sites (3) versus reference stream sites (10).

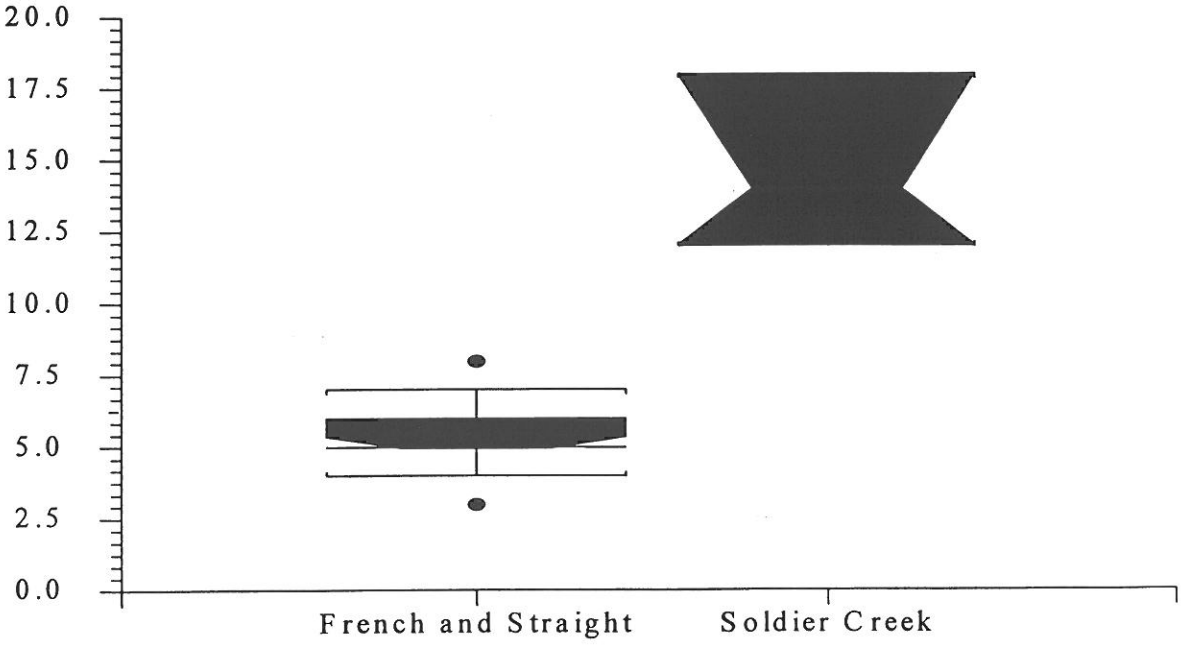


Figure 10. Stream discharge values for each site in the Soldier Creek study area (Jackson County, Kansas) during the July 1996 study period.

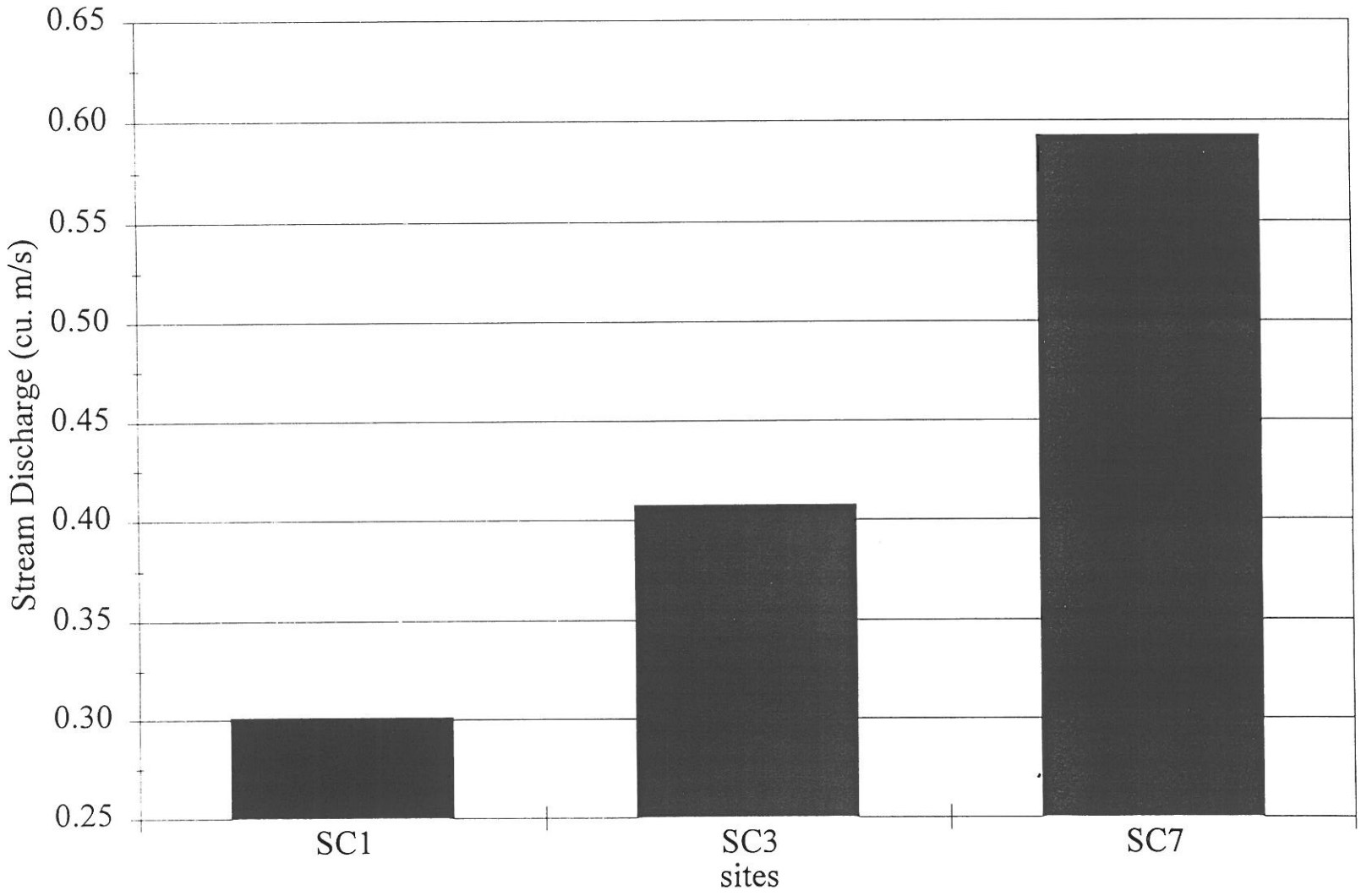
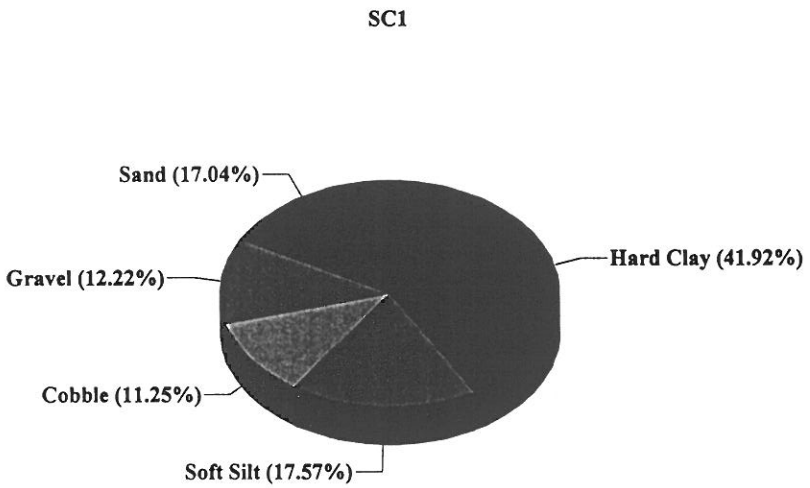
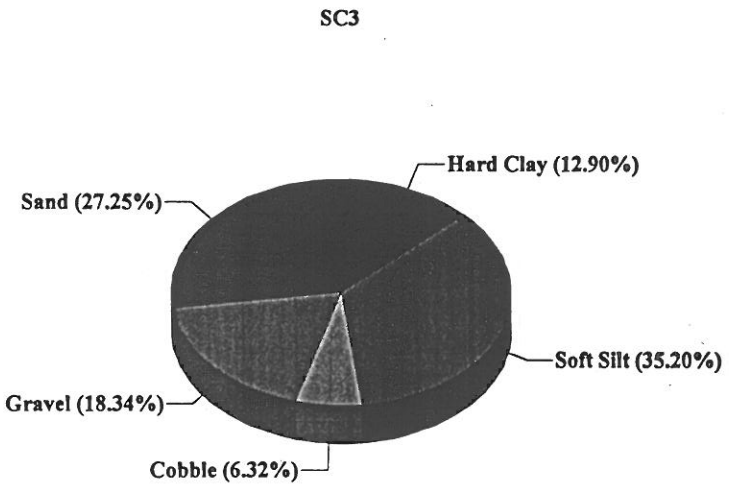


Figure 11. Percent stream bottom cover for inorganic substrate occuring in each site in Soldier Creek (Jackson County, Kansas) during the July 1996 study period.





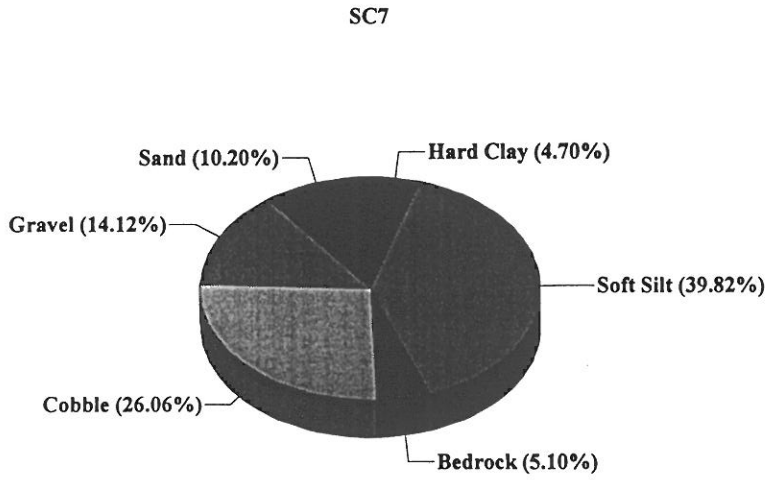
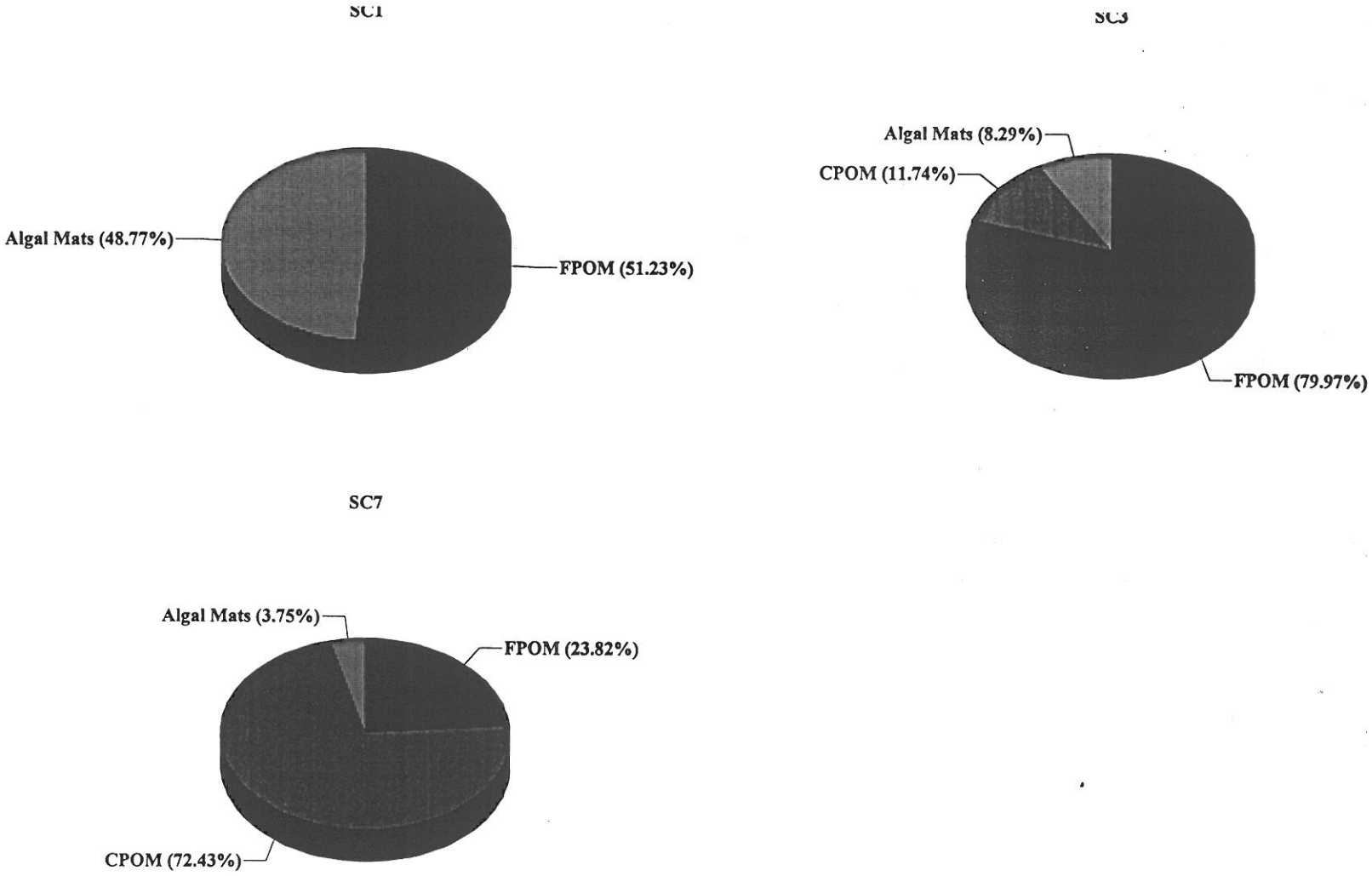


Figure 12. Percent stream bottom cover for organic substrates occuring at each site in Soldier Creek (Jackson County, Kansas) July 1996 Study Period.

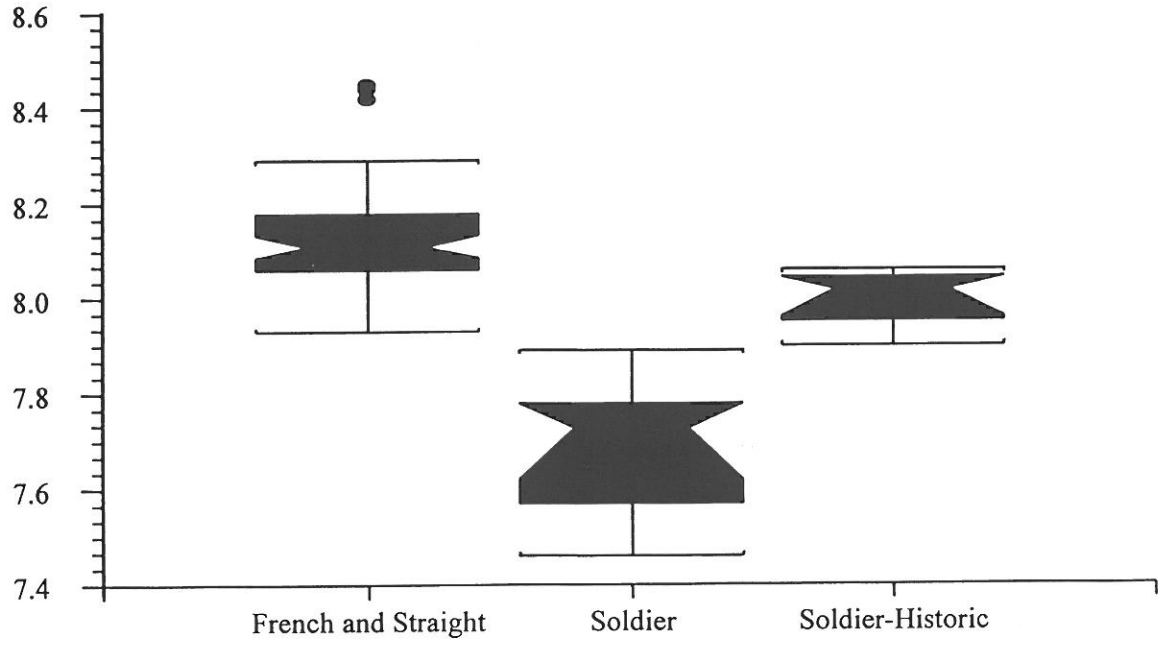


Water Quality

Both current and historic values for a number of water quality parameters for Soldier Creek were compared to composite values for these same variables for French and Straight Creeks. Where possible, comparisons were made for current values in relation to the 1984 study values for Soldier Creek. However, data was not available for certain variables in both the historic and reference data sets. The box plots for various water quality data variables are displayed in Figures 13 - 21 such that multiple comparisons can be made both between the two Soldier Creek studies and the reference watersheds.

The Kansas surface water criteria for pH ranges from 6.5 to 8.5 for the protection and maintenance of aquatic life. The median pH value for the current Soldier Creek study was 7.7, meeting the surface water standard, but somewhat lower than IQR values shown for the reference (Figure 13). The median pH value for the previous Soldier Creek study (historic study) was about 8.0, which was slightly less than the median value for the reference streams. While it is difficult to assign a definite cause for difference between stream pH values, contrasting pH values were not attributed to pollution but were probably the result of a number of natural factors including geology, the carbon cycle and primary production.

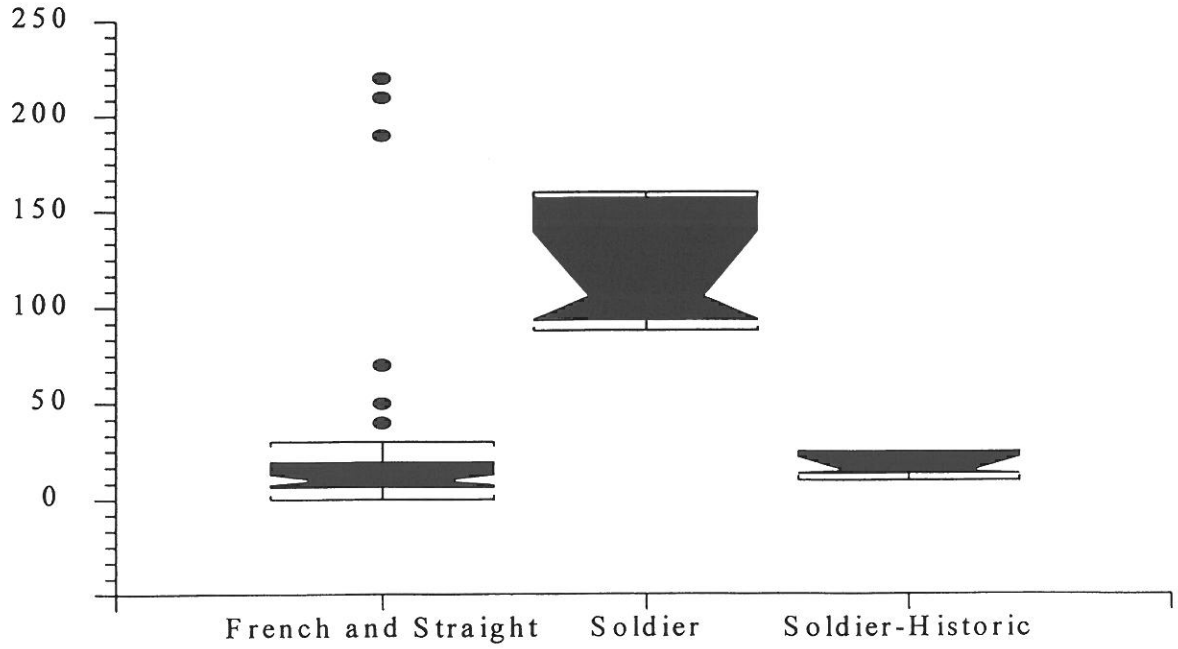
Figure 13. Box plots of pH values for Soldier Creek sites versus reference sites.



The median turbidity value and associated IQR for Soldier Creek was higher than the reference stream IQR (Figure 14). In contrast, historic turbidity values for Soldier were similar to reference streams values. Higher turbidity values in Soldier Creek may be a result of increases in suspended sediment or algal cells associated with algal productivity. Prolonged high turbidity values can cause alterations in the stream trophic structure and reduce both primary and secondary production. As with differences in pH, it is difficult to assess whether differences in turbidity are due to natural or anthropogenic causes.

Increases in turbidity may cause similar circumstances due to an abundance of suspended algae, as well as create fluxes in pH, oxygen, and nutrient values that may further affect stream biota. Kansas surface water standards for suspended solids maintain that artificially imposed suspended solids levels shall not impair the behavior, reproduction, physical habitat or any other factors related to any organism utilizing surface water systems. The turbidity data collected on Soldier Creek is not extensive enough to make this determination.

Figure 14. Box plots of turbidity values (NTU) for Soldier Creek sites versus reference sites.



Kansas surface water standard for dissolved oxygen (D.O.) is set at a minimum level of 5.0 mg/L, for the protection of aquatic life. The IQR for D.O. in reference streams was approximately 8.25 mg/L to 8.75 mg/L (Figure 15). While the current Soldier Creek median value was well above this range (11.5 mg/L), the historic Soldier Creek median value also exceeded this range (9.25 mg/L). The higher D.O. values in Soldier Creek may have been related to increased primary production in this larger stream with a more open canopy. Because median D.O. values for both Soldier Creek studies were above D.O. saturation values at recorded stream temperatures, it is probable that elevated D.O. was indeed photosynthestically produced. The River Continuum Concept (Vannote et al. 1980) supports this idea, suggesting that larger streams similar to this area of Soldier Creek, have a higher primary production potential than smaller headwater streams (i.e. the reference streams).

Conductivity can be influenced by a number of factors including surrounding geology, precipitation, decomposing organic and other sources of ions. The median conductivity values for Soldier ($\cong$ 620 µohms) and historic Soldier ($\cong$ 660 µohms) falls within the range for the reference streams of 570 to 660 µohms (Figure 16).

The alkalinity of water is a measure of its acid-neutralizing capacity, and as such represents the buffering capacity of water in acid-base reactions. The alkalinity in reference streams ranged from about 185 mg/L to 200 mg/L as $CaCO_3$. Both the current and historic Soldier Creek data distributions were higher than the reference IQR with medians at about 250 and 260 mg/L respectively (Figure 17). Streams in this area are naturally well buffered due to the surface geology, which is high in calcium carbonate.

The median values for hardness in the current Soldier study (250 mg/L) and historic Soldier study (300 mg/L) were both outside the IQR found for the reference streams. Photosynthesis, de-nitrification and/or $CaCO_3$ dissolution can cause hardness values to increase (Stumm and Morgan 1996).

The narrative Kansas surface water criteria for aquatic life support indicates that nutrient introduction shall neither hamper present aquatic life nor cause the acceleration of undesirable aquatic organisms. The nutrient and biological data available in this study were not extensive enough to make this determination. The current Soldier Creek study median level of total nitrogen was below the IQR of nitrogen in reference streams, indicating potentially lower nutrient impacts (Figure 18). No nitrogen data was available from the historic Soldier Creek study. Phosphorus concentrations for both present and historic Soldier Creek data sets (median value at 0.1 mg/L) were within the IQR for the reference streams (Figure 19).

Fecal coloform concentrations in Kansas surface water can not exceed a geometric mean of 200 organisms or colonies per 100 mL of water for contact recreation purposes. The geometric means for the available data sets could not be calculated and no comparisons could be made with the Kansas surface water standards. Non-contact recreational uses can not exceed 2,000 organisms per 100 mL of water. The median value for fecal coloform concentrations in the current Soldier Creek study were about 200 organisms per 100 mL (Figure 20). This value was below the IQR for historic Soldier Creek data, which ranged from around 250 to around 2300 organisms per 100 mL.

The remaining data is presented in graphic form for Soldier Creek alone. These variables were either not available for reference streams or from the historic Soldier Creek study, or were of no value in comparison to reference streams. Water and air temperature values ranged from 28 to 32 °C, and generally decreased from the top to the bottom sites (Figure 21). Average chemical oxygen demand (COD) values varied from a low of 2 mg/L at SC3 to a high of 6 mg/L at SC7 (Figure 22). These COD values were not considered high in comparison to other streams in the region, which frequently contain COD values greater than 10 mg/L.

Figure 15. Box plots of dissolved oxygen values (mg/L) for Soldier Creek sites versus reference sites.

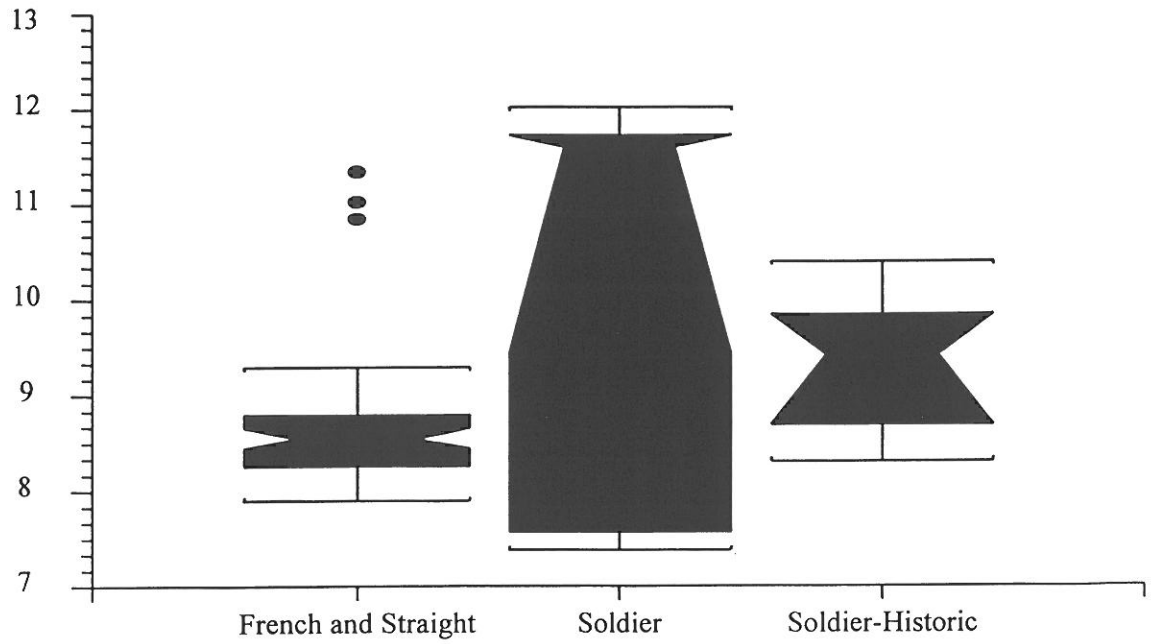


Figure 16. Box plots of conductivity values (mV) for Soldier Creek sites versus reference sites

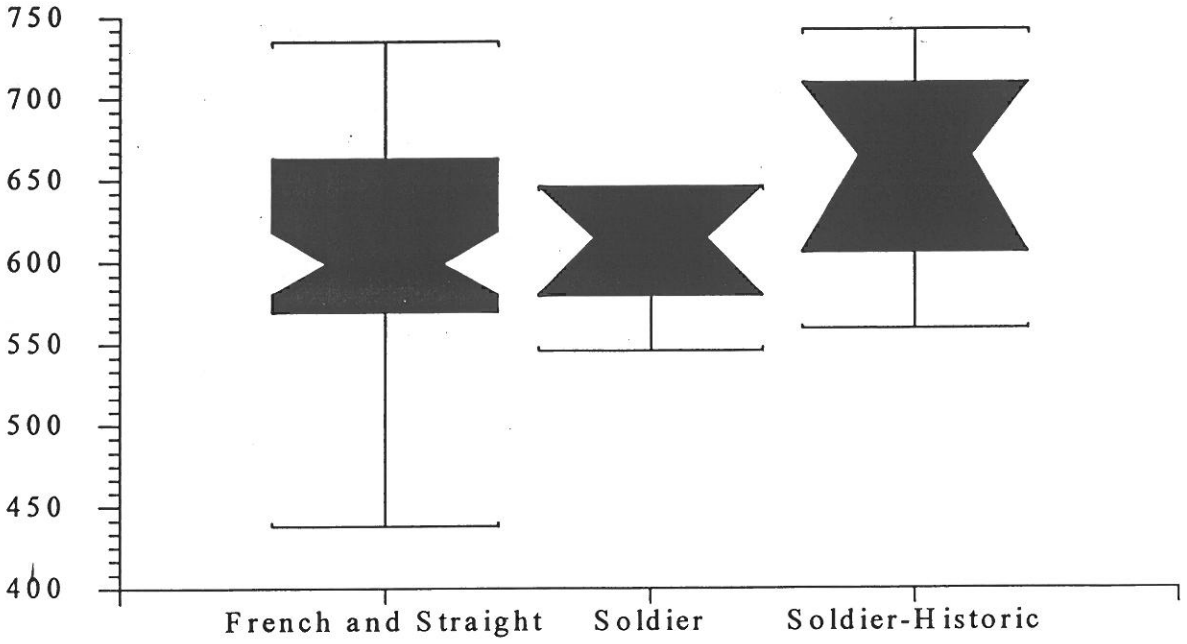


Figure 17. Box plots of total alkalinity values (mg/L) for Soldier Creek sites versus reference sites.

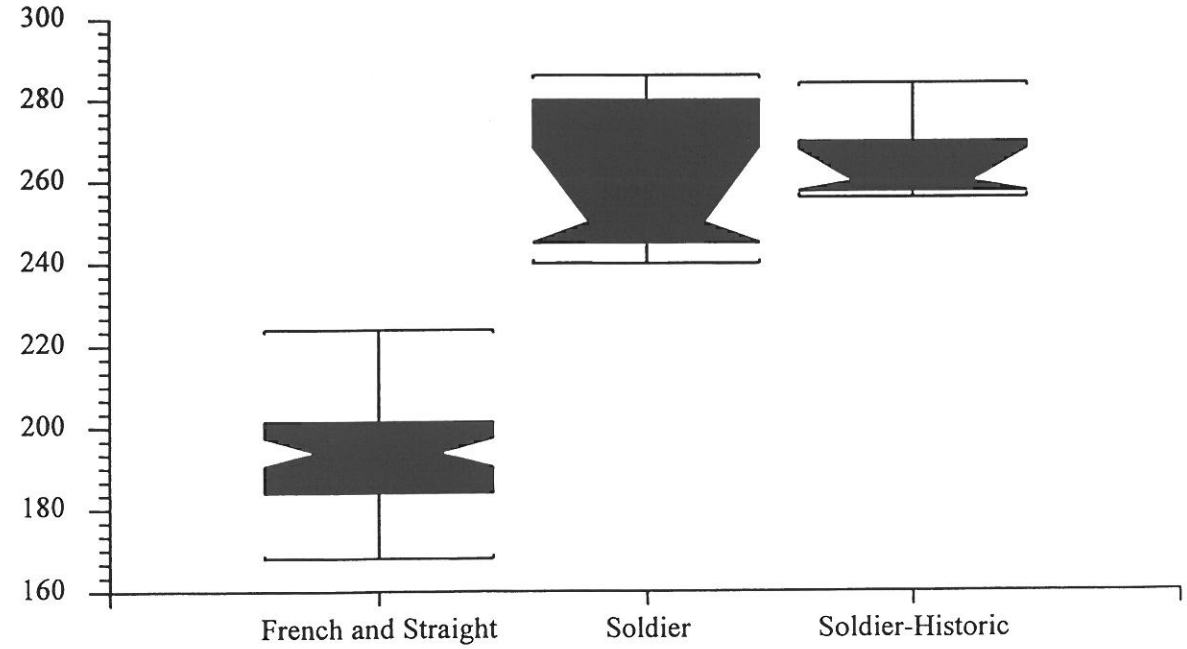


Figure 18. Box plots of total nitrogen values (mg/L) for Soldier Creek sites versus reference sites.

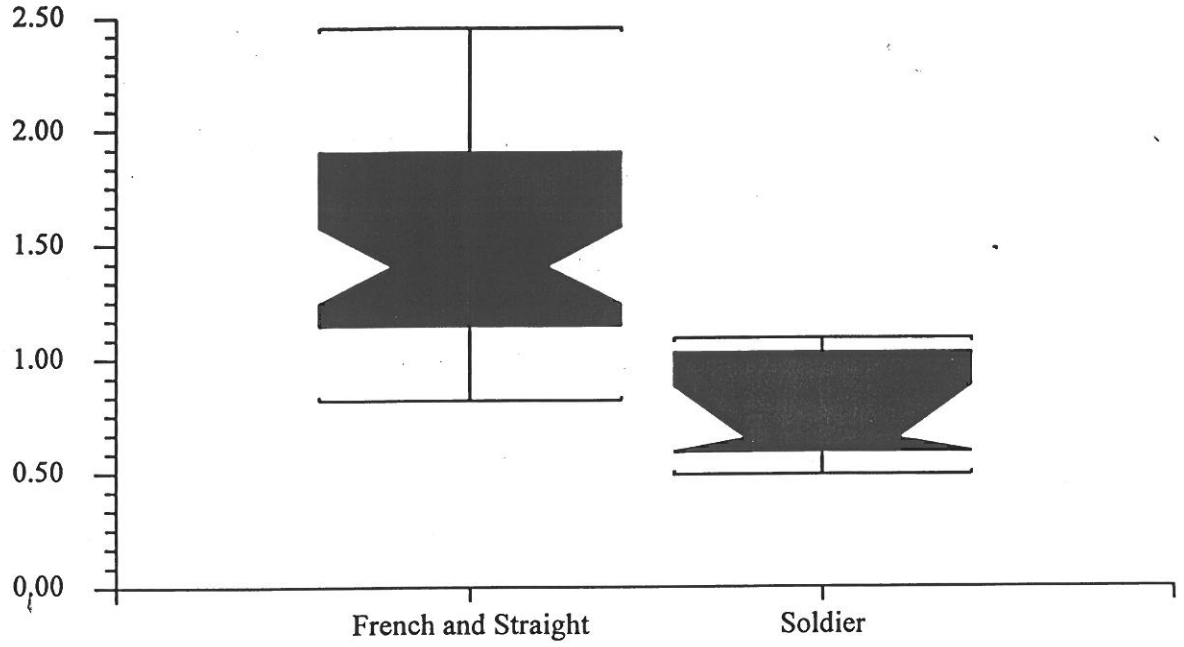


Figure 19. Box plots of total phosphorus values (mg/L) for Soldier Creek sites versus reference sites.

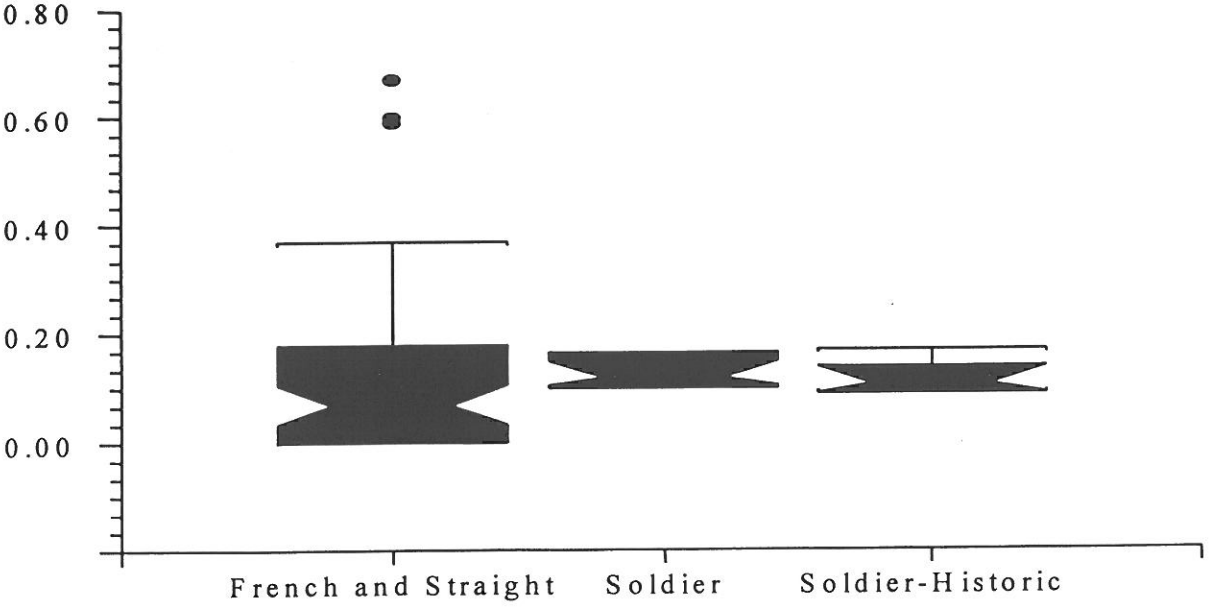
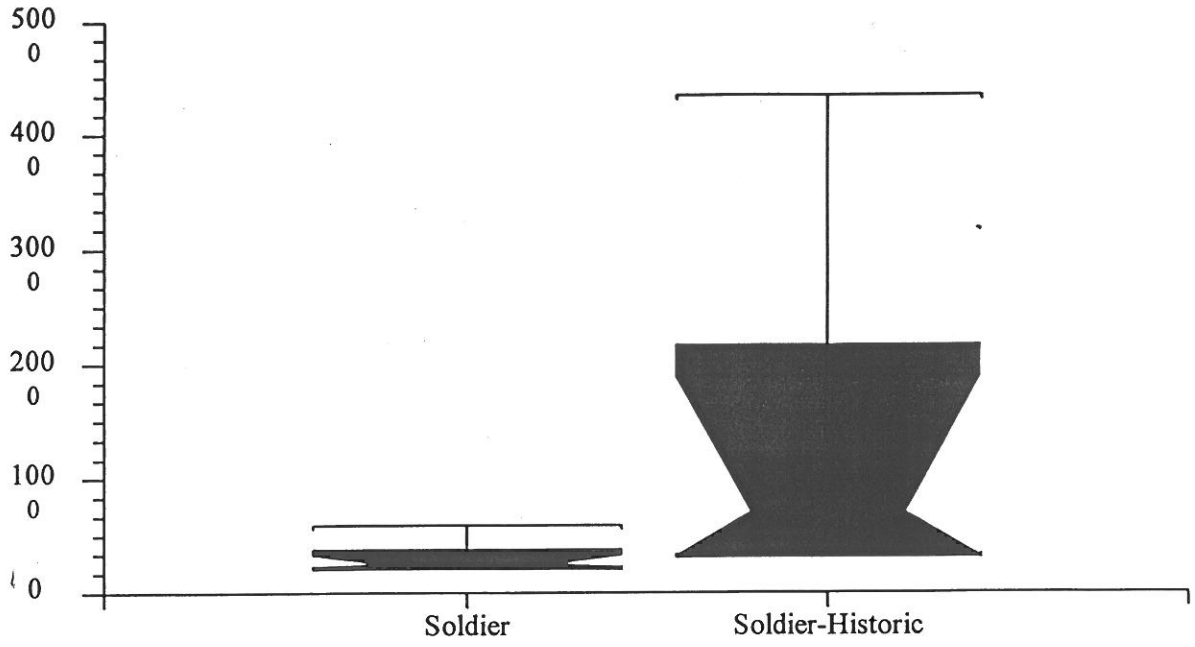


Figure 20. Box Plots of total fecal coloforms (per 100 mL) for Soldier Creek sites versus reference sites.



Average ammonia values were low, varying from 0.135 at SC3 to 0.165 mg/L at SC 1 (Figure 23). The Kansas surface water standard for total ammonia is 5.95 mg/L (measured as N mg/L) for waters having a pH of 8.0 (median value) and a water temperature of 30 °C. Average oxidation-reduction potential (ORP) values were 196 mV in SC1, 199 mV in SC3 and 207 mV in SC7 (Figure 24). Oxidation and reduction (redox) reactions mediate the behavior of many chemical constituents in aquatic ecosystems, but a number of factors limit straightforward interpretation of these values. In general, ORP values in the ranges found here indicate that most chemical reactions are potential oxidation reactions. Values for additional cations and anions can be found in Figure 25. In general, cation and anion concentrations increased in a downstream direction.

Figure 21. Average temperature values for Soldier Creek sites (Jackson County, Kansas during the July 1996 study period.

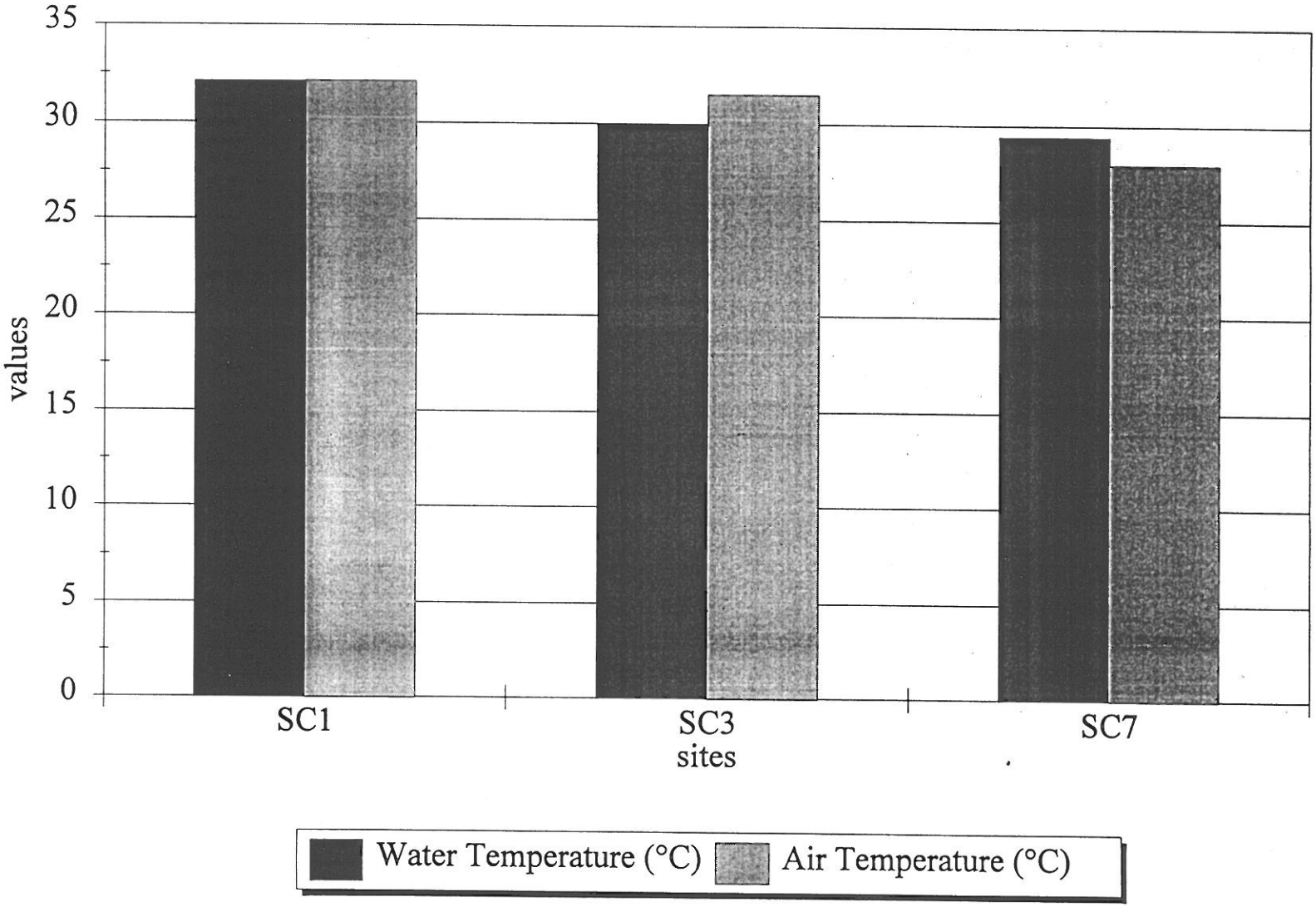


Figure 22. Average chemical oxygen demand values for Soldier Creek sites (Jackson County, Kansas) during the July 1996 study period.

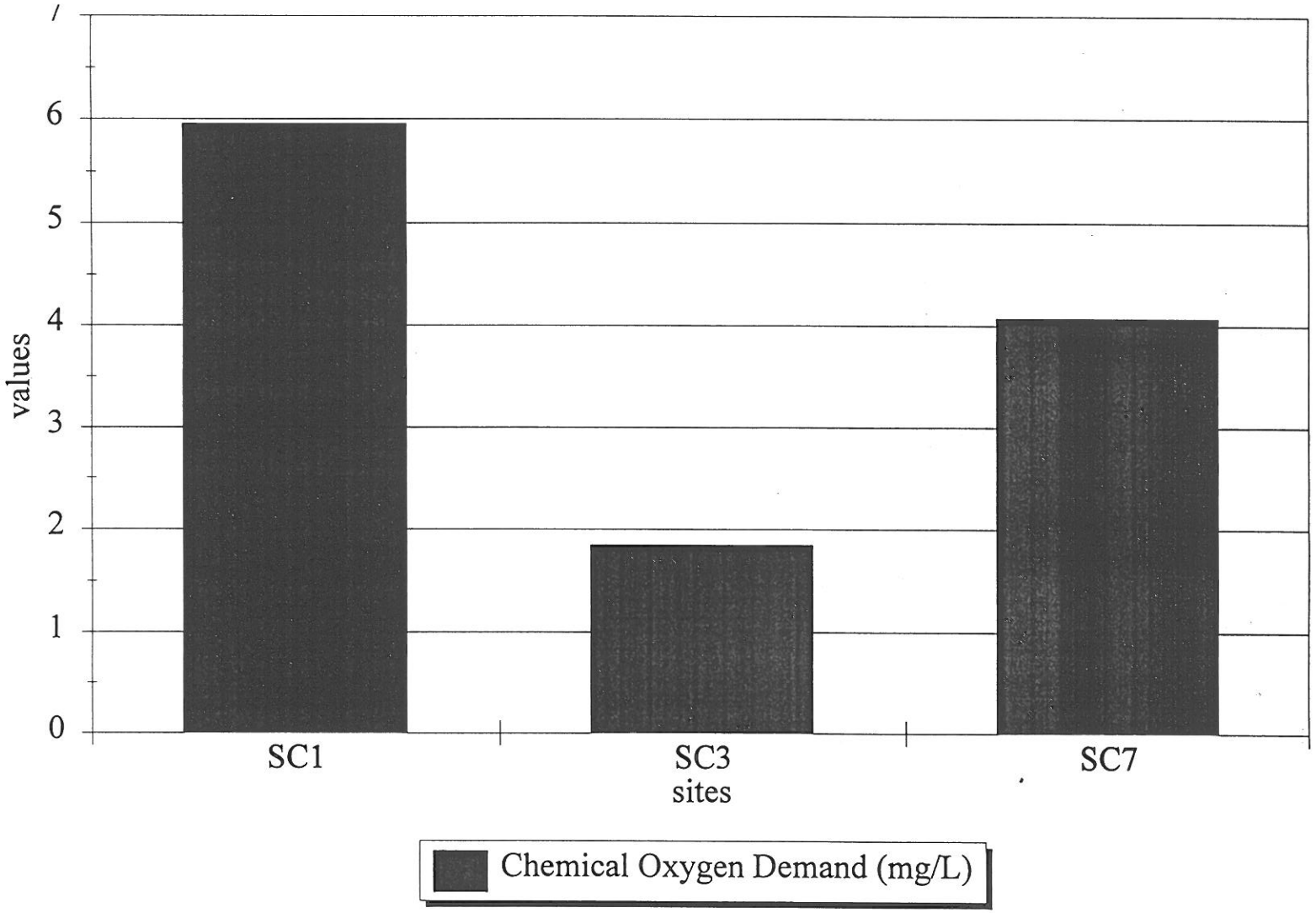


Figure 23. Average ammonia values for Soldier Creek sites (Jackson County, Kansas) during the July 1996 study period.

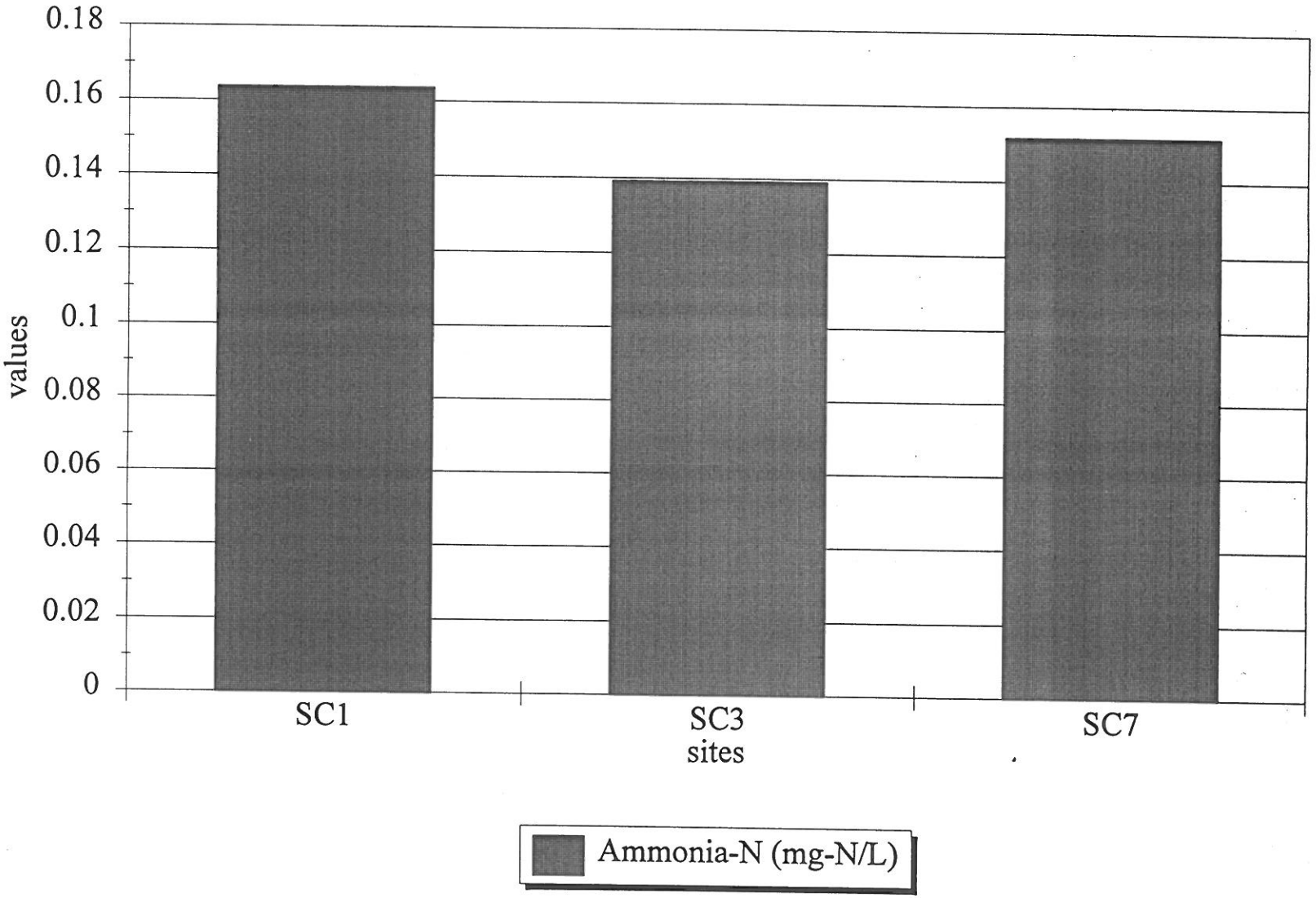


Figure 24. Average oxidation-reduction potential values for Soldier Creek sites (Jackson County, Kansas) during the July 1996 study period.

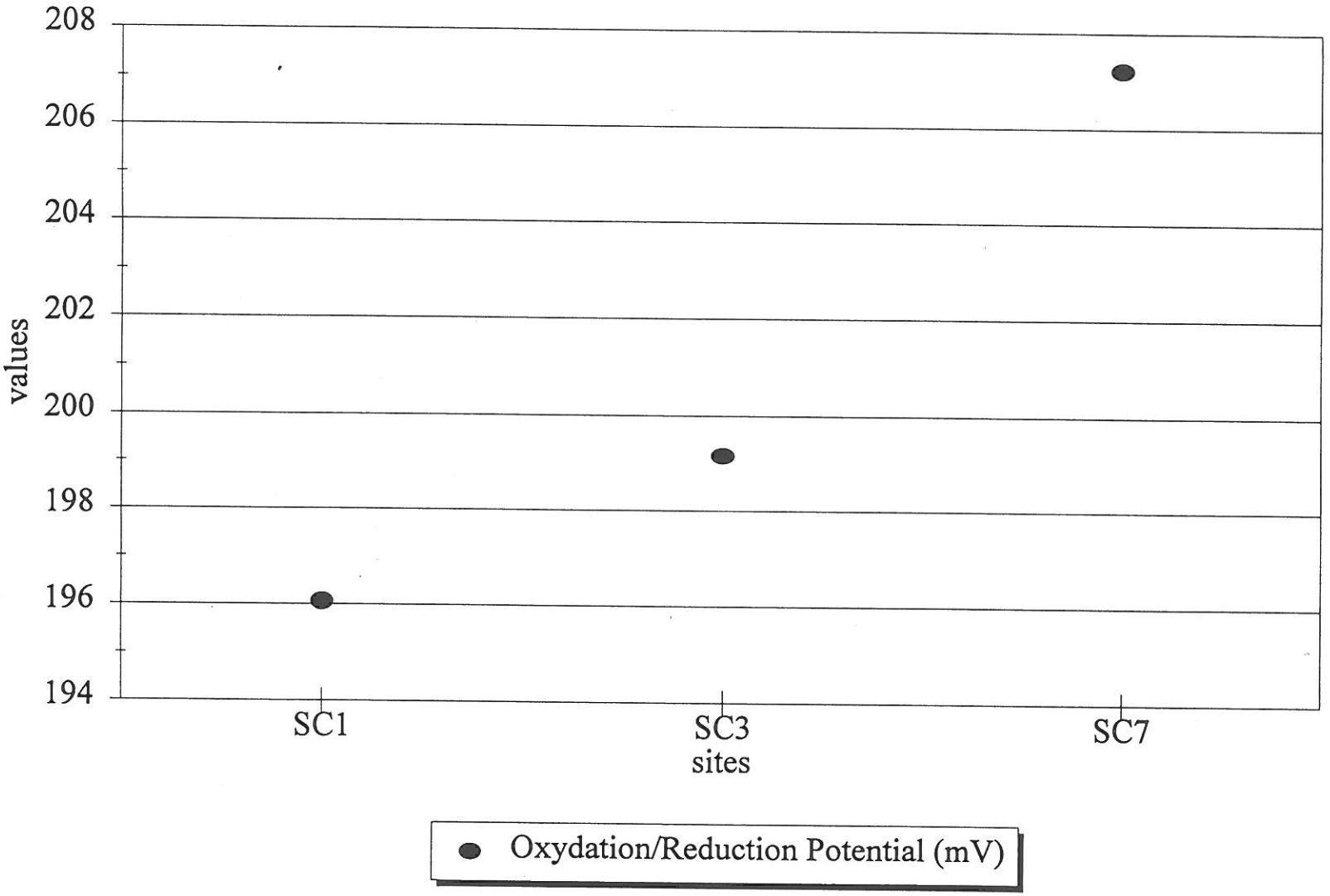
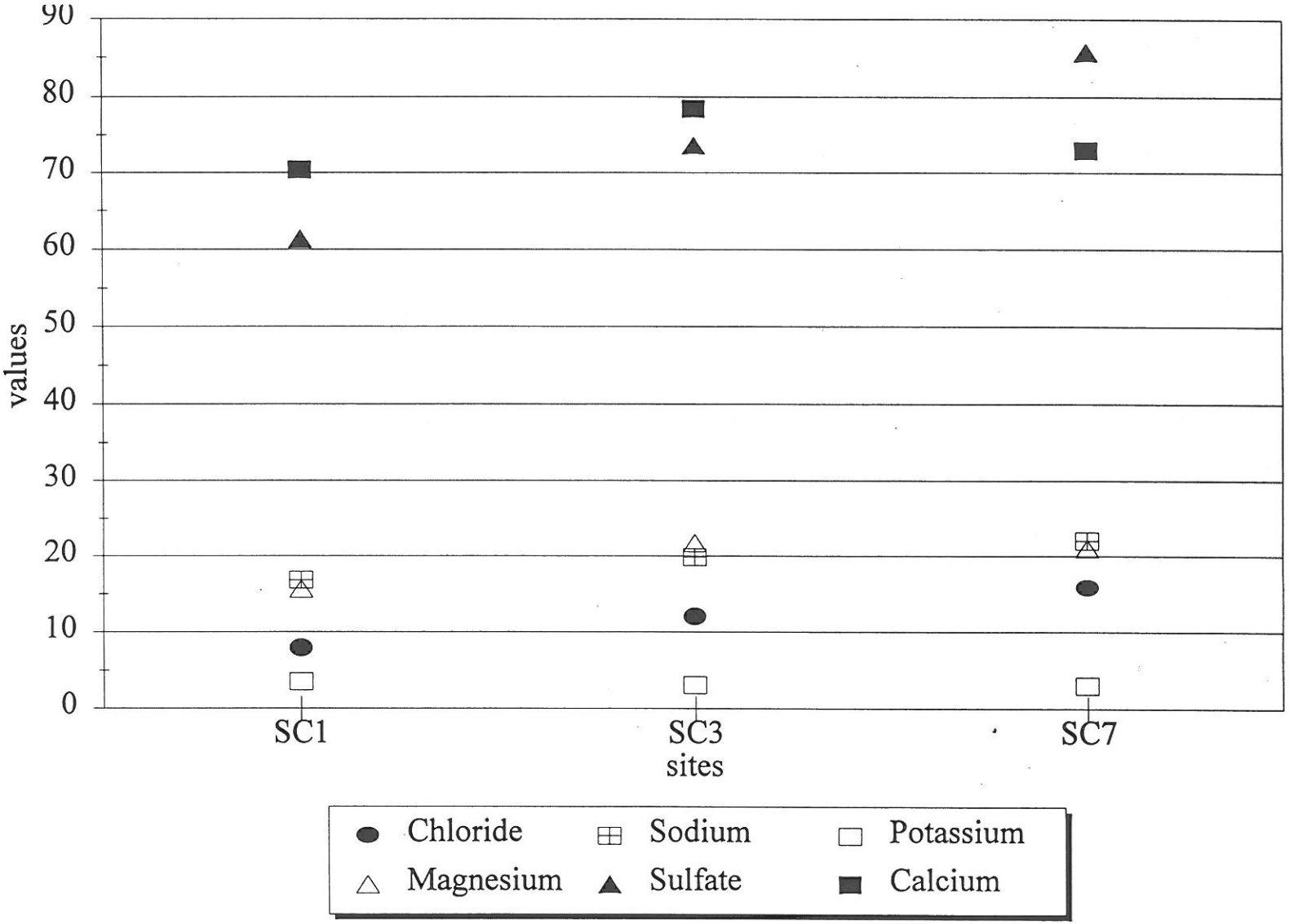


Figure 25. Average site values for selected cations and anions in the Soldier Creek study (Jackson County, Kansas) July 1996. All ion values recorded as mg/L.



Fish Community

Comparisons were made between fish data collected as part of the 1978-1983 Soldier Creek study conducted by KDHE (KDHE 1984) and fish collections taken as part of the current study (1996-1997). Care must be exercised when assessing the data relative to potential changes in fish fauna over time due to differences in the number of samples taken and sampling methodologies. Each station (SC1, SC3, SC7) was sampled in June of 1979 and 1980 by KDHE and during the current study in June of 1996 and 1997. Additional samples were taken in August and November of 1997. Only the June samples were used for comparisons between historic and current fish data to avoid seasonal influences. In addition, KDHE used both seining and poisoning (fish toxicant) in their quantitative sampling, while KBS used exhaustive seining and electroshocking with a backpack shocker. For the historic study, fish samples were collected on SC1 through exhaustive seining and rotenone (fish toxicant) use, while samples on SC3 and SC7 were collected using only rotenone. While these differences in sampling methodologies may influence the interpretation of some data comparisons, other inferences were possible.

No comparisons were made between fish communities in Soldier Creek and the reference streams because of noted differences in stream flow and size of the drainage basins. Both the total number of fish species and community structure are influenced by stream size (e.g. Karr et. al. 1986, Miller et al. 1988, EPA 1996) and until these potential effects can be determined for these streams, direct comparisons seem unwise. The current and historic fish data for Soldier Creek are summarized in Tables 2-8. In addition, graphical assessments of species richness and relative abundance (Figures 26 and 27) were made for fish collected at each comparable study site in Soldier Creek.

Tables 2 and 3 were provided solely for the purpose of displaying the original fish data used to calculate the values used for comparisons between current and historic sampling efforts. Tables 2 and 3 summarize total fish abundance per site for the historic and current Soldier Creek studies, respectively. The discussion of the fish data will center around Tables 6 and 7, and Figures 26 and 27. Total biomass per site for fish species collected during the current study are presented in Table 4 and 5. Table 8 provides a composite total fish abundance for all sites during 1997 sampling, including fish data for the three study tributaries that flow into Soldier; Crow Creek (SC5A), Southbranch Creek (SC6) and James Creek (SC9).

Comparisons of the fish species occurrences for both studies are tabulated in Table 6. Overall, only 3 species obtained during the KDHE study were not found in the current study. These species included *Notemigonus crysoleucas*, *Ameiurus melas* and *Ameiurus natalis*. The single specimen of *Notemigonus crysoleucas* (golden shiner) was considered an introduced individual and not representative of an established fish population (KDHE 1984).

A number of stream fishes found in the historic study are tolerant to a broad spectrum of water quality and habitat conditions and were expected to occur in this study area of Soldier Creek. The common carp (*Cyprinus carpio*), creek chub (*S. atromaculatus*) and black bullhead (*A. melas*) are common stream species in this region of Kansas and can tolerate a variety of stream conditions including highly turbid water and silty stream bottom habitats (Cross 1967). Less common species in this region, such as the white sucker *(C. commersoni*) and yellow bullhead (*A. natalis*) prefer clear water habitats with rock substrates, while the orange spotted sunfish (*L. humilis*) shows little habitat preference and is minimally affected by high turbidity levels and water level fluctuations.

Fish species found in current sampling efforts but not historic efforts included six species: *Lepomis megalotis, Luxilus cornutus, Pylodictis olivaris, Percina caprodes, Aplodinotus grunniens* and *Pimephales vigilax*. Of these six, *Aplodinotus grunniens* and *Pimephales vigilax* were found only during the August and November samples of 1997 and were not included in the analyzed data. The only published records of flathead catfish (*P. olivaris*) in Soldier Creek indicate that it occurred only in the lower most section of the creek near its confluence with the Kansas River (KDHE 1984, Cross and Collins 1995).

Other than the noted shifts or changes in the presence and absence of some species, few apparent changes in relative abundance (percent of total abundance) were observed for most species (Table 7). *Campostoma anomalum*, *Notropis ludibundus* and *Pimephales promelas* were all more abundant in historic samples than in current samples. *Cyprinella lutrensis* and *Pimephales notatus* both displayed higher relative abundance in the current sampling period than in the historic sampling efforts. Only small changes in relative abundance of the remaining species were noted, due, in part, to their small contributions to overall relative abundance in both the historic and current studies.

The channel catfish (*Ictaluras punctatus*) and flathead catfish (*Pylodictis olivaris*) are species which had a small effect on overall relative abundance but a larger effect on relative biomass in both historic and current

sampling efforts and are of special concern to the Prairie Band Potowatomi Tribe. Hand-fishing for these catfishes is popular on the reservation where this activity has cultural and religious significance. Overall relative abundance of channel catfish declined from 9.14% in historic samples to 2.42% in current samples. This apparent decline in relative abundance might be attributed to sampling error, changes in overall water quality and/or habitat. Within the confines of this study few significant water quality differences were noted between the KDHE and current studies. Habitat resource associated with historic conditions were not quantified so no comparisons can be made between studies. However, the current habitat data for Soldier Creek sites indicated that deep-water and crevice habitats were limited, yet both of these habitat types are highly desirable for the maintenance of large populations of these catfish. The addition or maintenance of these habitats (e.g. under-cut banks, log jams, submerged logs) could increase habitat for adults and juveniles, and increase spawning sites (i.e. crevice habitats), both of which could help to sustain higher local populations of these important and popular catfishes.

Species richness in current collections increased at Sites SC1 and SC7 in comparison to the historic study (Figure 26). When contrasted with past richness values, five additional species were collected at SC1 while a single new species was taken at SC7 in the current study efforts. However, at SC3 18 species were recorded during the historic study while only 17 species were found at this same site in 1996-1997. Site 7 showed the greatest species richness with 20 species in the current study. The family Cyprinidae had fairly similar richness values for the current and historic study at all sites. Three species of Ictaluridae were recorded at SC1 for both sampling periods, with the number of species increasing to five for SC3 and SC7 in the KDHE study, but decreased to four in the current study, with the loss of *A. melas* and *A. natalis* and the addition of *P. olivaris*. Catostomidae showed the least amount of change with only *M. macrolepidotum* added to SC1 and lost from SC3. Centrarchidae richness rose from one to three species at SC1, remained constant at SC3 and increased at SC7. The Percids showed some changes with *E. spectabile* now occuring at SC7, and *P. caprodes* present at both SC1 and SC7. *Percina caprodes* was absent from the KDHE study in historic collections but three individuals were found in the current study.

The relative abundance of fish families are displayed in Figure 27. The Cyprinidae were excluded from this figure as they compose over 80% of the abundance in all sites in both study periods, and inclusion of this large percentage group would have complicated examination of changes occurring in these groups comprising the remainder of the population. The Ictaluridae showed a small drop in abundance from historic to current sampling in

Site SC1, but the trend was reversed at SC3. At SC7, the relative abundance of Ictaluridae dropped from 9.5% in historic populations to less than 1% in the current populations. The Catostomidae showed a small increase in relative abundance from historic to current sampling at SC1 and approximately a 3% loss at both SC3 and SC7. The Centrarchidae appear to maintain relatively similar relative abundance, or decreased slightly from historic to current. The Percidae, while appearing in current samples at SC7 and not historic, showed slight decreases at SC1 and increases at SC3 and SC7 in relative abundance values.

Table 2: Total fish abundance for Soldier Creek sites (Jackson County, Kansas) sampled during the summer (June) of 1979 and 1980. Total stream length sampled at eash site varied between sites.

Site	SC1	SC1	SC3	SC3	SC7	SC7
Date	21 June 1979	4 June1980	20 June 1979	14 June 1980	19 June 1979	19 June 1980
Cyprinidae						
Campostoma anomalum	2678	2699	214	2380	40	43
Cyprinella lutresis	264	531	679	492	630	331
Cyprinus carpio	0	0	0	0	18	10
Notemigonus crysoleucas	0	0	0	0	1	0
Notropis ludibundus	2306	2549	2247	3426	965	768
Phenacobuis mirabilis	225	231	65	187	9	4
Pimphales notatus	329	594	239	670	104	342
Pimphales promelas	593	2038	118	776	215	220
Semotilus atromaculatus	321	493	1104	1474	98	112
Catostomidae						
Carpiodes carpio	4	0	17	106	171	119
Catostomus commersonii	175	75	669	19	25	26
Moxostoma macrolepidotum	0	0	1	0	3	1
Ictaluridae						
Ameiurus natalis	11	3	8	14	5	21
Ameiurus melas	5	0	1	6	0	3
Ictalurus punctatus	0	0	6	64	289	124
Noturus exilis	151	150	5	5	1	3
Noturus flavus	0	0	16	13	4	2
Centrarchidae						
Lepomis cyanellus	18	40	61	22	6	32
Lepomis humilis	0	0	0	0	14	0
Micropterus salmoides	0	0	0	1	0	0
Percidae						
Etheostoma spectabile	194	241	98	172	0	0

Table 3: Total fish abundance for June samples of Soldier Creek (Jackson County, Kansas) during the summers of 1996 and 1997. Total stream length sampled at each site varied between sites.

Site	SC1	SC1	SC3	SC3	SC7	SC7
	96	97	96	97	96	97
Cyprinidae						
Campostoma anomalum	4	69	14	5	7	77
Cyprinella lutrensis	1817	226	941	346	825	1005
Cyprinus carpio	0	2	0	0	0	0
Luxilus comutus	0	0	1	0	1	1
Notemigonus crysoleucas	0	0	0	0	0	0
Notropis ludibundus	326	246	288	553	101	144
Phenacobius mirabilis	9	147	1	23	2	26
Pimephales notatus	330	121	511	77	279	416
Pimephales promelas	6	46	23	14	2	61
Pimephales vigilax	0	0	0	0	0	0
Semotilus atromaculatus	0	93	0	107	0	186
Catostomidae						
Carpiodes carpio	2	13	3	6	2	3
Catostomus commersonii	0	66	0	60	0	142
Moxostoma macrolepidotum	1	0	0	0	1	0
Ictaluridae						
Ameiurus melas	0	0	0	0	0	0
Ameiurus natalis	0	0	0	0	0	0
Ictaluras punctatus	9	4	31	8	22	4
Noturus exilis	20	7	3	12	0	1
Noturus flavus	5	4	0	2	1	1
Pylodictis olivaris	0	0	0	1	0	3
Centrarchidae						
Lepomis cyanellus	2	0	0	1	0	1
Lepomis humilis	0	0	0	0	0	2
Lepomis megalotis	7	0	8	3	3	1
Micropterus salmoides	2	0	0	0	0	0
Percidae						
Etheostoma spectabile	2	50	4	9	3	8
Percina caprodes	0	4	0	0	0	1
Total	2542	1098	1828	1227	1249	2083

Table 4: Total fish biomass (grams) for Soldier Creek sites (Jackson County, Kansas) sampled during the summer (June-July) of 1996.

Site	SC1	SC1	SC1	SC3	SC3	SC3	SC7	SC7	SC7
Habitat	pool1	run 2	riffle 1	pool 1	riffle 1	run 1	run 1	pool 1	riffle 1
Cyprinidae	0	0	0	0	2.6	0.6	0	0	2.5
Campostoma anomalum	0.8	0.7	0.6	0	3.3	28.2	3.4	0	1.5
Cyprinella lutresis	521.3	611.5	85.3	158.3	296.3	284.1	209.7	158.3	168.4
Luxilus cornutus	0	0	0	1	0	0	0	1	0
Notropis ludibundus	146.7	151.8	45.3	63.3	154.8	78.7	11	63.3	12.5
Phenacobuis mirabilis	13.1	9.8	4.7	0	0	3.1	5.3	0	0
Pimphales notatus	151.2	59.4	0	140.5	58	184.7	8.7	140.5	35
Pimphales promelas	1.7	5.4	0	0	0	21.9	0.5	0	0.6
Catostomidae									
Carpiodes carpio	0	480.5	0	731.6	0	143.1	0	731.6	0
Moxostoma macrolepidotum	0	90.5	0	0	0	0	0	0	82.3
Ictaluridae									
Ictalurus punctatus	48.4	9.5	0	175	2.3	32.2	0	175	17.6
Noturus exilis	0	0	36	0	4.7	0	0	0	0
Noturus flavus	0	0	18.5	0	0	0	7.8	0	0
Polydictis olivaris	0	0	0	18.4	0	0	0	18.4	0
Centrarchidae									
Lepomis cyanellus	0	3.7	0	0	0	0	0	0	0
Lepomis megalotis	44.7	14.9	0	18.4	0	21.1	0	18.4	0
Micropterus salmoides	0.2	0.6	0	0	0	0	0	0	0
Percidae									
Etheostoma spectabile	0.2	0	0	0.4	0	0.2	0.2	0.4	0

Table 5: Total fish biomass (grams) for Soldier Creek Sites 1,3 and 7 sampled in June of 1997.

Site	SC1	SC1	SC1	SC3	SC3	SC7	SC7
Habitat	run 1	riffle 1	pool 1	run 1	riffle 1	run 1	pool 1
Month	June	June	June	June	June	June	June
Cyprinidae							
Campostoma anomalum	53.8	2.4	7.3	6.4	0.4	27.6	4.6
Cyprinella lutrensis	159.8	208.3	137.5	204.3	249.6	364.2	256.4
Cyprinus carpio			1.4				
Luxilus comutus							1
Notemigonus crysoleucas							
Notropis ludibundus	73.6	186.5	144.2	453	112.4	65.2	27
Phenacobius mirabilis	11.2	52.4	53.7	6.1	0.9	2.6	2.5
Pimephales notatus	52.3	11.8	169	104.9	24.2	362.1	75.6
Pimephales promelas	42.7		32.9	31.4		64.2	3.6
Pimephales vigilax							
Semotilus atromaculatus	17.1	1.7	31.6	51.1	20.5	23.1	12.5
Catostomidae							
Carpiodes carpio	2.7			448.3		87.8	
Catostomus commersonii	11.8	0.8	12.6	27.7	2.6	23.4	10.6
Moxostoma macrolepidotum							
Ictaluridae							
Ameiurus melas							
Ameiurus natalis							
Ictaluras punctatus	90.6		42.8	33.6		1766	2.6
Noturus exilis	2.9	21.7			34.1	7.4	
Noturus flavus		37.5			11.8		25.6
Pylodictis olivaris				1700		98	133.6
Centrarchidae							
Lepomis cyanellus				9.9			6.7
Lepomis humilis						3.1	4.4
Lepomis megalotis				54.3			2.2
Micropterus salmoides							
Percidae							
Etheostoma spectabile	9.2	3.8	4.8	0.8	0.9	0.4	4.4
Percina caprodes	5.5	1	0.5			0.3	

Table 6: Fish presence/absence data for the historic (1979-1980) and current (1996-1997) studies in Soldier Creek (Jackson County, Kansas).

Site	SC1	SC1	SC3	SC3	SC7	SC7
	historic	current	historic	current	historic	current
Cyprinidae						
Campostoma anomalum	X	X	X	X	X	X
Cyprinella lutrensis	X	X	X	X	X	X
Cyprinus carpio		X			X	
Luxilus comutus				X		X
Notemigonus crysoleucas					X	
Notropis ludibundus	X	X	X	X	X	X
Phenacobius mirabilis	X	X	X	X	X	X
Pimephales notatus	X	X	X	X	X	X
Pimephales promelas	X	X	X	X	X	X
Pimephales vigilax						
Semotilus atromaculatus	X	X	X	X	X	X
Catostomidae						
Carpiodes carpio	X	X	X	X	X	X
Catostomus commersonii	X	X	X	X	X	X
Moxostoma macrolepidotum		X	X		X	X
Ictaluridae						
Ameiurus melas	X		X		X	
Ameiurus natalis	X		X		X	
Ictaluras punctatus		X	X	X	X	X
Noturus exilis	X	X	X	X	X	X
Noturus flavus		X	X	X	X	X
Pylodictis olivaris				X		X
Centrarchidae						
Lepomis cyanellus	X	X	X	X	X	X
Lepomis humilis					X	X
Lepomis megalotis		X		X		X
Micropterus salmoides		X	X			
Percidae						
Etheostoma spectabile	X	X	X	X		X
Percina caprodes		X				X
Total Number of Species	14	19	18	17	19	20

Table 7: Relative fish abundance data for the historic (1979-1980) and current (1996-1997) studies in Soldier Creek (Jackson County, Kansas).

Site	SC1	SC1	SC3	SC3	SC7	SC7
	historic	current	historic	current	historic	current
Cyprinidae						
Campostoma anomalum	31.78	2.01	16.87	0.62	1.74	2.52
Cyprinella lutrensis	4.70	56.13	7.62	42.13	20.19	54.92
Cyprinus carpio	0.00	0.05	0.00	0.00	0.59	0.00
Luxilus cornutus	0.00	0.00	0.00	0.03	0.00	0.06
Notemigonus crysoleucas	0.00	0.00	0.00	0.00	0.02	0.00
Notropis ludibundus	28.70	15.71	36.90	27.53	36.42	7.35
Phenacobius mirabilis	2.70	4.29	1.64	0.79	0.27	0.84
Pimephales notatus	5.46	12.39	5.91	19.25	9.37	20.86
Pimephales promelas	15.55	1.43	5.81	1.21	9.14	1.89
Pimephales vigilax	0.00	0.00	0.00	0.00	0.00	0.00
Semotilus atromaculatus	4.81	2.55	16.77	3.50	4.41	5.58
subtotal	93.70	94.56	91.52	95.06	82.15	94.03
Catostomidae						
Carpiodes carpio	0.02	0.41	0.80	0.29	6.09	0.15
Catostomus commersonii	1.48	1.81	4.47	1.96	1.07	4.26
Moxostoma macrolepidotum	0.00	0.03	0.01	0.00	0.08	0.03
subtotal	1.50	2.25	5.28	2.26	7.24	4.44
Ictaluridae						
Ameiurus melas	0.03	0.00	0.05	0.00	0.06	0.00
Ameiurus natalis	0.08	0.00	0.14	0.00	0.55	0.00
Ictaluras punctatus	0.00	0.36	0.46	1.28	8.68	0.78
Noturus exilis	1.78	0.74	0.07	0.49	0.08	0.03
Noturus flavus	0.00	0.25	0.19	0.07	0.13	0.06
Pylodictis olivaris	0.00	0.00	0.00	0.03	0.00	0.09
subtotal	1.89	1.35	0.91	1.87	9.50	0.96
Centrarchidae						
Lepomis cyanellus	0.34	0.05	0.54	0.03	0.80	0.03
Lepomis humilis	0.00	0.00	0.00	0.00	0.29	0.06
Lepomis megalotis	0.00	0.19	0.00	0.36	0.00	0.12
Micropterus salmoides	0.00	0.05	0.01	0.00	0.00	0.00
subtotal	0.34	0.30	0.55	0.39	1.09	0.21
Percidae						
Etheostoma spectabile	2.57	1.43	0.08	0.43	0.00	0.33
Percina caprodes	0.00	0.11	0.00	0.00	0.00	0.03
subtotal	2.57	1.54	0.08	0.43	0.00	0.36

Table 8: Total site abundances for 1997 sampling periods (June, August and November).

Site	SC1	SC3	SC7	SC5A	SC6	SC9
Habitat	All	All	All	All	All	All
Cyprinidae						
Campostoma anomalum	105	1051	393	419	0	1260
Cyprinella lutrensis	3653	1678	2750	1560	3	24
Cyprinus carpio	2	0	0	0	0	0
Luxilus comutus	0	18	180	216	0	0
Notemigonus crysoleucas	0	0	0	0	0	0
Notropis ludibundus	766	1345	1493	335	14	45
Phenacobius mirabilis	358	280	92	34	5	2
Pimephales notatus	1708	1962	3113	347	246	0
Pimephales promelas	150	276	159	164	0	2
Pimephales vigilax	0	0	2	0	0	0
Semotilus atromaculatus	237	246	421	1053	365	1286
Catostomidae						
Carpiodes carpio	22	36	4	0	0	0
Catostomus commersonii	77	78	153	273	13	54
Moxostoma macrolepidotum	53	206	72	0	0	0
Ictaluridae						
Ameiurus melas	0	0	0	0	0	0
Ameiurus natalis	0	1	0	5	0	0
Ictaluras punctatus	164	130	27	0	0	0
Noturus exilis	75	36	13	22	0	0
Noturus flavus	11	7	2	0	0	0
Pylodictis olivaris	0	3	3	0	0	0
Centrarchidae						
Lepomis cyanellus	3	2	6	7	0	0
Lepomis humilis	0	0	8	56	0	0
Lepomis megalotis	9	12	9	0	0	0
Micropterus salmoides	0	0	0	0	0	0
Percidae						
Etheostoma spectabile	297	78	77	180	27	192
Percina caprodes	5	1	2	0	0	0
Sciaenidae						
Aplodinotus grunniens	0	0	1	0	0	0
Totals	7695	7446	8980	4671	673	2865

Figure 26: Species richness of fish families collected in the historic and current study of Soldier Creek (Jackson County, Kansas).

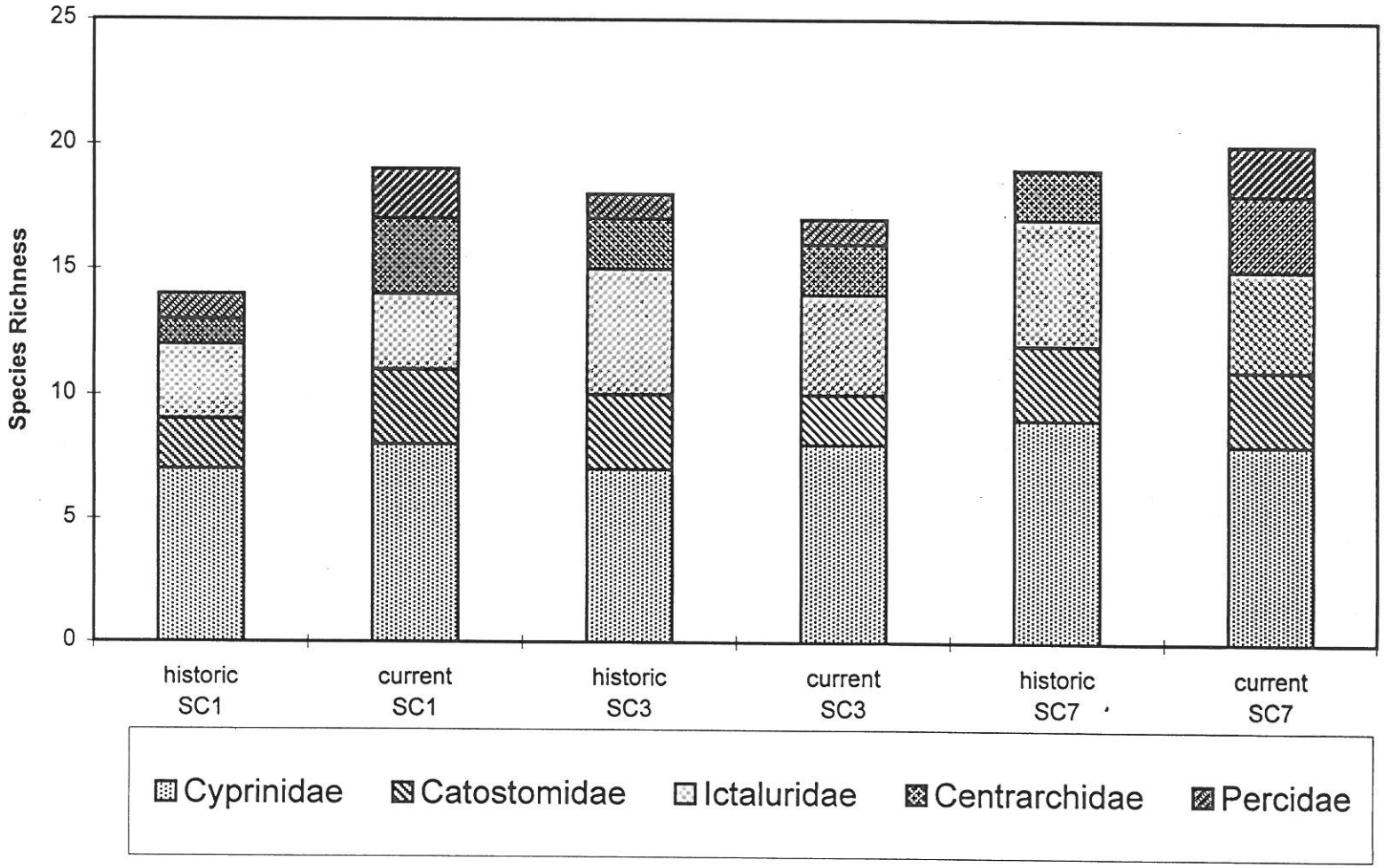
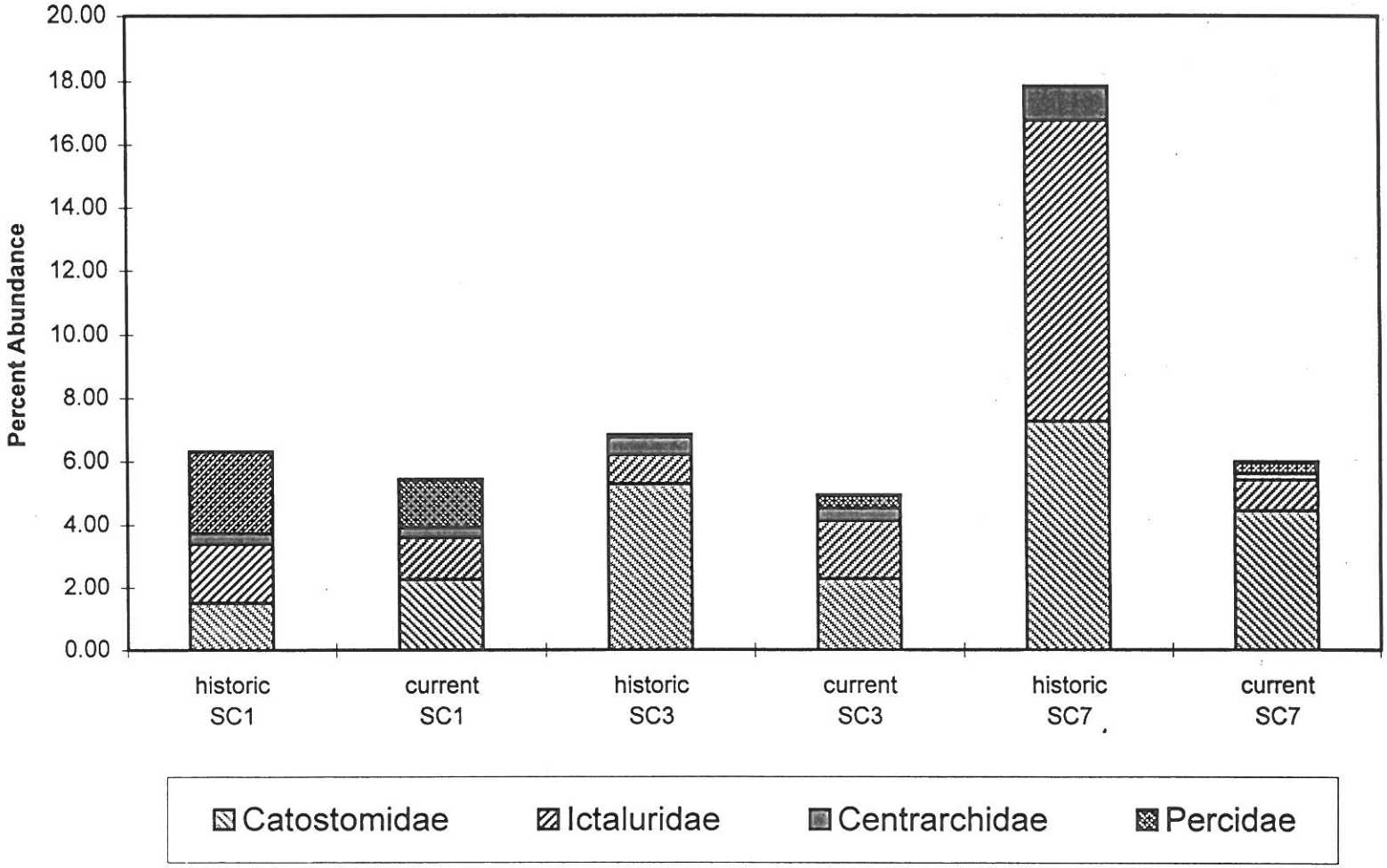


Figure 27: Relative abundance values of fish families collected in the historic and current study of Soldier Creek (Jackson County, Kansas).



Macroinvertebrate Community

Macroinvertebrates were sampled using a one-minute sampling effort that involved kicking the bottom substrate, disturbing cobble, sediment, algal masses and macrophytes. Dislodged invertebrates drifted or were swept into a 500 micron mesh D-net held downstream of each agitated microhabitat. Attempts were made to sample all microhabitats capable of supporting benthic invertebrates. Concurrent with sampling, a habitat analysis was performed at all sites to determine quality and quantity of habitat sampled for each invertebrate collection (Huggins and Moffett 1988).

The condition of Soldier Creek's macroinvertebrate community was evaluated according to habitat heterogeneity, total taxa richness, community composition, relative abundance and EPT richness. Diversity indices (Gleason's, Shannon's and Brillioun's) were also calculated to assess Soldier's biological condition. Calculation of diversity indices was accomplished with ECOMEAS, a software program developed for the Kansas Biological Survey (Slater 1986). Box plots provided a statistical reference for examination of several macroinvertebrate parameters.

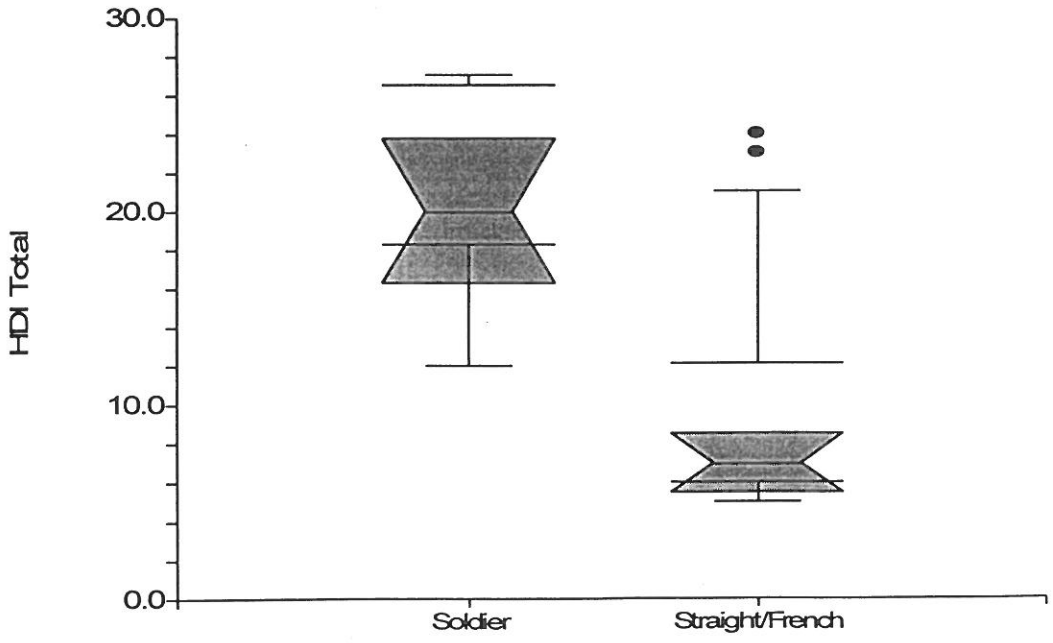
Efforts were made to temporally standardize the data sets between Soldier and the reference watersheds in order to provide a suitable framework for comparison. For example, field sampling for Soldier occurred twice in spring 1996-1997, and once in summer and fall 1997. Therefore, Straight and French macroinvertebrate data was specifically selected to include two spring collections 1992-1993, one summer 1993 and one fall 1993 collection. On the other hand, comparisons between historic Soldier and current Soldier should be cautiously interpreted. Historic Soldier's macroinvertebrate data was acquired through a number of extensive, qualitative collecting methods. Although insects collected at blacklight traps were omitted from this study (trapped specimens may have originated from nearby streams), other methods of collection were incorporated. In the historic study, insects were qualitatively collected with drift nets, D-frame nets and hand-picking. In contrast, care was taken in the present Soldier Creek study to quantitatively sample the invertebrate community using a timed approach and a D-frame net.

In-stream Habitat

The quality and quantity of available stream habitat for macroinvertebrates must be considered when examining stream invertebrate community composition. Because macroinvertebrate diversity, richness and abundance may differ in streams due to either water quality and/or habitat quality (e.g. Huggins and Moffett 1988, Ward 1992, Allan 1995). The Habitat Development Index (HDI) provides a quantitative strategy for evaluating the quality of habitat available to stream invertebrates. Each stream macrohabitat is ranked numerically according to depth, velocity, percent cobble, percent cobble embeddedness, presence\absence of algal masses, and densities of organic debris or detritus, macrophytes and bank vegetation (For a detailed description see Huggins and Moffett 1988). High HDI scores suggest above average habitat heterogeneity that can support a diverse macroinvertebrate fauna (Anderson 1990).

HDI values for the current Soldier Creek study contrasted significantly with reference stream values. The median HDI score of 20 for Soldier Creek greatly exceeded the 6.0-8.0 range exhibited by the reference streams (Figure 28). Although considered to possess above average water quality, the reference streams are characterized by a homogeneous sand bottom substrate with reduced habitat diversity.

Figure 28: Box plot of HDI measurements taken from Soldier Creek and the reference streams.



Aquatic invertebrates

Degradation of the benthic community may be manifest by reduced taxa richness, and/or shifts in community compositon in comparison to reference conditions, and by the absence of pollution intolerent taxa such as Ephemeroptera, Plecoptera and Tricoptera (Rosenberg and Resh 1996). Often, affects on community and ecosystem structure and dynamics can also occur and include changes in abundance and biomass, loss of keynote species, changes in trophic structure and function, change in dominance patterns, alternations in spatial structure and reduced ecosystem stability (e.g. Sheehan 1988, Kelly and Harwell 1989, La Point 1995).

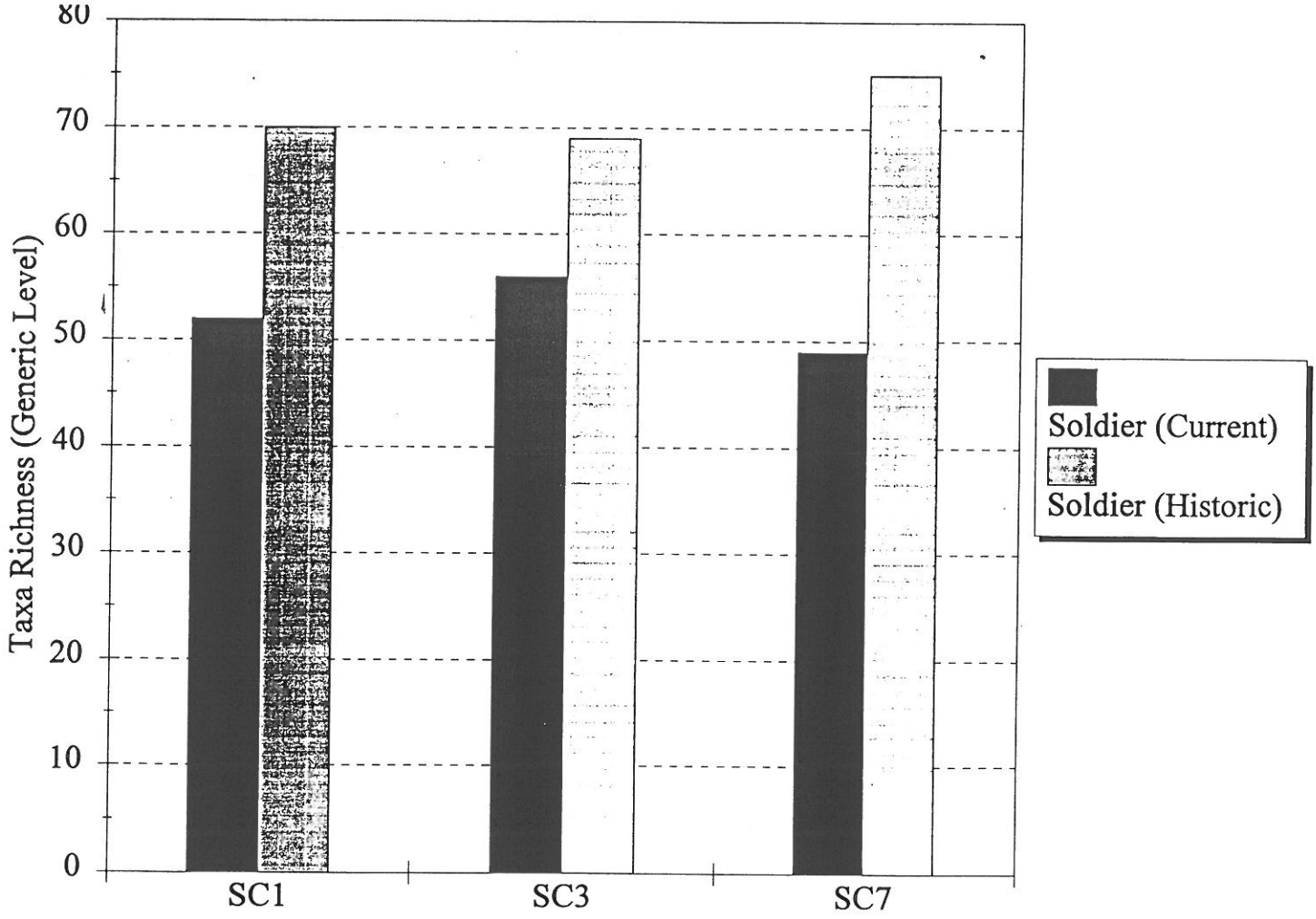
Taxa Richness

Family richness did not deviate significantly between present Soldier, historic Soldier, French and Straight Creeks. Current Soldier macroinvertebrate samples comprised 44 insect families, a value shared by Straight Creek but slightly inferior to historic Soldier (49 families) and French (50 families) creeks (Appendix 1). However, analysis at the generic level showed that current Soldier possessed reduced taxa richness in comparison to historic Soldier. Invertebrate samples from current Soldier yielded 74 insect genera. On the other hand, 97 insect taxa were collected from historic Soldier Creek. Furthermore, collection sites on current Soldier supported 52 (SC1), 56 (SC3), and 49 (SC7) genera, whereas the same sites on historic Soldier supported 70 (SC1), 69 (SC3) and 75 (SC7) genera, respectively (Figure 29). It appears that the discrepency in generic richness can be attributed to the elevated number of Hemiptera and Coleoptera taxa within historic Soldier Creek. The discrepency in generic richness may be a result of the intensive collecting efforts incorporated into the historic KDHE study. While taxa collected at blacklight insect traps were not included in this analysis, other methods of collection--drift nets, d-frame aquatic nets and hand picking--were included. Caution should be taken when interpreting comparisons between historic Soldier's qualitative collecting efforts and current Soldier's quantitative methods.

Community Composition

While the taxa richness within each insect order does not deviate significantly between Soldier and the reference streams the relative abundance of individuals differs markedly. Figure 30 highlights the enumerations of insects within each order (and including oligochaeta) in comparison to the sum of all insects/oligochaetes. It is

Figure 29: Site comparisons of taxa richness within current and historic Soldier Creek (Jackson Co. Kansas).

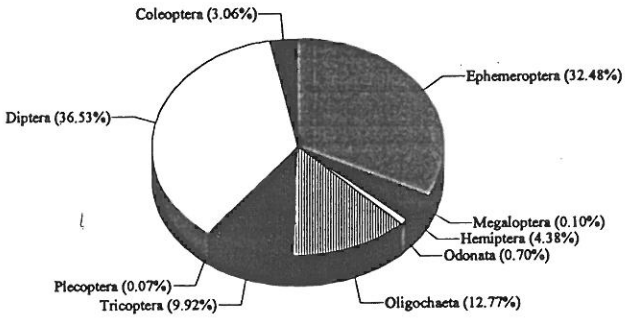


evident that Soldier supports a larger percentage of mayflies (32.48%) than does Straight (13.96%) or French (12.48%). Additionally, caddisflies are considerably more abundant in Soldier (9.92%) than in Straight (1.61%) and French (1.82%). On the other hand, although considered to possess above average water quality, both reference streams support high densities of Diptera and oligochaetes, ubiquitous organisms that can thrive in stressed environments. This can be attributed to the lack of heterogeneous in-stream habitat within Straight and French Creek. There simply is not enough suitable microhabitat to support dense populations of varied taxa. However, Soldier possesses significantly higher quality in-stream habitat and therefore should be capable of supporting larger populations of different taxa. Figure 30 illustrates that, indeed, Soldier supports a more balanced invertebrate community in comparison to the reference streams.

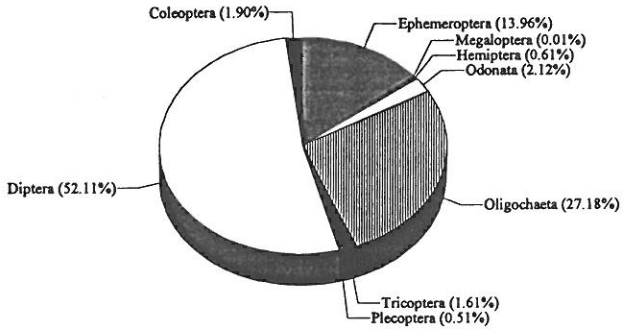
EPT Measures

Most taxa within the orders Ephemeroptera, Plecoptera and Tricoptera (EPT) are considered sensitive to slight perturbations in water quality. Therefore, an analysis of taxa richness and population density within these orders may reflect a stream's biotic condition, with high EPT values indicative of above average water quality (e.g. Plafkin it al 1989, Ohio EPA 1987, Fore and Karr 1996). Site comparisons of EPT richness (generic level) showed that current Soldier exceeded historic Soldier in the number of EPT genera present. Within current Soldier Site 1, Site 3 and Site 7 supported 23, 26 and 20 EPT taxa respectively, while the same sites on historic Soldier yielded 18 (SC1), 19 (SC3) and 18 (SC7) EPT genera. At the family level Soldier Creek supported approximately the same number of EPT taxa as both reference streams. Soldier's sixteen families did not differ significantly from Straight's fourteen and French's nineteen families. On the other hand, Soldier surpassed both reference streams with densities of mayflies, stoneflies and caddisflies. Enumerations of insects revealed that EPT individuals comprised over half (51.25%) of Soldier Creek's invertebrate samples, while maintaining smaller proportions within Straight (22.07%), and French's (16.96%) insect communities (Figure 31). It is not surprising that Soldier Creek supports elevated densities of EPT individuals in comparison to the reference streams. To reiterate, in constrast to the reference streams, Soldier Creek possesses greater in-stream habitat complexity which should be capable of supporting a diverse and abundant benthic fauna.

Soldier



Straight



French

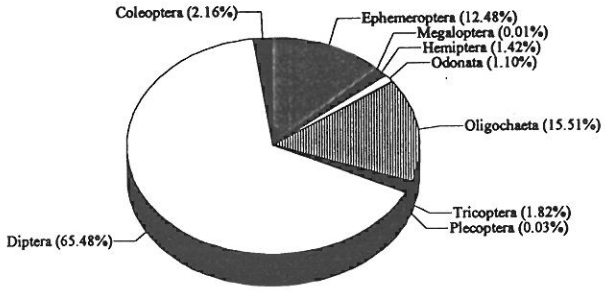
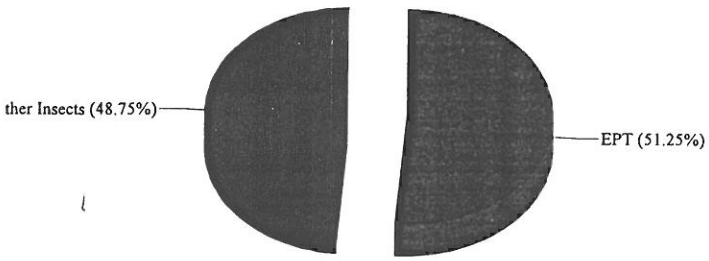
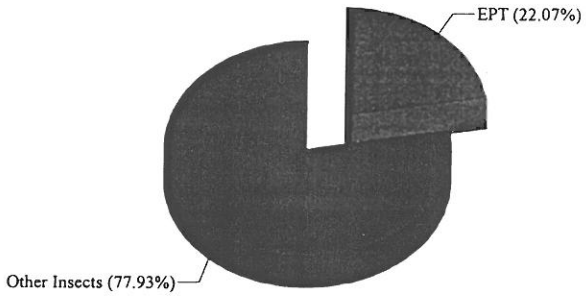


Figure 30: Relative abundances of invertebrates collected from Soldier, Straight and French Creeks.

Soldier



Straight



French

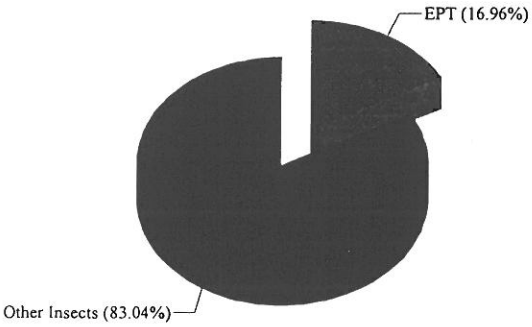


Figure 31: Relative abundance of Ephemeroptera, Plecoptera and Tricoptera as a percentage of total insect abundance.

Diversity Indices

Diversity indices combine taxa diversity and evenness (the number of individuals within each taxa) into a single value representing a stream's biotic condition. Results are commonly incorporated in biomonitoring programs with a high value delineating a diverse, stable community (Washington 1984). Box plots of Shannon's, Brillioun's and Gleason's diversity indices suggest that current Soldier did not differ significantly, in diversity index parameters, from the reference streams. Median box plot values for current Soldier varied little from each reference stream's median value for all indices compared (Figures 32,33,34). This connotes an above average aquatic condition for current Soldier as the reference streams have been predetermined to be minimally disturbed (stressed) systems.

Figure 32: Box plot of Shannon's diversity index for Soldier Creek versus the reference streams.

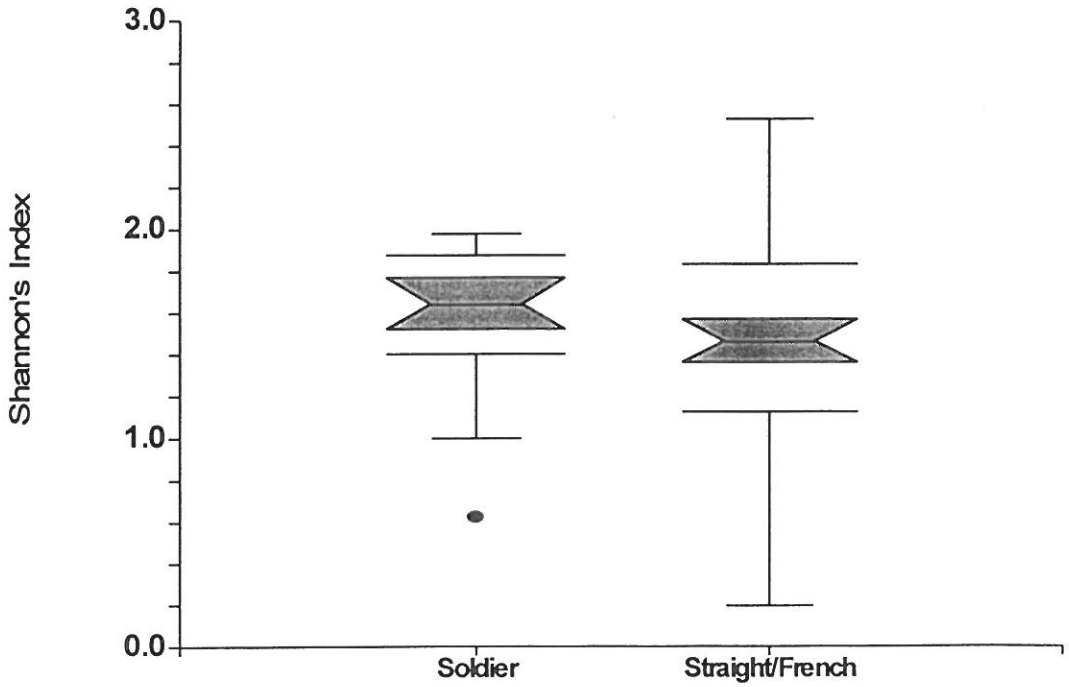


Figure 33: Box plot of Brillioun's diversity index for Soldier Creek versus the reference streams.

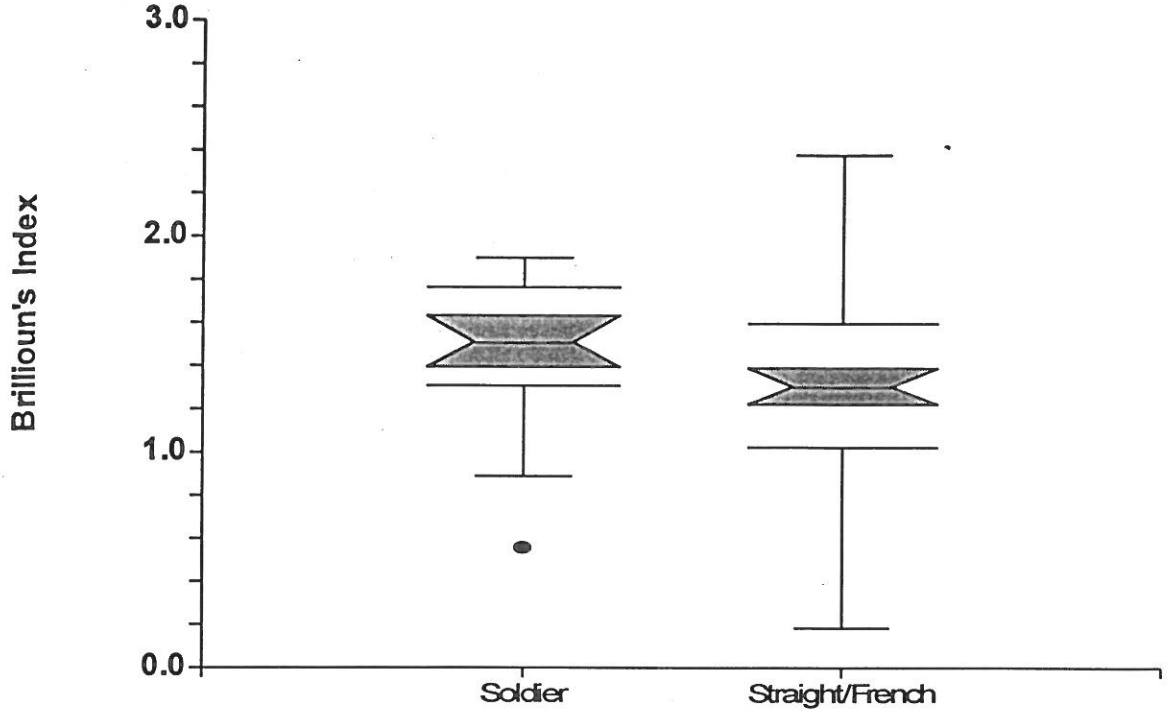
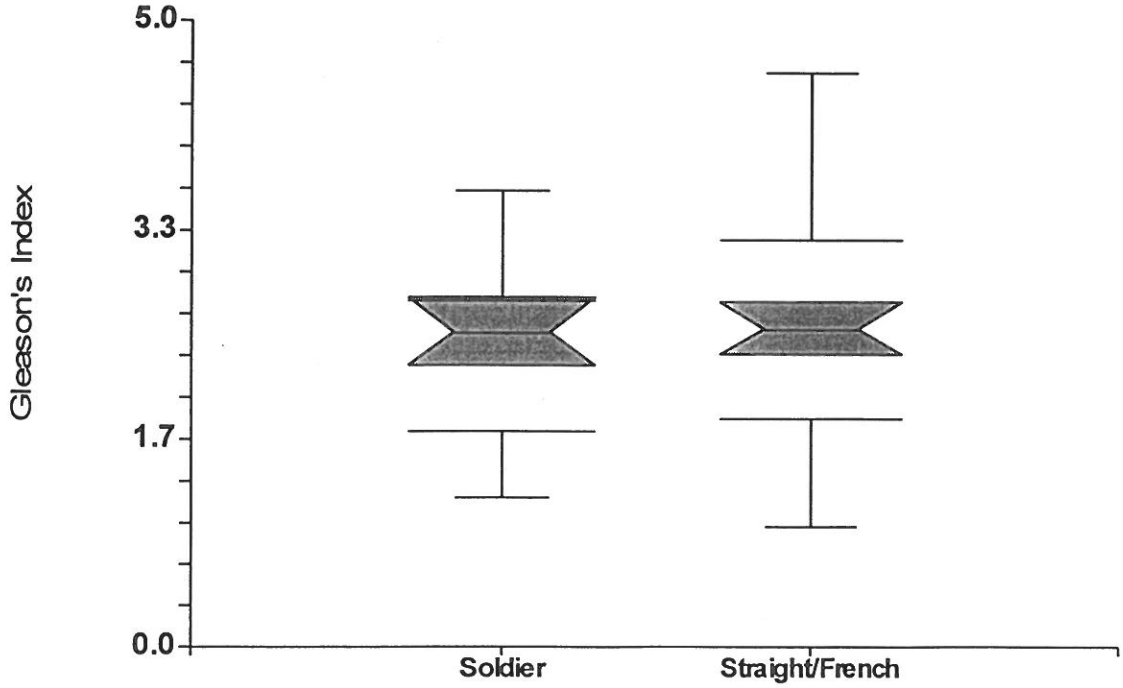


Figure 34: Box plot of Gleason's diversity index of Soldier Creek versus the reference streams.



Conclusion

Soldier Creek repeatedly scored as well or better when compared with the historic condition and with a "minimally impacted" reference condition for a multitude of chemical, habitat and biological measures. Soldier Creek possessed similar water quality to the historic Soldier Creek and/or the reference condition in terms of dissolved oxygen, conductivity, alkalinity, phosphorus and fecal coliform. Surprisingly, Soldier Creek exhibited significantly lower values for nitrogen than did the reference condition. The low values for phosphorus and nitrogen indicate that nutrient enrichment from fertilizer applications and livestock impacts is minimal in this watershed.

According to the habitat analysis, Soldier Creek surpassed the reference condition when in-stream habitat parameters were examined. Soldier Creek consistently exceeded the reference condition for the Debris Loading Index, the Habitat Richness Index and the Habitat Development Index. These indices measure the quality and quantity of habitat available to stream invertebrates and fish and provide an indirect measure of the potential energy (organic matter) that is available to these organisms. The in-stream habitat data suggests that Soldier Creek should be capable of supporting a diverse and abundant stream community.

Overall, the macroinvertebrate and fish data from the 1996-1997 collections indicate that Soldier Creek possesses good water quality and is relatively unchanged from its historic condition. Comparisons between historic data, the reference data and current data illustrates that Soldier Creek consistently scores as well or better on the biological metrics used within this study. For example, the total number of fish species was higher in current Soldier (56 species) than in historic Soldier Creek (51 species). In fact, the overall data showed some species shift but no consistent loss of species which would indicate a continued deterioration of water quality. In addition, a number of extrinsic factors could have contributed to observed changes in fish community composition and overall loss or gain of some species between study periods in the various segments of Soldier Creek. It is important to note that sampling error associated with the different studies may have played a major role in the differences found. The use of rotenone in historic sampling provided researchers with the ability to sample the entire population of fish in a designated area. The disparities in sampling efforts might, in part, explain the similarities in the abundant taxa, i.e. the Cyprinidae, between historic and current sampling and the lack of similarity in less abundant taxa. Based on

the comparisons made between various parameters derived from historic and current fish data, Soldier Creek appears to be in good condition or at least as good of condition as was found during the historic study.

The relatively healthy condition of current Soldier is further supported by the macroinvertebrate data. The habitat analysis from Soldier Creek described a heterogeneous stream habitat capable of supporting diverse assemblages of benthic organisms. Moreover, of the five macroinvertebrate parameters or metrics (total richness, community composition, abundance, EPT richness and diversity) examined for Soldier's macroinvertebrates, only generic richness inferred that Soldier's water quality may be degraded. From this metric it could be concluded that Soldier Creek today has deteriorated from the condition described in the historic KDHE study. However, it is more likely that differences in genera richness have originated from variations in sampling methodology. Soldier Creek exhibited a benthic community rich with Ephemeroptera and Tricoptera, taxa considered to be pollution sensitive. The relative abundance of mayfly and caddisfly nymphs in Soldier Creek far exceeded abundances found in Straight and French Creek. Moreover, Soldier clearly possessed a more balanced invertebrate community in comparison to the reference streams. Rather than being dominated by Diptera and oligochaetes, as are Straight and French, Soldier supports larger populations of different taxa. Box plot comparisons of Shannon's, Brillioun's and Gleason's diversity indices indicated that the diversity of the macroinvertebrate community in Soldier Creek was very similar to that found in Straight and French Creek.

However, while almost all water chemistry, habitat and biological measures support the assessment that Soldier Creek is similar to the reference condition, and is relatively unchanged from the historic condition, there are a few results that indicate the integrity of Soldier Creek is being compromised. Soldier Creek scored above the reference condition and/or the historic condition for measures of turbidity and erosional erea; and scored below the reference condition for measures of riparian condition. While it is difficult to determine if the elevated turbidity values are a result of organic or inorganic particles, the evidence suggests that erosion and excessive sediment input may be compromising the ecological integrity of Soldier Creek. Inorganic sedimentation may result in decreased primary productivity, shifts in community composition and reductions in less tolerant taxa and density of stream organisms (Lemly 1982, Lenat 1984). Excessive sediment loads may settle and eventually result in the homogenization of the stream substrate. However, a healthy riparian zone will provide stability to streambanks, thereby reducing soil erosion and will remove soil as water passes through (EPA 1990). While most of the

chemical, biological and habitat variables examined in this study indicated that Soldier Creek is a healthy watershed, relatively unchanged from the historic condition, the turbidity measures provide evidence that Soldier Creek has been altered from the historic condition by anthropogenic impacts.

The ecological integrity of Soldier Creek has no doubt deteriorated from pre-european settlement condition, yet this stream stretch appears to support a rather diverse natural fish and invertebrate community. Water quality (elevated turbidity) and channel conditions (excessive erosional area, inferior riparian condition) may be contributing factors that limit potential improvements in the biotic community health of the segment of Soldier Creek that flows into and through the Potawatomi Indian Reservation.

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Appendix

Appendix A: Different levels of taxa richness calculated for the study watersheds.

Stream	Class	Order	Family	Genus
French	8*	18*	50	NA
Straight	8*	18*	44	NA
Soldier (Historic)	6*	15*	49	97**
Site 1	6*	15*	39	71**
Site 3	6*	14*	38	69**
Site 7	5*	13*	42	75**
Soldier (Current)	11*	23*	44	74**
Site 1	10*	20*	35	52**
Site 3	8*	18*	37	56**
Site 7	7*	16*	33	49**
Crow	9*	19*	36	56**
Southbranch	7*	14*	23	28**
James	9*	18*	35	50**

*all invertebrates (including non-Insecta)

**excluding chironomid genera

Appendix B: Taxa list for Soldier Creek, Jackson Co, Kansas collected June 1996 and June, August, November 1997.

Coleoptera
- Family Dryopidae
  - *Helichus sp.*
- Family Dytiscidae
  - *Hydroporus sp.*
- Family Elmidae
  - *Dubiraphia sp.*
  - *Macronychus sp.*
  - *Stenelmis sp.*
- Family Gyrinidae
  - *Dineutus sp.*
  - *Gyrinus sp.*
- Family Haliplidae
  - *Peltodytes sp.*
- Family Helophoridae
  - *Helophoris sp.*
- Family Hydrophilidae
  - *Enochrus sp.*
  - *Tropisternus sp.*
  - *Berosus sp.*

Diptera
- Family Ceratopogonidae
  - *Bezzia sp.*
  - *Ceratopogon sp.*
  - *Probezzia sp.*
- Family Chironomidae (see attached 1996 taxa list)
- Family Culicidae sp.
  - *Anopheles sp.*
- Family Empididae
  - *Hemerodromia sp.*
- Family Ephydridae
- Family Muscidae
- Family Psychodidae
  - *Pericoma/Telmatoscopus sp.*
  - *Psychoda sp.*
- Family Simuliidae
  - *Simulium sp.*
- Family Sciomyzidae
- Family Stratiomyiidae
  - *Calopharyphus sp.*
- Family Tabanidae
  - *Chrysops sp.*
  - *Tabanus sp.*
- Family Tipulidae
  - *Erioptera sp.*
  - *Hexatoma sp.*
  - *Limonia sp.*
  - *Tipula sp.*

Ephemeroptera
- Family Baetidae
  - *Baetis sp.*
  - *Centroptilum sp.*
  - *Procloeon sp.*
- Family Caenidae
  - *Brachycercus sp.*
  - *Caenis sp.*
- Family Ephemeridae
  - *Hexagenia sp.*
- Family Heptageniidae
  - *Heptagenia sp.*
  - *Leucrocuta sp.*
  - *Stenacron sp.*
  - *Stenonema sp.*
- Family Isonychidae
  - *Isonychia sp.*
- Family Leptophlebiidae
  - *Choroterpes sp.*
  - *Leptophlebia sp.*
- Family Polymitarcyidae
  - *Ephoron sp.*
- Family Trycorythidae
  - *Trycorythodes sp.*

Hemiptera
- Family Corixidae
  - *Palmacorixa sp.*
  - *Sigara sp.*
  - *Trichocorixa sp.*
- Family Gerridae
  - *Trebobates sp.*
- Family Veliidae
  - *Microvelia sp.*
  - *Rhagovelia sp.*

Megaloptera
- Family Corydalidae
  - *Corydalis sp.*
- Family Sialidae
  - *Sialis sp.*

Plecoptera
- Family Capniidae
  - *Allocapnia sp.*
- Family Perlidae
  - *Perlesta sp.*

Appendix B continued

Soldier Creek taxa

Odonata
- Family Aeshnidae
  - *Nasiaechna pentacantha*
- Family Calyopterigidae
  - *Calyopteryx sp.*
  - *Hetaerina sp.*
- Family Coenagrionidae
  - *Argia sp.*
  - *Enallagma sp.*
- Family Gomphidae
  - *Erpetogomphus sp.*
  - *Gomphus sp.*
  - *Progomphus sp.*

Tricoptera
- Family Helicopsychidae
  - *Helicopsyche sp.*
- Family Hydropsychidae
  - *Cheumatopsyche sp.*
  - *Hydropsyche sp.*
- Family Hydroptilidae
  - *Hydroptila sp.*
  - *Ochrotrichia sp.*
  - *Orthotrichia sp.*
- Family Leptoceridae
  - *Ceraclea sp.*
  - *Nectopsyche sp.*
  - *Oecetis sp.*
- Family Philopotamidae
  - *Chimarra sp.*
- Family Polycentropodidae

Other
- Gastropoda
  - Family Ancylidae
  - Family Lymnaeidae
  - Family Physidae
- Pelecypoda
- Cladocera
- Copepoda
- Ostracoda
- Talitridae (*Hyalella azteca)*
- Nematoda
- Oligochaeta
- Turbellaria
- Decapoda
- Glossiphoniidae
- Erpobdellidae
- Branchiobdellida
- Hydroida (*Hydra sp.*)
- Hydracarina

Appendix B continued

Kansas/Jackson Co.	Soldier Creek	Collected June 1996

Chironomid taxa

Family Chironomidae

Axarus sp.
Brillia flavifrons
Chironomus sp.
Cladotanytarsus sp.
Cladotanytarsus mancus gr.
Cricotopus spp.
Cricotopus bicinctus
Cricotopus trifascia
Cricotopus/Orthocladius gr.
Cryptochironomus cf. blarina
Cryptotendipes sp.
Dicrotendipes cf. tritomus
Dicrotendipes neomodestus
Diplocladius cf. cultriger
Microtendipes pedellus gr.
Nanocladius cf. distinctus
Nanocladius cf. rectinervis
Nilotanypus fimbriatus
Parachironomus sp.
Paracladopelma nereis
Parakiefferiella cf. bathophila
Parametriocnemus sp.
Paratanytarsus sp.
Polypedilum cf. halterale
Polypedilum cf. scalaenum
Polypedilum convictum gr.
Polypedilum fallax
Polypedilum illinoense gr.
Pseudochironomus sp.
Rheotanytarsus sp.
Saetheria cf. tylus
Stictochironomus sp.
Tanypodinae
Tanytarsus gregarius & lugens gr.
Tanytarsus mendax gr.
Tanytarsus pallidicornis & aculeatus gr.
Tanytarsus sp. A of Goldhammer
Tanytarsus sp. D of Goldhammer
Tanytarsus sp. K of Goldhammer
Tanytarsus sp. V of Goldhammer
Telopelopia okoboji
Thienemanniella sp.
Thienemanniella cf. xena
Thienemanniella sp. C of Epler
Thienemannimyia gr.

Appendix C: Taxa list for Crow Creek, Jackson Co., Kansas collected June, August, November 1997

Coleoptera
- Family Dytiscidae
  - *Hydroporus sp.*
- Family Elmidae
  - *Dubiraphia sp.*
  - *Stenelmis sp.*
- Family Gyrinidae
  - *Gyrinus sp.*
- Family Hydrophilidae
  - *Tropisternus sp.*
  - *Laccobius sp.*
- Family Scirtidae
  - *Cyphon sp.*

Diptera
- Family Ceratopogonidae
  - *Bezzia sp.*
- Family Chironomidae
- Family Culcidae
  - *Anopheles sp.*
  - *Culex sp.*
- Family Dolichopodidae
  - *Dolichopus sp.*
- Family Empididae
  - *Hemerodromia sp.*
- Family Ephydridae
- Family Psychodidae
  - *Pericoma/Telmatoscopus sp.*
- Family Simuliidae
  - *Simulium sp.*
- Family Stratiomyidae
  - *Nemotelus sp.*
  - *Stratiomys sp.*
- Family Tabanidae
  - *Chrysops sp.*
  - *Tabanus sp.*
- Family Tipulidae
  - *Gonomyia sp.*
  - *Hexatoma sp.*
  - *Limonia sp.*
  - *Pilaria sp.*
  - *Tipula sp.*

Ephemeroptera
- Family Baetidae
  - *Baetis sp.*
  - *Centroptilum sp.*
- Family Caenidae
  - *Brachycercus sp.*
  - *Caenis sp.*

Ephemeroptera cont.
- Family Ephemeridae
  - *Hexagenia sp.*
- Family Heptageniidae
  - *Heptagenia sp.*
  - *Leucrocuta sp.*
  - *Stenacron sp.*
  - *Stenonema sp.*
- Family Isonychidae
  - *Isonychia sp.*
- Family Trycorythidae
  - *Trycorythodes sp.*

Hemiptera
- Family Corixidae
  - *Palmacorixa sp.*
  - *Sigara sp.*
- Family Gerridae
- Family Veliidae
  - *Microvelia sp.*
  - *Rhagovelia sp.*

Odonata
- Family Calyopterigidae
  - *Calyopteryx sp.*
  - *Hetaerina sp.*
- Family Coenagrionidae
  - *Argia sp.*
  - *Enallagma sp.*
- Family Gomphidae
  - *Gomphus sp.*
  - *Progomphus sp.*

Plecoptera
- Family Capniidae
  - *Allocapnia sp.*
- Family Perlidae
  - *Perlesta sp.*

Tricoptera
- Family Hydropsychidae
  - *Cheumatopsyche sp.*
  - *Hydropsyche sp.*
- Family Hydroptilidae
  - *Hydroptila sp.*
  - *Neotrichia sp.*
- Family Leptoceridae
  - *Oecetis sp.*
- Family Polycentropodidae
  - *Polycentropus sp.*

Appendix C continued

Megaloptera
- Family Corydalidae
  - *Corydalus sp.*
- Family Sialidae
  - *Sialis sp.*

Other
- Gastropoda
  - Ancylidae
  - Lymnaeidae
  - Physidae
- Pelecypoda
- Copepoda
- Cladocera
- Oligochaeta
- Turbellaria
- Nematoda
- Decapoda
- Hydracarina
- Hydroida (*Hydra sp.*)
- Branchiobdellida

Appendix D: Taxa list for Southbranch Creek, Jackson Co, Kansas collected June, November 1997 (August collection was unsuccessful due to lack of instream flow).

Coleoptera
- Family Dytiscidae
  - *Hydroporus sp.*
- Family Elmidae
  - *Stenelmis sp.*

Diptera
- Family Ceratopogonidae
  - *Bezzia sp.*
- Family Chironomidae
- Family Dolichopodidae
  - *Dolichopus sp.*
- Family Empididae
  - *Hemerodromia sp.*
- Family Muscidae
  - *Limnophora sp.*
- Family Psychodidae
  - *Maruina sp.*
  - *Pericoma/Telmatoscopus sp.*
  - *Psychoda sp.*
- Family Simuliidae
  - *Simulium sp.*
- Family Stratiomyidae
  - *Nemotolus sp.*
- Family Tabanidae
  - *Chrysops sp.*
  - *Tabanus sp.*
- Family Tipulidae
  - *Erioptera sp.*
  - *Gonomyia sp.*
  - *Tipula sp.*

Ephemeroptera
- Family Baetidae
  - *Centroptilum sp.*
- Family Caenidae
  - *Brachycercus sp.*
  - *Caenis sp.*
- Family Ephemeridae
  - *Hexagenia sp.*
- Family Heptageniidae
  - *Heptagenia sp.*
- Family Isonychidae
  - *Isonychia sp.*

Hemiptera
- Family Gerridae
  - *Gerris sp.*

Odonata
- Family Calyopterygidae
  - *Calyopteryx sp.*
- Family Gomphidae
  - *Gomphus sp.*

Plecoptera
- Family Capniidae
  - *Allocapnia sp.*

Tricoptera
- Family Hydropsychidae
  - *Cheumatopsyche sp.*
- Family Hydroptilidae
  - *Hydroptila sp.*

Other
- Gastropoda
  - Family Ancylidae
  - Family Lymnaeidae
  - Family Physidae
- Copepoda
- Decapoda
- Oligochaeta
- Turbellaria
- Hydracarina
- Branchiobdellida

Appendix E: Taxa list for James Creek, Jackson Co, Kansas collected June, August, November 1997

Coleoptera
- Family Dryopidae
  - *Helichus sp.*
- Family Dytiscidae
  - *Agabus sp.*
  - *Laccophilus sp.*
  - *Hydroporus sp.*
- Family Elmidae
  - *Dubiraphia sp.*
  - *Stenelmis sp.*
- Family Gyrinidae
  - *Dineutus sp.*
- Family Haliplidae
  - *Peltodytes sp.*
- Family Hydrophilidae
  - *Berosus sp.*
  - *Tropisternus sp.*

Diptera
- Family Ceratopogonidae
  - *Bezzia sp.*
- Family Chironomidae
- Family Culicidae
  - *Aedes sp.*
  - *Anopheles sp.*
  - *Culex sp.*
  - *Culiseta sp.*
- Family Dolichopodidae
  - *Dolichopus sp.*
- Family Empididae
  - *Hemerodromia sp.*
- Family Ephydridae
- Family Muscidae
- Family Psychodidae
  - *Pericoma/Telmatoscopus sp.*
- Family Sciomyzidae
- Family Simuliidae
  - *Simulium sp.*
- Family Stratiomyidae
  - *Nemotelus sp.*
  - *Stratiomys sp.*
- Family Tabanidae
  - *Chrysops sp.*
  - *Tabanus sp.*
- Family Thaumaleidae
- Family Tipulidae
  - *Gonomyia sp.*
  - *Hexatoma sp.*
  - *Limonia sp.*
  - *Ormosia sp.*

Ephemeroptera
- Family Baetidae
  - *Baetis sp.*
  - *Procloeon sp.*
- Family Caenidae
  - *Caenis sp.*
- Family Heptageniidae
  - *Heptagenia sp.*
  - *Leucrocuta sp.*
  - *Stenacron sp.*
  - *Stenonema sp.*
- Family Leptophlebiidae
- Family Trycorythidae
  - *Trycorythodes sp.*

Hemiptera
- Family Corixidae
  - *Sigara sp.*
- Family Veliidae
  - *Microvelia sp.*

Megaloptera
- Family Sialidae
  - *Sialis sp.*

Odonata
- Family Aeshnidae
  - *Nasiaechna pentacantha*
- Family Coenagrionidae
  - *Argia sp.*
- Family Gomphidae
  - *Progomphus sp.*

Plecoptera
- Family Capniidae
  - *Allocapnia sp.*

Tricoptera
- Family Hydropsychidae
  - *Cheumatopsyche sp.*
- Family Limnephilidae
- Family Phryganeidae
  - *Agrypnia* sp.

Appendix E continued

Other

- Gastropoda
  - Family Ancylidae
  - Family Lymnaeidae
  - Family Physidae
- Pelecypoda
- Copepoda
- Cladocera
- Oligochaeta
- Turbellaria
- Nematoda
- Decapoda
- Hydra
- Brachiobdellida