Aquatic invertebrates and fishes of the Washita River in the Washita Battlefield National Historic Site

Final Report

by

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Executive summary

1. The Washita Battlefield National Historic Site (WBNHS) is a unit of the National Park Service located in Roger Mills County, west of Cheyenne, Oklahoma,
2. The water in the Washita River is slightly alkaline and has a high conductivity, in part because of a measurable salinity.
3. Aquatic invertebrates and fish were sampled three times during 2002-2003, and two light samples of aerial insects were collected.
4. Eighty-two taxa of aquatic invertebrates, 26 taxa of aerial insects, and 16 species of fish were identified from the WBNHS.
5. The high faunal diversity in the Washita River in the WBNHS is partly attributed to a combination of habitat-specific sampling, and the use of both quantitative and qualitative methods for collecting aquatic invertebrates.
6. Invertebrate associations differed among habitats. In particular, organic matter, fine sediments, and the beaver pond had distinct assemblages, as demonstrated by non-metric multidimensional scaling and clustering analysis.
7. Many invertebrate taxa were associated with specific habitats (shifting sand, silt-covered sand, exposed roots, woody debris, beaver pond, etc.) or habitat groups (e.g., slow water habitats). For example, the beetle *Helichus* was generally found on wood.
8. A rapid bioassessment of habitat conditions of the Washita River was conducted. The habitat scored low on epifaunal cover, pool variability, sediment deposition, and channel sinuosity.
9. The fauna of the Washita River at the WBNHS is apparently more diverse than it is below Foss Reservoir. Foss Reservoir may negatively affect some species inhabiting the upper Washita River.
10. Potential taxa for biomonitoring consideration are listed.

Introduction

The Washita Battlefield National Historic Site (WBNHS) became a part the Park Service System in 1996. The historic site commemorates a battle between the Cheyenne people and the U.S. military. Since this 1869 battle and the subsequent land runs in the 1890's, the land has been extensively altered by its use in agriculture. Efforts are currently being undertaken to restore the native vegetation at the site with the goal of creating a pre-agricultural landscape. As part of this goal, faunal inventories are being done to describe the current status of species and communities within the site, and to develop a baseline dataset to use in assessing restoration efforts.

One of the main landscape features of the site is the Washita River, which is important both historically and biologically. Biologically, the river directly supports fish, macroinvertebrate, algal, and meiofaunal communities. Indirectly, it supports a riparian zone, and a large number of animals that live in or use the riparian zone or river.

The fish and invertebrate communities in the Washita Battlefield National Historic Site are poorly known; indeed, there have been few studies of the aquatic fauna in that portion of Oklahoma. The overall objective of this study was to survey the fish and macroinvertebrate faunas within the Washita Battlefield National Historic Site. The specific objectives were to:

1. characterize the physical habitat of the river
2. inventory the aquatic invertebrate and fish communities
3. describe habitat-specific assemblages of invertebrates
4. describe the macroinvertebrate and fish communities using standard metrics,
5. compare the fish and macroinvertebrate inventories from the WBNHS to other sites along the Washita River, and
6. identify taxa that are rare or might otherwise have biomonitoring significance.

Methods: macroinvertebrate sampling

Seasonal differences in the invertebrate fauna of the Washita River were characterized by sampling in the summer, fall and spring. Sampling dates were:

- Summer: 29-30 June 2002
- Fall: 12-13 November 2002
- Spring: 6 April 2003

Stratified sampling was used to insure sampling along the length of the river. The access road to the Washita River approached the river at the upstream, western edge of the WBNHS. The region of the river at this western edge was the upstream site (mile 0.0); the other four sites were located near 0.2-mile increments along the road (miles 0.2, 0.4, 0.6, and 0.8). The downstream mile 0.8 site was reached by foot, as it was past the end of the road, and was located in the area of the large elm shading the river. Sites included about 40 meters of river length.

During the summer sampling, water level was low and a variety of distinct habitats could be distinguished. These habitats were classified as:

1. bare, actively moving sand
2. silt-covered sand (primarily along the edges)
3. exposed roots (primarily of elms or grasses)
4. leaf packs/fine woody debris (primarily small clumps of leaves and debris caught on sticks in the channel)
5. coarse woody debris (branches and/or logs and their accumulations of finer debris)
6. backwaters (areas with downstream, but no upstream connection with the channel, or pools completely isolated from the channel)
7. gravel over sand (areas with a thin layer of fine gravel)
8. emergent grass at the channel edges

9. beaver pond: submerged vegetation and exposed roots
10. beaver pond: general (in the water column and in the bottom substrate)

Many of these habitats are illustrated in Appendix 1. Habitats were not always present at each site. Generally, two quantitative and two qualitative samples were collected for each habitat type among the five sampling sites. Quantitative samples were taken with a Hess sampler (mesh size = 0.5 mm; sampled area = 690 cm^2), which provides an estimate of species abundance and habitat associations. Qualitative samples were taken using hand nets (mesh size = 0.25 or 1.5 mm) to sweep though an area or to catch dislodged materials; or substrates were individually searched and organisms directly removed. Qualitative samples provided presence/absence data, habitat associations, and were valuable for compiling a more complete taxonomic list for the WBNHS.

Additionally, eight habitat-specific samples (see list above; exclusive of 9 and 10) were collected in the summer sampling from the river starting below the beaver dam and continuing through the 'oxbow' area. This involved about 3 hours effort by 2 collectors (= 6 man-hours).

During the Fall and Spring samplings, water level was higher and water transparency was low; consequently, habitat-specific sampling was not practical. During these samplings, qualitative samples were collected at each of the five sites.

Invertebrate samples were preserved in 70% ethyl alcohol. In the laboratory, invertebrates were sorted from the sediment and organic material in the samples and identified to the lowest feasible taxon (often genus). Chironomids require considerable effort (and skill) to identify and their identification was contracted out and results are pending. A list of chironomid taxa will be supplied when available.

Three to five crayfish traps (unbaited metal 'Gee' minnow traps) were set out for one night during each of the three sampling periods. Traps were confined to the beaver pond during the summer because of the low water levels in the river; traps were placed in both the beaver pond area and the river during the other samplings. Most crayfish were released, and one specimen of each species was retained for identification.

Light-trapping was done during the summer sampling (22 Jun 2002) and again on 22 Aug 2002). Light trapping involved setting out one or two battery-operated, self-collecting UV light traps on the river bank. Traps were set for approximately two hours, and the contents preserved with ethyl alcohol. Light trapped adults of mayflies, stoneflies, and caddisflies were sent to experts for identification. Dr. Boris Kondratieff (Colorado State University) identified the mayflies and stoneflies; Dave Ruiter (Centennial, CO) identified the caddisflies.

Methods: water quality and physical habitat description

The physical habitat was described during the initial summer sampling. Water chemistry and discharge were measured during each of the three sampling times listed above. Methods used to describe the physical and chemical features at the sampling sites were:

A. Each of the five sampling sites were mapped to show the general locations of bends in the channel, side pools, coarse woody debris, shade, emergent vegetation, and other features. Notes were also taken on substrate types, riparian and aquatic vegetation, and percent shade.

B. Measurements were taken to calculate discharge: channel width and a set of distances, depths and mean water velocities.

C. Water clarity was measured directly with a horizontal clarity tube (Kilroy and Biggs 2002) and sampling for suspended sediment used a depth-integrated suspended sediment sampler. Suspended sediment samples were filtered onto pre-weighed glass fiber filters, which were then ashed (at 500 °C for 1 hour) and re-weighed to determine the ash (= suspended sediment) content.

D. Dissolved oxygen, conductivity, salinity, and water temperature were measured with a YSI handheld unit. The pH was measured with an Orion meter.

E. Each site was ranked for habitat features using EPA Rapid Bioassessment Protocols (Barbour et al. 1999) during the summer sampling.

Methods: fish

Fish were sampled separately from the invertebrates and habitats/water chemistry. The schedule for fish sampling was:

- Summer: 23 August 2002
- Winter: 16 December 2002
- Summer: 9 July 2003

Fish sampling used seining with a fine-meshed seine. Seining a sand river is an effective method of inventorying fish because there are few places for fish to hide and escape capture. All captured fish were identified, counted, and released. The relative numbers caught indicate the relative numbers in the habitat. No collection of specimens was made.

Results

Characterization of the Washita River

The location of the five study sites in decimal degrees from GPS are listed below and shown on Figure 1.

Table 1. GPS coordinates of Washita River sampling sites.

Mile 0.0	N 35.62047º	W 99.71275º
Mile 0.2	N 35.62186º	W 99.70968º
Mile 0.4	N 35.62090º	W 99.70520º
Mile 0.6	N 35.62298º	W 99.70413º
Mile 0.8	N 35.62434º	W 99.70090º

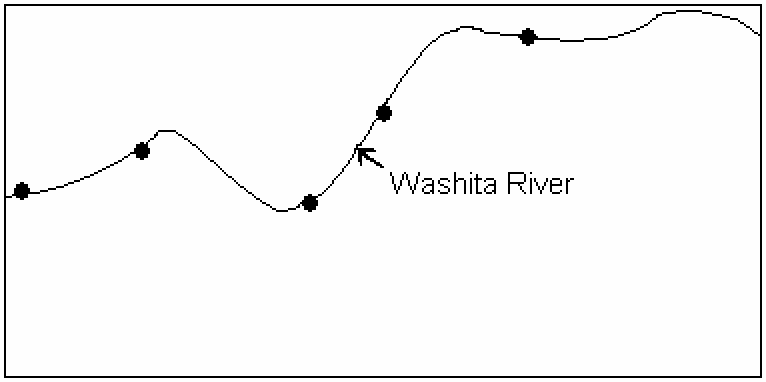

Fig. 1. Map of the WBNHS showing the location of the Washita River
and the five sampling sites (indicated by black circles). The length of the WBNHS is 1 mile.

The Washita River enters the WBNHS in the Mile 0.0 sampling area, which was a beaver pond during the summer sampling. Downstream of the beaver pond, the stream is characteristically sand-bottomed, with low proportions of other habitats. Woody debris in the stream had been recently increased because of control of salt cedar, during which a few of the downed trees entered the water.

The riparian zone supports mostly grasses and scrubs, resulting shade of less than 20% at all survey sites during the summer.

Physical and chemical parameters are summarized in Table 2. Water temperatures were highest in the summer, when temperature also varied considerably during the day. Water temperature was recorded at 22 °C in the morning and 35 °C at 3 pm. Shallow water, low shade, and low flow contributed to high water temperatures. High temperatures can be stressful to aquatic organisms because of the resultant elevated body temperatures and metabolic rates of the exothermic fish and invertebrates, and the reduced solubility of oxygen at a time when metabolic oxygen demand is high.

Table 2. Mean water quality characteristics of the Washita River during the survey. Blank tables cells indicate missing data.

	Summer (June)	Fall (November)	Spring (April)
Water temperature (ºC)	29.7	12.2	11.6
Dissolved oxygen (ppm)		12.89	10.63
Conductivity (µS/cm)	2214	1468	1614
Salinity (ppt)	1.0	0.7	0.8
pH	8.1		8.0
Clarity (cm)	78.5 (pond) 45.5 (stream)	25.2	
Discharge (ft^3/s)	2.9	54.1	25.2
Suspended sediments (mg/l)	14.2 (pond) 25.7 (stream)	53.6	25.4

Both conductivity and salinity were high, especially during summer low flows. This result is consistent with the high salinities occurring downstream in Foss Reservoir, where the salt content of the water reduces its useful (without desalination).

Water flow (discharge) affects the suspended sediment concentration because water flow largely determines how much sediment can be picked up and carried. The relationship between discharge and suspended sediment is shown as a regression in Fig. 2. The regression line can be used to estimate the suspended sediment load of the stream at different discharges. Additional data on discharge and suspended sediment concentrations, especially at flows higher than those measured here, would improve the accuracy and range of this suspended sediment rating curve.

Suspended sediment clouds the water and reduces clarity. Hence, water clarity was reduced when the discharge was high in the fall and was lower in the beaver pond than in downstream sites during the summer, reflecting sedimentation of fines in the still-water conditions in the beaver pond.

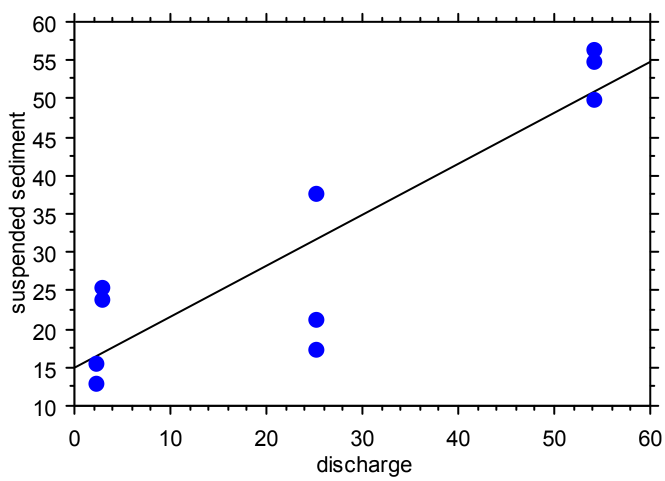

Fig. 2. Regression of discharge and suspended sediment in the Washita River at the WBNHS. Regression equation: suspended sediment= 15.014 + 0.663 * discharge. $R^2 = 0.79$

Rapid Bioassessment

Habitat quality was scored at each of the five sampling sites during the summer sampling using EPA's Rapid Bioassessment Protocols (Barbour et al. 1999; downloadable at: http://www.epa.gov/owow/monitoring/rbp/). The results are summarized in Table 3. This protocol generally has a low gradient stream option for several of the habitat categories, and the assessment used descriptions with this low-gradient option.

Epifaunal substrate/available cover refers to submerged structures, including stones, wood, and undercut banks. These structures provide habitat and refuge for stream organisms. The study sites were mostly scored as marginal (10-30% structure), with structure primarily as woody debris and leaf packs. One site scored poor (less than 10%).

Pool substrate characterization ranks the substrate on the bottom of pools. Coarser sediments, variety in sediment type, and plants are all desirable because they provide better habitat for organisms. All pools scored as suboptimal because they lacked coarser sediments, such as gravel, and because roots and aquatic plants were not commonly present.

Pool variability considers the variation among pools in terms of pool size and depth. Pools in the sampled regions of the Washita River ranged from marginal (= most pools are shallow) to poor (= most pools are small and shallow, or pools are absent). The beaver pond, which formed a large but shallow pool, received the highest pool variability score of 10.

Sediment deposition estimates both the amount of sediment being deposited on the bed and the formation of bed characteristics that develop as a result of sediment deposition (e.g., islands). In the Washita River, sediment deposition is common because the bed was mostly sand, much of which was moving (as indicated by a lack of deposited fine organic material and silt). In the beaver pond, however, sedimentation was low within the WBNHS, but probably high upstream where streamflow entered the pond and water velocity dropped.

Channel flow status refers to the extent that water covers the channel. A wetted channel provides more habitat area than a partly dry channel. The Washita River is incised and generally has steep banks. In the beaver pond, the entire channel was filled (= optimal), whereas downstream, exposed point bars, side bars, and islands are common (= suboptimal to marginal).

Channel alteration is a measure of direct changes in the channel form by humans. No man-made structures (e.g., weirs or rip-rap) in the stream were seen in the WBNHS. However, the channel was rather straight in some areas, indicating that it had been partly channelized.

Channel sinuosity refers to how much the stream meanders. Meandering increases the diversity of habitats, thereby increasing the biodiversity of the fauna and the refuges available to the fauna during high flows. Relatively straight sections of channel result in suboptimal to marginal scores in the Washita River.

Bank stability scores the condition of the banks in observed signs of erosion (bare, crumbling soil, exposed roots) or the potential to erode (steep banks). The sandy soil surrounding the Washita River is prone to erosion, especially because the stream is incised and the banks are often steep. However, much of the bank is well vegetated with grasses and shrubs, and obvious erosion is patchy, resulting in suboptimal scores.

Plant protection of the banks refers to plants along the bank and in the streamward riparian zone; these plants protect the banks from erosion, provide habitat for aerial adult aquatic insects and shade the stream. At the WBNHS, the riparian zone is relatively wide, and is bounded on the right (south) bank by old field areas that are being restored to native vegetation. Because of the wide riparian zone, the zone was rated as optimal or suboptimal HOWEVER the quality of the riparian zone vegetation is wanting. Grasses and recently deceased (by a control program) salt cedar are very common riparian plants. Riparian trees, such as willow and cottonwood, are uncommon. Hence, the riparian plants provide little shade, which contributes to heating of the stream water during the summer, and little habitat for birds, adult aquatic insects and other residents of the riparian zone.

Table 3. Summary of rapid bioassessment scores for each of the five Washita River sampling sites. Sites are scored by written criteria and by comparison with photographs, generally on a scale of 0 (=very poor) to 20 (= highly optimal). Within this range, there are four levels: poor (0-5), marginal (6-10), suboptimal (11-15), and optimal (16-20). The 'b' after item numbers refers to category with a low gradient option; if available, this option was always chosen for the Washita River sites.

Item #	Habitat feature	Mile 0.0	Mile 0.2	Mile 0.4	Mile 0.6	Mile 0.8
1	Epifaunal cover	8	8	9	3	9
2b	Pool substrate	12	15	14	14	15
3b	Pool variability	10	5	5	2	7
4	Sediment deposition	18		9	10	6
5	Channel flow status	20	15	13	10	10
6	Channel alteration	19	16	14	15	16
7b	Channel sinuosity	14	11	6	7	9
8	Bank stability	11	15	15	17	15
9	Plant protection	14	15	17	17	17
10	Riparian zone	19	16	19	20	19

Inventory of the aquatic macroinvertebrate and fish communities. Eighty-two non-chironomid taxa of aquatic invertebrates were collected in the stream samples (Appendix 2). Beetles (Coleoptera), mayflies (Ephemeroptera) and dragonflies/damselflies (Odonata) were especially speciose. Twenty-six taxa of caddisflies, mayflies and stoneflies were identified from the light trap samples (Appendix 2), and sixteen species of fish were found in the stream (Appendix 2).

Although all listed taxa of invertebrates and fish captured in the Washita River obviously live there, the location of immature stages of the adult insects captured with the light traps is unknown. Adult insects can disperse by flying and, once airborne, may be additionally transported by winds. Because there is no other aquatic habitat nearby and because the traps were placed next to the Washita River, it is assumed that captured insects are from the Washita River within or near the WBNHS.

Faunal-habitat associations: invertebrates

Many of the taxa collected have specific habitat preferences and requirements and, consequently, are associated with particular habitats. Knowledge of the associations between invertebrates and habitats can be useful in planning habitat modification (e.g., adding woody debris to the river) and biomonitoring (ensuring the right habitats are sampled to monitor specific species or assemblages). Habitat-specific sampling during the summer enabled comparison of the macroinvertebrate fauna among habitat type at the WBNHS.

The composition of invertebrate communities can be displayed using clustering and/or ordination. Clustering produces a tree-like diagram with branch points showing the similarity of samples; ordination produces a scatter plot of points, each of which represents a sample relative to its similarity to other samples. The technique used to display habitat-specific assemblages at the WBNHS was non-metric multidimensional scaling (MDS) and clustering, both using a Bray-Curtis similarity matrix derived from presence/absence data on the 34 qualitative and quantitative samples collected during the summer (program: Primer 5; Primer-E, Ltd.). The cluster results were used to define clusters within the MDS ordination (Figure 3). Invertebrate taxa associated with specific habitats were identified using their frequency of occurrence in the different sample types (Table 4).

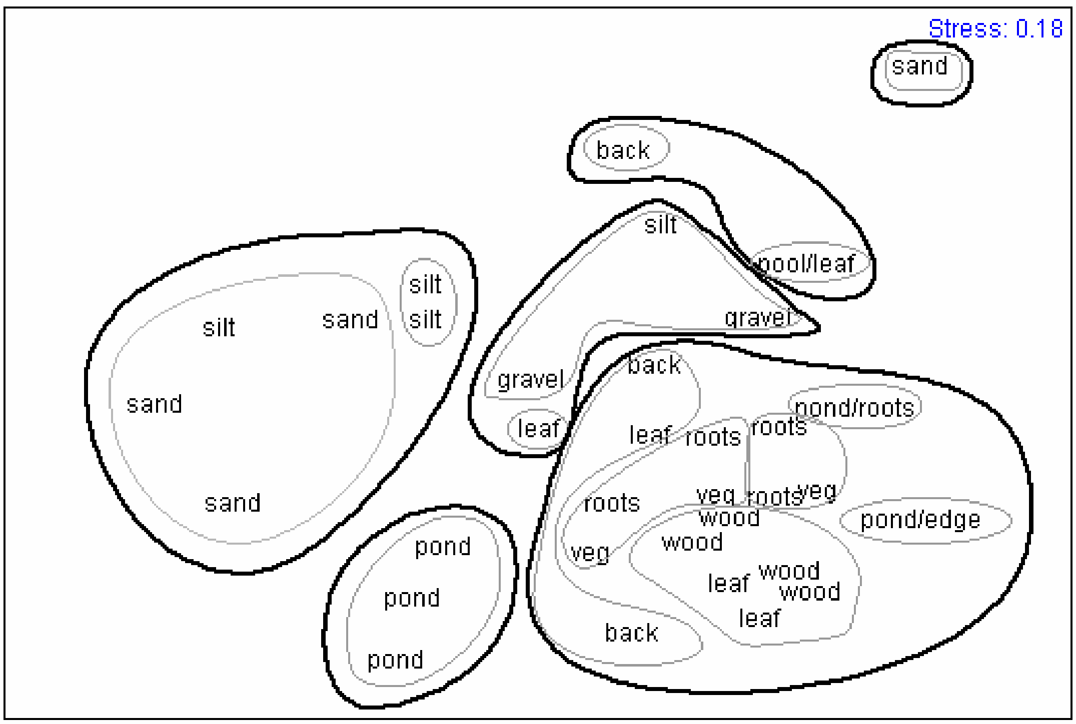

Fig. 3. MDS ordination of invertebrate assemblages in 34 samples collected in the Washita River in summer 2002. Samples are labeled by habitat type ('sand' = bare sand, 'silt' = silt-covered sand, 'roots' = exposed roots, 'leaf' = leaf packs, 'wood' = coarse woody debris, 'back' = backwaters, 'gravel' = gravel over sand, 'pond' = beaver pond). Gray circles show 50% similarity among samples; black circles show 30% similarity, based on clustering.

Sand and silt-covered sand samples formed a cluster characterized by the gomphid dragonfly nymphs, which characteristically burrow in sediments and lie-in-wait for passing prey. Sand sediments were dominated by a single species (*Progomphus obscurus*), whereas silt-covered sand usually had a second species (*Erpetogomphus* *designatus*) and sometimes hemipterans (*Rhagovelia*), which live on the surface of these near-shore habitats. The isolated sand sample contained only *Tricorythodes* sp.

Table 4. Characteristic taxa in habitats of the WBNHS Washita River during the summer.

Habitat	Characteristic taxa
Sand	*Progomphus obscurus*
Silt-covered sand	*Erpetogomphus designatus*, *Progomphus obscurus*
Woody debris	*Perlesta*, *Helichus*, *Microcylloepus*, *Stenelmis*, *Heptagenia*, *Isonychia*
Leaf packs	*Heterelmis*, *Stenelmis*, *Dubiraphia*
Exposed roots	*Dubiraphia*, *Musculium*, planarians, *Paracloeodes*
Organic matter	*Tricorythodes*, *Hetaerina americana*, *Physella*
Backwaters	*Caenis*, *Trichocorixa*, *Hydroporus*, *Physella*
Beaver pond	*Caenis*, *Callibaetis*, *Paracloeodes*, *Nectopsyche*, *Progomphus obscurus*
Slow flow	*Berosus*, *Erpetogomphus designatus*, *Nectopsyche*

Samples with organic matter (woody debris, leaf packs, emergent vegetation, and exposed roots) formed a large cluster (Fig. 3). This organic matter provides an architecturally rich substrate and is stable in comparison to the dominant shifting sand substrate at WBNHS. Organic matter also contributes to the food web, primarily through the decomposition pathway (fungus and bacteria). Taxa common on all organic substrates were the mayfly *Tricorythodes*, the rubyspot damselfly *Hetaerina americana*, and pond snails (*Physella*).

There are several sub-clusters within the organic matter cluster. These clusters are woody debris, roots and emergent vegetation (two clusters), backwaters, and beaver-pond associated (two clusters). Leaf pack samples are intermixed among other clusters, which results from their diverse nature (e.g., leaf material deposited at the bottom of pools is a very different habitat from leaf litter caught in woody debris in the current).

Wood provides a stable surface that is often relatively smooth and may be located in fast flow. Taxa associated with wood include stoneflies (*Perlesta*), several dryopoid beetles (e.g., *Helichus*), and the mayflies *Heptagenia* and *Isonychia*. Some dryopoid beetles consume wood or hide in crevices of wood. *Heptagenia* is a flattened mayfly and smooth, stable wood surfaces are an appropriate habitat, and *Isonychia* is a filter-feeder (with long filtering hairs on its front legs) and wood provides an appropriately stable habitat in flow. Roots and leaf packs also have associated invertebrates (Table 4).

The beaver pond provided a pond-like habitat within the river, although the temporal nature of this pond is seasonally restricted. The pond was present during the summer, but was absent and the river was free-flowing at the time of the fall and spring samplings. Invertebrates associated with the beaver pond habitat included some mayfly taxa, including *Callibaetis*, which is commonly found in ponds.

The backwater habitat included both backwaters on the channel sides and isolated pools on the bank (not attached to the river). Many of the backwaters had black anoxic sediment just below the surface and higher water temperature than the main channel. Air-breathing beetles (e.g., *Hydroporus*) and hemipterans (e.g., *Trichocorixa*) were found in these backwaters, as were *Physella* snails.

Several of the habitat types can be characterized as slow flow areas; such habitats are many of the organic matter sites, the beaver pond, and backwaters. *Berosus* (a weak swimming water beetle), *Nectopsyche* (a caddisfly that can swim), and the burrowing dragonfly *Erpetogomphus designatus* were all common in these habitats.

In conclusion, the Washita River in the WBNHS has a mosaic of different habitats and these habitats have characteristic associated invertebrates. As a result, the invertebrate fauna of the Washita River is very diverse. Limiting sampling to only the dominant habitats (sand and silt-covered sand) would miss many species and result in a much lower measured diversity. High water and high turbidity during the non-summer samplings precluded effective habitat-specific sampling, but similar habitat-faunal associations were likely present.

Faunal-habitat associations: fish
Because of the nature of seining in a small river, it was not practical to separately inventory habitat-faunal assemblages for fish. However, observations were made of some habitat assemblages. Backwaters contained numerous mosquitofish (*Gambusia affinis*), which were also abundant in the slower water along the river edges. Red shiners (*Cyprinella lutrensis*) were often seen near woody debris piles, and the single longnose gar (*Lepisosteus osseus*) was caught in the beaver pond.

Faunal metrics
Various metrics were calculated separately for each of the 14 quantitative Hess samples and are shown in Table 5. Chironomids were often the numerical dominants, and because identification of chironomids below the family level was not yet available, chironomids were not included in the Shannon-Weiner diversity calculations (their inclusion would bias the results through affecting evenness); whereas they were included in the percent EPT calculations (where subdivision of chironomids was not needed).

The Shannon-Weiner biodiversity index condenses assemblage information into a single number that incorporates both richness (= the number of species) and evenness (= the evenness in the spread of individuals among species). Thus, diversity increases with more species and with more evenness among species.

Results from the diversity calculations (Table 5) are most easily visualized by plotting the diversity values (as relative bubble sizes) on the MDS plot for invertebrates in Hess samples (Fig. 4). Diversity is highest in samples with organic matter (e.g., roots, leaf packs and emergent vegetation) and is lowest in sand and silt. Evenness was similar among samples, whereas richness differed greatly and resulted in the pattern of diversity (e.g., organic substrates had richer faunas and higher diversity the inorganic substrates, such as sand and silt-covered sand).

Table 5. Summary of metrics from the quantitative invertebrate samples.

Sample type	No.of species [1]	Number of organisms [1]	Evenness	Shannon-Weiner diversity (log e) [2]	Number of organisms [3]	Percent EPT [3,4]
Pond	6	12	0.91	1.63	58	13.8
Pond	5	15	0.79	1.27	53	15.1
Pond/roots	14	67	0.81	2.14	73	52.1
Sand	1	3		0.00	28	10.7
Sand	1	1		0.00	19	0.0
Silt	2	4	0.81	0.56	21	0.0
Silt	3	5	0.96	1.05	12	25.0
Gravel	6	17	0.86	1.54	29	41.4
Roots	13	70	0.73	1.86	84	36.9
Roots	13	60	0.60	1.53	99	10.1
Leaf pack	13	29	0.90	2.31	37	21.6
Leaf pack	14	54	0.88	2.32	72	43.1
Vegetation	12	33	0.92	2.29	125	10.4
Vegetation	13	47	0.91	2.33	66	24.2

[1] excluding chironomids
[2] calculated without inclusion of the chironomid data
[3] including chironomids
[4] EPT = Ephemeroptera (mayflies), Trichoptera (caddisflies), and Plecoptera (stoneflies)

Percent EPT (= Ephemeroptera, Plecoptera, and Trichoptera) is a metric designed to assess the percent of these generally good water-quality indicative organisms relative to the rest of the fauna. This metric works best in stony streams. Sandy streams, as typified by the Washita River, have considerable fine sediments and have summers with low flow and warm temperatures; hence, the faunas in these streams are generally more tolerant of 'adverse' conditions. Consequently, the Washita River has few species of stoneflies and caddisflies, and the genera that were found are tolerant groups. Mayflies in the Washita River are diverse, but again, most taxa are tolerant ones.

Percent EPT data (Table 5) are shown as bubbles on the MDS plot of Hess samples (Fig. 4). Sand, silt, and pond habitats have low %EPT values, which is consistent with a general EPT taxa preference for coarser substrates and running waters. Percent EPT values are generally higher among more solid substrates, including gravel and organic substrates, although there is considerable variability, even between samples from the same habitat type. This high variation may indicate that this metric should be used with caution at this site.

WBNHS.summer Hess by habitat and diversity

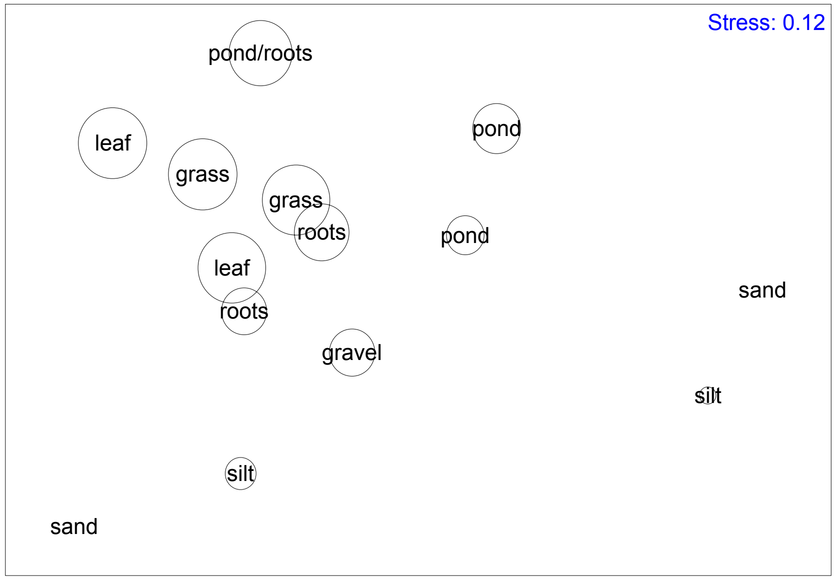

Fig. 4. MDS plot of invertebrate assemblages in the 14 quantitative samples from the Washita River, collected during the summer sampling. Bubbles that are superimposed on the MDS plot show relative Shannon-Weiner diversity among samples.

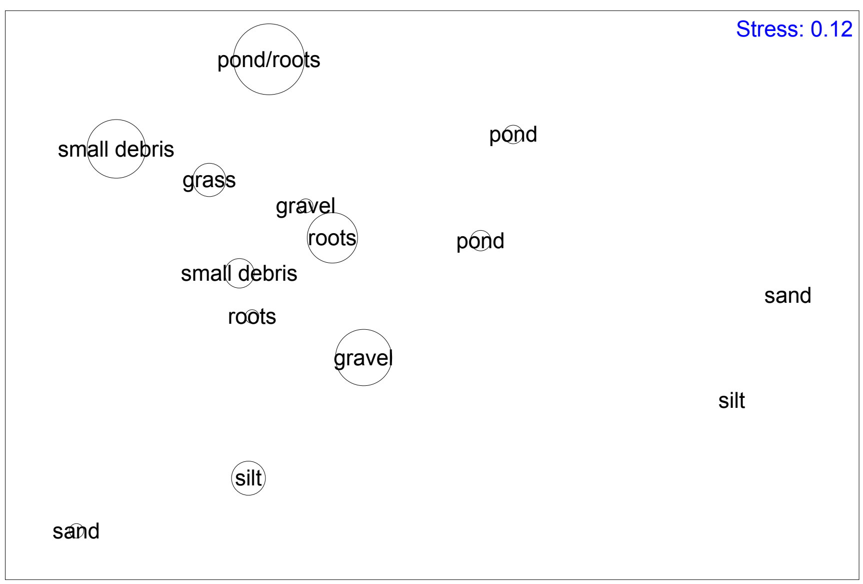

Fig. 5. MDS plot of invertebrate assemblages in the 14 quantitative samples from the Washita River, collected during the summer sampling. Bubbles that are superimposed on the MDS plot show the relative percent EPT metric of the samples.

The percent of green sunfish was a suggested metric for evaluating fish assemblages. Green sunfish are often found in slow moving streams and in ponds. In the sampled area of the Washita River, mosquitofish (*Gambusia affinis*) and red shiners (*Cyprinella lutrensis*) were extremely abundant, comprising between 79% and 91% of all individuals in the three sampling periods (see Appendix 2 for the assemblages composition for fish). Consequently, the percentages of the other species were small, and green sunfish do not appear to be a good indicator of environmental conditions because of their low numbers in this sandy stream (green sunfish are less than 1% of the total fish catch in all sampling periods).

Another possible set of fish species to track are those species that are generally found in hard-bottomed streams; these fish are the central stoneroller (*Campostoma anaomalum*), and the orangethroat darter (*Etheostoma spectabile*). Both of these species are uncommon and together contribute about 1% of the total number of individuals.

The moderately common fish species in the sampling sites are tolerant of siltation and turbidity, and include the sand shiner (*Notropus stramineus*), the bullhead and fathead minnows (*Pimephales vigilax* and *Pimephales promelas*), and the plains killifish (*Fundulus zebrinus*).

Comparison of the biodiversity between this survey and other Washita River surveys. Previous surveys of macroinvertebrates of the upper Washita River were concentrated on the river below Foss Reservoir, where there were studies in the 1970's of benthic invertebrates before and after the operation of a desalination plant (Morris and Madden 1978, Magdych 1979). Like this study, these surveys involved several samplings. Additionally, there are records of the freshwater prawn *Palaemonetes kadiakensis* in the Washita River above Foss Reservoir (Pigg and Cheper 1998). Fish records include unpublished data on fishes occurring just below Foss Reservoir in 2001 from Richard Broughton (Oklahoma Biological Survey) and records of the central stoneroller near the WBNHS (Milligan and Lemmons 1993).

Comparison of the results of the present macroinvertebrate survey with previous surveys and records required two preliminary steps: combining the previous surveys into one dataset and standardizing the resulting dataset with the current study. Standardizing the datasets involved reducing the WBNHS data to the taxonomic level of genus and thereby losing several taxa, removing groups WBNHS taxa that were not included in the earlier surveys (microcrustaceans), and deleting chironomids from the previous surveys because the WBNHS chironomid data are not yet available.

The resulting datasets contained 68 genera from the WBNHS, 43 genera from previous surveys, and a total of 92 taxa. There were only 19 genera in common between the two datasets. The small overlap resulted from: (1) taxonomic changes since the 1970's (for example, the fingernail clam genus *Musculium* (found at the WBNHS) was formerly a subgenus of *Sphaerium* (found in previous surveys); but there is no way to determine whether they were the same organism), (2) habitat differences between the sites, and (3) differences in sampling methods.

The second reason for the difference in diversity is habitat differences; namely, the Washita River below Foss Reservoir is larger than at WBNHS and is influenced by the reservoir. Reservoirs strongly impact the macroinvertebrate fauna in the outflowing rivers because of reservoir-associated changes in water temperature, flow regime, oxygen levels, and suspended particles. For example, waters below reservoirs often have high populations of filter-feeding caddisflies and, indeed, both *Hydropsyche* and *Cheumatopsyche* are found below Foss Reservoir, whereas only *Cheumatopsyche* was at WBNHS. For similar reasons, the fauna of WBNHS contains a number of small stream and spring -characteristic taxa that were not found below Foss Reservoir. These include the damselflies *Hetaerina americana* and *Argia* sp., two stoneflies, and a flatworm.

The third reason (differences in sampling methods) results from previous surveys being quantitative only (i.e., using an enclosed sampler), whereas this study combined quantitative sampling with searching by hand (qualitative sampling). Qualitative sampling can include habitats hard to sample quantitatively, especially the water surface, the water column, and woody debris; and also allows collection of rarer taxa that may not be picked up in the small area sampled quantitatively. Indeed, we found many more Hemiptera, which tend to be surface dwellers or live in the water column, and several more wood-inhabiting taxa (e.g., some riffle beetles) than did the Foss surveys. We also collected 2 species of crayfish, a group that is unlikely to be collected using quantitative sampling because of their low densities in the upper Washita River.

Nine species of fish were found in a single August sampling of the Washita River below Foss Reservoir. This is smaller than the August sampling at WBNHS, where all 16 species were caught in this initial sampling. Both surveys were done by the same person, using the same methods (seining). Fishes at the WBNHS include plains species (e.g., the plains killifish *Fundulus zebrinus* and the sand shiner *Notropis stramineus*) and/or species tolerant of turbidity, and two species that are more typically found in stony streams (the central stoneroller *Campostoma anomalum* and the orangethroat darter *Etheostoma spectabile*). Fishes below Foss reservoir include some larger predatory species (the largemouth bass *Micropterus salmoides* and the introduced striped bass *Morone saxatilis*).

In conclusion, both the invertebrate and fish faunal lists from this study of the WBNHS have more species than comparable surveys in the more-impacted area of the Washita River below Foss Reservoir.

Biomonitoring

Eligible species for inclusion in a biomonitoring program are species that indicate desirable conditions at the site (sentinel species), or that are declining in numbers or are rare. Below is a list of potential species that may be included in a biomonitoring program for the WBNHS, with reasons for the inclusion of each taxon.

1. *Paracloeodes* (*minutus*?). This small mayfly is found in sandy streams, but is seldom collected and this record may be a new state record.
2. Plecoptera. The stoneflies *Perlesta* (*decipiens*?) and *Hydroperla crosbyi* are good candidates for biomonitoring because stoneflies are not often found in warm sandy streams. They are also easily found, clinging to woody debris or, in the winter, submerged vegetation.
3. *Hetaerina americana*. The rubyspot damselfly commonly occurs in small streams and is a predator that is typically found in organic debris. Adults are pretty and is an interesting insect for visitors. Monitoring of distinctive adults would be easy.
4. *Isonychia* is a filter-feeding mayfly that is often in stony streams, but is associated with woody debris in the Washita River.
5. Dryopoid and elmid (riffle) beetles. The WBNHS has a diverse fauna of these small aquatic beetles, and different genera are apparently characteristic of different habitats.
6. *Corydalus*, a hellgrammite, was uncommon at the site. These insects are fierce predators during their aquatic larval stage, whereas adults feed little, if at all. Eggs are laid on leaves overhanging the water and hatching young fall onto the water. One egg mass was found on an elm branch over the water. A lack of riparian trees can negatively affect recruitment in this group, hence tracking this group may demonstrate positive effects of riparian restoration. Monitoring can include looking for their large, distinctive egg masses.
7. Beavers. The beaver dam produces a pond in which the summer water temperatures are lower, and which supports both invertebrates and fish that are characteristic of this particular habitat. The woody riparian zone is fairly well developed in the beaver pond area.
8. The central stoneroller (*Campostoma anomalum*) and the orangethroat darter (*Etheostoma spectabile)* because both species are more characteristic of stony streams than of sandy streams.

Acknowledgements
Many people helped with this project. The fish collection and identification were headed by Dr Rich Broughton, with field help from Paulette Reneau and Chad Hargrave. Shane Jones helped with invertebrate sampling and did the rapid bioassessment work. I especially thank Kurt Foote, who helped with paperwork and logistics, introduced me to the site, and helped with fieldwork. The vascular plant team of Amy Buthrod and Dr Bruce Hoagland ran a set of light traps for me during their August sampling trip. Dr. Boris Kondratieff and Dave Ruiter kindly identified the EPT taxa from the light trap samples. Aleksandra Stojanoska and Heather Bragg sorted the invertebrates from the field samples. Ferrella March is continuing to identify the chironomid larvae. And the plankton at the Survey did a terrific job of tracking the budget.

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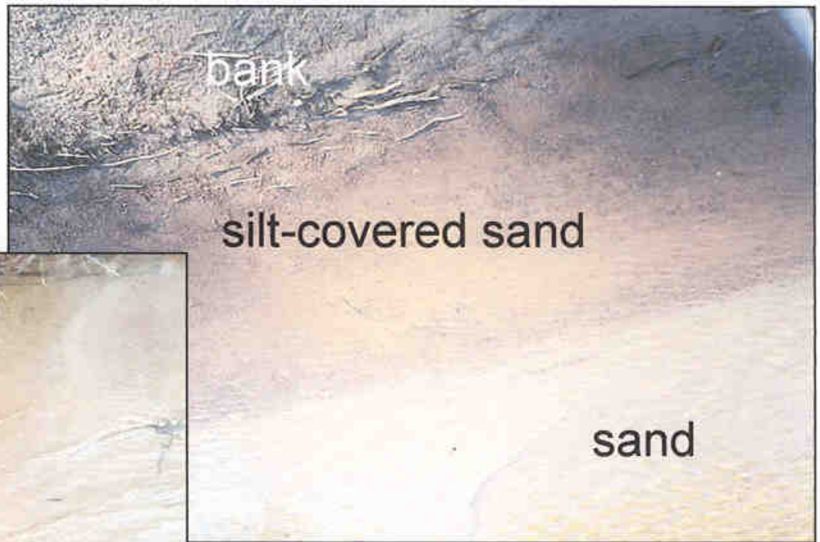
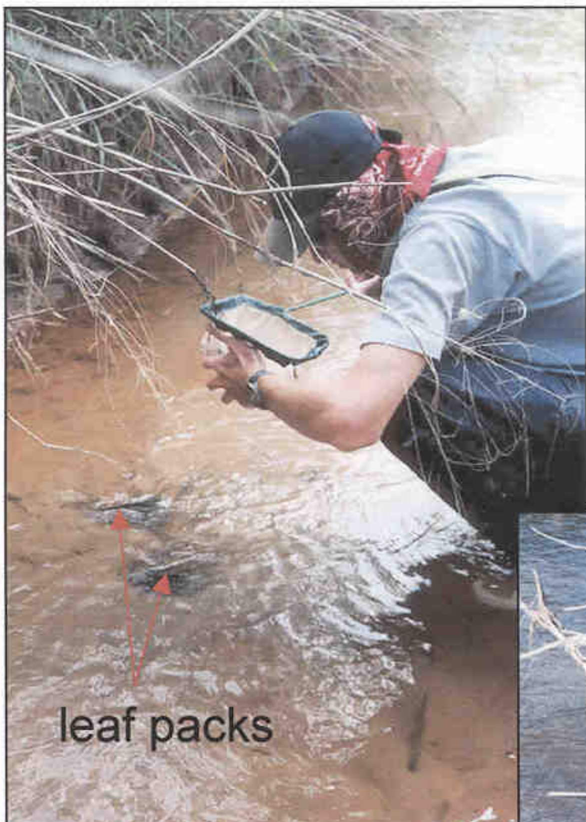
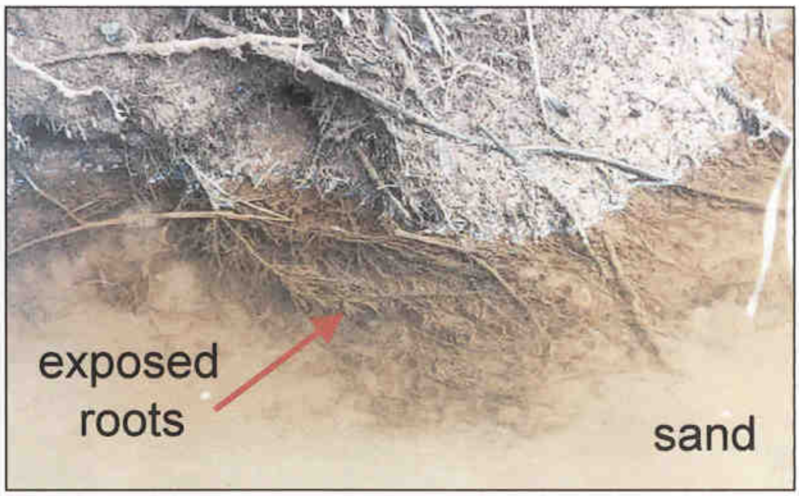
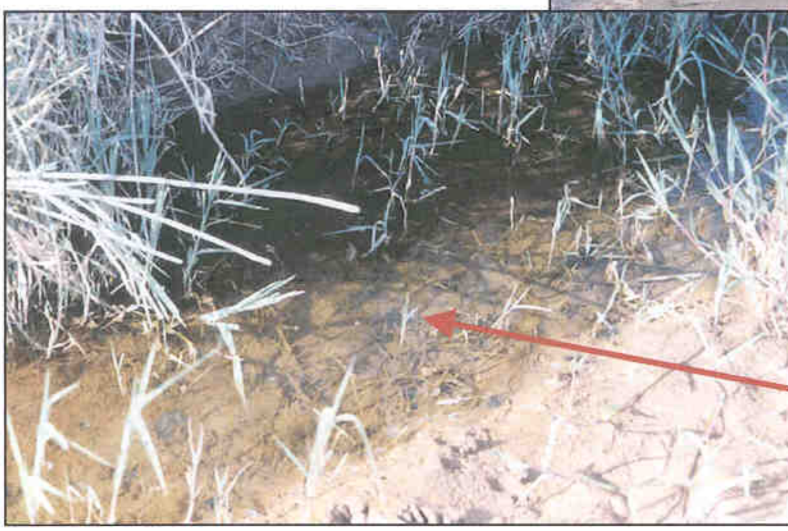
Appendix 1. Photographs of habitat types and habitat features





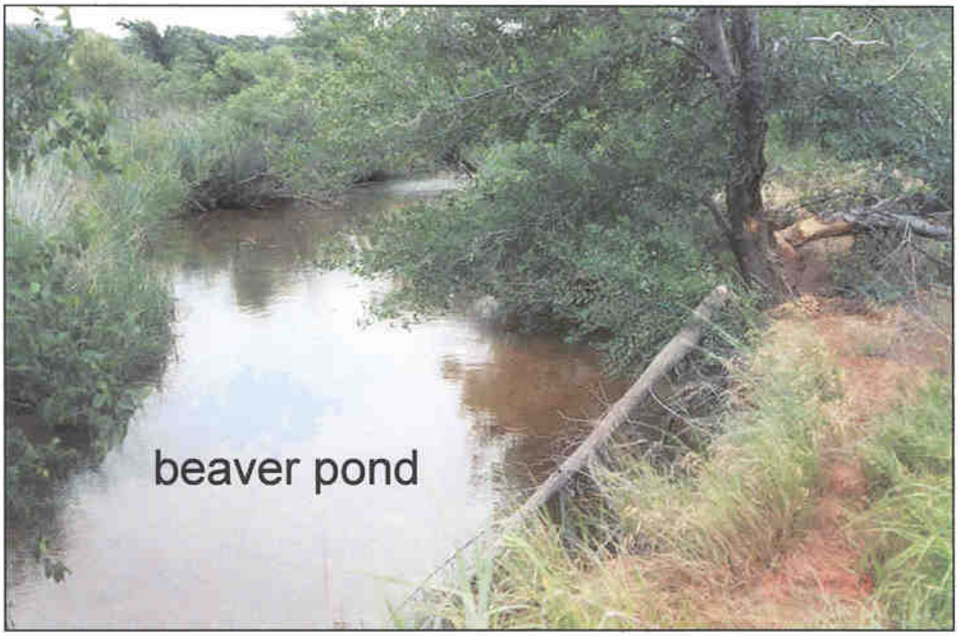


coarse woody debris



backwaters

emergent vegetation



Note the riparian trees overhanging the water and the resultant shade on the water.

High meander section with a point bar in the foreground. Note the paucity of trees in the riparian zone.

Area with high erosion potential. The stream-side riparian zone contains only grasses.

Appendix 2. Lists of aquatic invertebrates, aerial adults and fish from the Washita River in the WBNHS

Aquatic Invertebrates
(the number of samples with each taxon are indicated)

			season			summer								
			summer	fall	spring	pond	silt	sand	gravel	leaf	roots	wood	veg	back
		total number of samples	34	5	7	5	4	4	2	4	4	4	3	3
Collembola	Poduridae	*Podura aquatica*		2										
Ephemeroptera	Baetidae	*Callibaetis*	4	1		3								1
		Fallceon quilleri	11	1	2	1			1	2	3	2	2	
		Paracloeodes	14	2		3	1		2	1	3	1	1	2
	Caenidae	*Caenis*	14	1	6	3		1		2	2	1	2	3
	Heptageniidae	*Heptagenia*	8	2	7	2				1		3	1	1
	Isonychidae	*Isonychia*	10		1				2	2	1	4	1	
	Tricorythidae	*Tricorythodes*	24			2	1	1	2	4	4	4	3	2
Odonata	Calopterygidae	*Hetaerina americana*	17		1	1				4	4	4	3	1
	Coenagrionidae	*Argia bipunctulata*	3								1			1
		unidentified	1								1			
	Gomphidae	*Erpetogomphus designatus*	27	2	3	2	3	1	2	4	4	4	3	3
		Gomphus externus	4						1			1		1
		Progomphus obscurus	17	3	2	3	3	3	1	2	1	1	1	2
	Libellulidae	*Libellula*		1	1									
Plecoptera	Perlidae	*Perlesta*	5	3	6					2		3		
	Perlodidae	*Hydroperla*		1	1									
Hemiptera	Belostomatidae	*Belostoma*	1	1									1	
	Corixidae	*Sigara*		2										
		Trichocorixa	2	1	1									2
	Gerridae	*Aquarius*	1											
		Gerris	1			1								
	Gyrinidae	*Dineutus*		1										
	Hydrometridae	*Hydrometra*	1											1
	Veliidae	*Rhagovelia*	6				2		1	1		2		
		Microvelia	1	1										1
Trichoptera	Hydropsychidae	*Cheumatopsyche*	3							1	1	1		
	Hydoptilidae	*Hydroptila*	2								1	1		
		Ithytrichia clavata	3								2	1		
	Leptoceridae	*Nectopsyche*	21			5				3	4	4	3	2

			season			summer								
			summer	fall	spring	pond	silt	sand	gravel	leaf	roots	wood	veg	back
Coleoptera	Dytiscidae	*Agabus*		3	3									
		Hydroporus	6	4	2						1		1	3
		Laccophilus	2	1										2
		Uvarus	3							2				1
		Uvarus (patterned)	3								2		1	
	Dryopidae	*Helichus*	9		1	1				2	1	4	1	
	Elmidae	*Dubiraphia*	6							2	3		1	
		Heterelmis	4							2		1	1	
		Microcylloepus pusillus	8	1						1	1	3	2	1
		Stenelmis	11							3	2	4	1	1
	Haliplidae	*Haliplus*	2			2								
		Peltodytes	5	2	1	2					2		1	
	Helophoridae	*Helophorus*	2			1							1	
		Helophorus (small)	1											1
	Hydrochidae	*Hydrochus*	1										1	
	Hydrophilidae	*Berosus*	17	3	1	2	1		1	2	3	3	2	2
		Berosus (dark)	1											1
		Crenitulus	1											1
		Cymbiodyta	1											1
		Enochrus	3		1					1				2
		Tropisternus	6	1	1	1						1	1	2
		Paracymus	6			1				1		3		1
	Scirtidae	*Cyphon*	2			1								1
Megaloptera	Corydalidae	*Corydalis*	1									1		
	Sialidae	*Sialis*	2								1			1
Diptera	Ceratopognidae	*Bezzia/Palomyia*	1							1				
		Culicoides	1			1								
	Chironomidae	*chironomid pupae*	25	5	6	5	3	3	1	4	3	1	3	1
	Simuliidae	*Simulium*		4										
	Stratiomyidae	*Nemotelus*		1	1									
		Stratiomys	1							1				
	Tabanidae	*Tabanus*	1	1										1
	Tipulidae	*Gonomyia*		1										
Nematoda					1									

			season				summer								
			summer	fall	spring		pond	silt	sand	gravel	leaf	roots	wood	veg	back
Planaria	unidentified		3									2	1		
Oligochaeta	Naididae	*Pristina leidyi*	1										1		
		Pristinella acuminata		1											
		unidentified			1										
	Tubificidae		1	2	2									1	
Hirudinea	Glossiphoniidae	*Placobdella ornata*	3								2		1		
Acari	sp. 1		1				1								
	larva			1											
Gastropoda	Lymnaeidae	*Fossaria*	5	1			2							1	1
	Physidae	*Physella*	14	5	5		1	1			1	3	3	2	2
Pelecypoda	Sphaeriidae	*Musculium*	7	1	1		1	1	1			3			
Decapoda	Cambaridae	*Orconectes nais*	2									1			
		Procambarus simulans													
Cladocera			1				1								
Amphipoda	Hyallelidae	*Hyalella*		1	1										
Copepoda	Cyclopoidea		2	3			2								
	Calanoidea			1											
	Harpacticoidea			1											
Ostracoda			1				1								

Adult aquatic insects (light trap samples)

			Jun	Aug
Ephemeroptera	Caenidae	*Caenis amica* Hagen	X	
		Caenis latipennis Banks	X	X
	Ephemeridae	*Hexagenia limbata* (Serville)	X	X
	Heptageniidae	*Stenonema* sp.	X	
	Isonychidae	*Isonychia rufa* McDunnough	X	
Plecoptera	Perlidae	*Perlesta decipiens*	X	
Trichoptera	Hydropsychidae	*Cheumatopsyche lasia* Ross 1938	X	
		Cheumatopsyche pettiti (Banks) 1908	X	
		Cheumatopsyche species Wallengren		X
		Hydropsyche bidens Ross 1938	X	
	Hydroptilidae	*Hydroptila angusta* Ross 1938	X	X
		Hydroptila pecos Ross 1941	X	
		Ithytrichia clavata Morton 1905	X	X
		Neotrichia species Mosely	X	
		Neotrichia okopa Ross 1939		X
		Ochrotrichia tarsalis (Hagen) 1861	X	
		Orthotrichia aegerfasciella (Chambers) 1873	X	X
		Oxyethira pallida (Banks) 1904	X	X
		Oxyethira species Eaton		X
	Leptoceridae	*Leptocerus americanus* (Banks) 1899	X	
		Nectopsyche species Muller	X	X
		Oecetis cinerascens (Hagen) 1861	X	X
		Oecetis ditissa Ross 1966		X
		Oecetis inconspicua (Walker) 1852	X	X
		Triaenodes injustus (Hagen) 1861	X	
		Triaenodes tardus Milne 1934	X	
	Philopotamidae	*Chimarra* species Stephens	X	
		Chimarra obscura (Walker) 1852	X	
	Polycentropodida	*Cernotina calcea* Ross 1938	X	
		Cyrnellus fraternus (Banks) 1913	X	

Fish

Family	Species	Common name	Number of individuals caught		
			Summer	Fall	Spring
Lepisosteidae	*Lepisosteus osseus*	longnose gar	1	0	0
Clupeidae	*Dorosoma cepedianum*	gizzard shad	9	0	5
Cyprinidae	*Cyprinella lutrensis*	red shiner	891	373	775
	Notropis stramineus	sand shiner	23	11	30
	Pimephales vigilax	bullhead minnow	31	50	47
	Pimephales promelas	fathead mnnow	47	6	33
	Campostoma anomalum	central stoneroller	5	0	6
	Phenacobius mirabilis	suckermouth minnow	2	3	6
Ictaluridae	*Ictalurus punctatus*	channel catfish	3	0	4
	Ameiurus natalis	yellow bullhead	3	0	2
Fundulidae	*Fundulus zebrinus*	plains killifish	40	57	48
Poeciliidae	*Gambusia affinis*	mosquitofish	1211	105	847
Percidae	*Etheostoma spectabile*	orangethroat darter	21	1	14
Centrarchidae	*Lepomis macrochirus*	bluegill	10	0	12
	Lepomis cyanellus	green sunfish	4	0	5
	Lepomis humilis	orangespotted sunfish	3	1	2

Appendix 3. Comparison of taxa in the Washita River at/near the WBNHS and below Foss Reservoir
(literature sources are listed in the text)

Invertebrates

			WBNHS	Foss	Both
Collembola	Poduridae	*Podura aquatica*	X		
Ephemeroptera	Baetidae	*Baetis*		X	X
		Callibaetis	X		
		Cloeon		X	
		Fallceon quilleri	X		
		Paracloeodes	X		
	Caenidae	*Caenis*	X	X	X
	Ephemeridae	*Hexagenia*		X	
	Heptageniidae	*Stenonema*		X	
		Heptagenia	X		
	Isonychidae	*Isonychia*	X		
	Leptophlebiidae	*Choroterpes*		X	
	Tricorythidae	*Tricorythodes*	X	X	X
Odonata	Calopterygidae	*Hetaerina americana*	X		
	Coenagrionidae	*Argia bipunctulata*	X		
		Enallagma		X	
	Gomphidae	*Dromogomphus*		X	
		Erpetogomphus designatus	X		
		Gomphus externus	X	X	X
		Progomphus obscurus	X	X	X
	Libellulidae	*Libellula*	X		
Plecoptera	Perlidae	*Perlesta*	X		
	Perlodidae	*Hydroperla*	X		
Hemiptera	Belostomatidae	*Belostoma*	X		
	Corixidae	*Cymatia*		X	
		Sigara	X		
		Trichocorixa	X		
	Gerridae	*Aquarius*	X		
		Gerris	X		
	Gyrinidae	*Dineutus*	X		
	Hydrometridae	*Hydrometra*	X		
	Veliidae	*Rhagovelia*	X		
		Microvelia	X		
Trichoptera	Hydropsychidae	*Cheumatopsyche*	X	X	X
		Hydropsyche		X	
	Hydoptilidae	*Hydroptila*	X		
		Ithytrichia clavata	X		
	Leptoceridae	*Ceraclea*		X	
		Leptocerus		X	
		Nectopsyche	X		
		Oecetis		X	
Coleoptera	Dytiscidae	*Agabus*	X	X	X
		Hydrovatus		X	
		Hydroporus	X		
		Laccophilus	X		
		Uvarus	X		
	Dryopidae	*Helichus*	X		

			WBNHS	Foss	Both
Coleoptera	Elmidae	*Dubiraphia*	X	X	X
		Heterelmis	X	X	X
		Microcylloepus pusillus	X		
		Stenelmis	X	X	X
	Gyrinidae	*Dineutus*		X	
	Haliplidae	*Haliplus*	X		
		Peltodytes	X		
	Helophoridae	*Helophorus*	X		
	Hydrochidae	*Hydrochus*	X		
	Hydrophilidae	*Berosus*	X	X	X
		Crenitulus	X		
		Cymbiodyta	X		
		Enochrus	X		
		Tropisternus	X	X	X
		Paracymus	X		
	Scirtidae	*Cyphon*	X	X	X
Megaloptera	Corydalidae	*Corydalis*	X		
		Dysmicohermes		X	
	Sialidae	*Sialis*	X		
Diptera	Athericidae	*Atherix*		X	
	Ceratopognidae	*Bezzia/Palomyia*	X	X	X
		Culicoides	X		
	Simuliidae	*Simulium*	X	X	X
	Stratiomyidae	*Euparyphus*		X	
		Nemotelus	X		
		Stratiomys	X		
	Tabanidae	*Tabanus*	X		
	Tipulidae	*Erioptera*		X	
		Gonomyia	X		
	Trachinidae	*Menetus*		X	
Nematoda			X	X	X
Planaria	unidentified		X		
Oligochaeta		unidentified	X	X	X
Hirudinea	Glossiphoniidae	*Placobdella ornata*	X		
Acari	sp. 1		X		
Gastropoda	Lymnaeidae	*Fossaria*	X		
		Lymnaea		X	
	Physidae	*Physella*	X	X	X
	Planorbidae	*Ferrissia*		X	
		Gyraulus		X	
		Helisoma		X	
Pelecypoda	Sphaeriidae	*Musculium*	X		
		Sphaerium		X	
Decapoda	Cambaridae	*Orconectes nais*	X		
		Procambarus simulans	X		
		Palaemonetes kadiakensis		X	
Amphipoda	Hyallelidae	*Hyalella*	X	X	X

Fish

Common name	family	Species	WBNHS	Foss	Both
longnose gar	Lepisosteidae	Lepisosteus osseus	X		
gizzard shad	Clupeidae	Dorosoma cepedianum	X		
red shiner	Cyprinidae	Cyprinella lutrensis	X	X	X
sand shiner		Notropis stramineus	X	X	X
bullhead minnow		Pimephales vigilax	X	X	X
fathead mnnow		Pimephales promelas	X		
central stoneroller		Campostoma anomalum	X	X	X
suckermouth minnow		Phenacobius mirabilis	X	X	X
channel catfish	Ictaluridae	Ictalurus punctatus	X		
yellow bullhead		Ameiurus natalis	X		
plains killifish	Fundulidae	Fundulus zebrinus	X		
mosquitofish	Poeciliidae	Gambusia affinis	X	X	X
orangethroat darter	Percidae	Etheostoma spectabile	X		
bluegill	Centrarchidae	Lepomis macrochirus	X	X	X
green sunfish		Lepomis cyanellus	X		
orangespotted sunfish		Lepomis humilis	X		
redear sunfish		Lepomis microlophus		X	
largemouth bass		Micropterus salmoides		X	
striped bass	Moronidae	Morone saxatilis		X	