Response of Water Quality and the Aquatic Community to a Reverse Osmosis Unit Discharge into the Wichita River, Texas

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ABSTRACT

The construction of a reverse osmosis (RO) water treatment unit at the Cypress Water Treatment Plant in Wichita Falls, Texas, afforded an opportunity to evaluate the effects of concentrated brine effluent on water quality in the Wichita River and responses of resident fish and benthic macroinvertebrate assemblages. Four sites, two upstream and two downstream of the proposed discharge point, were sampled three times a year in 2005 and 2008, prior to the plant beginning direct discharge of effluent to the river in February 2009. Post-project samples were collected in 2009 (twice), 2010 (twice), and 2011 (once). Continuous water quality monitoring data demonstrated significantly higher specific conductance downstream of the discharge compared to upstream. However, no significant differences for specific conductance were observed in instantaneous or short-term samples or for water grab samples analyzed for total dissolved solids (TDS), chloride, and sulfate, which likely related to the varying volume of discharge. Selenium was not detected in any samples. Fish and invertebrate assemblages did not appear significantly different when comparing upstream and downstream sites, though some annual and seasonal differences were observed. Historically, the Wichita River has been characterized as having relatively high dissolved solids or salt concentrations with streamflow being a principal influence on the instream levels of these constituents. The relative absence of significant post-project effects may be attributable to the native fauna reflecting those long-term salinity characteristics and its relationship to streamflow as well as the volume of RO effluent discharged to the river averaging substantially less than permitted capacity during the study period.

INTRODUCTION

Increasing demands for water, coupled with susceptibility to drought events, has caused Texas to consider all potential sources of water in its water planning efforts (TWDB 2013). Continuing drought has made desalination of brackish inland waters an increasingly considered approach to accommodate anticipated population and industry growth (Galbraith 2012). Texas currently has an estimated total municipal desalination capacity of about 123 million gallons per day (about 137,760 acre-feet per year) which includes 73 million gallons per day (about 81,760 acre-feet per year) of brackish groundwater desalination and 50 million gallons per day (about 56,000 acre-feet per year) of brackish surface water desalination (TWDB 2012).

Wichita Falls, Texas, and several nearby towns and communities have historically used two reservoirs on the Little Wichita River, lakes Arrowhead and Kickapoo, as their primary water supplies. Drought in the Wichita Falls area from 1995 to 2000 underscored the need for water sources in addition to those reservoirs (Langdon 2008). The City of Wichita Falls examined several options for an additional water source and decided to move ahead with reverse osmosis using water from two reservoirs on the Wichita River, lakes Kemp and Diversion, which have not been tapped as a municipal water source because of salinity levels (Langdon 2008).

The Wichita River is characterized by high concentrations of chlorides that emanate from salt springs located in the upper watershed (Haynie et al. 2011). As noted, the elevated chloride levels have resulted in the Wichita River being underutilized as a freshwater supply source. Congress enacted the Red River Chloride Control Project in 1959, directing the U.S. Army Corps of Engineers to develop a plan for controlling natural chloride discharges in areas including the upper Wichita River. The first of these control structures was completed in the Wichita River basin in 1987 (USACE 2003). Data (1996-2009) from eight monitoring sites on the Wichita River as well as the North, Middle, and South forks of the Wichita River demonstrated the lowest median specific conductance and chloride concentrations occur at the most downstream stations (Haynie et al. 2011). Specific conductance is an indirect measure of the presence of dissolved solids such as chloride.

In 2008, the City of Wichita Falls completed a reverse osmosis (RO) water treatment unit to reduce chloride concentrations to potable levels. The RO unit at the Cypress Water Treatment Plant began producing water in September 2008, though effluent was routed through an existing discharge and was not directly returned to the Wichita River until February 2009. In the treatment process, raw water from lakes Kemp and Diversion is transmitted to a holding facility northwest of Wichita Falls and becomes the source water for the RO plant. After pre-treatment, the water is passed through a semi-permeable membrane to reduce salts and other contaminants. Water from the RO process is then blended with water from lakes Kickapoo and Arrowhead. The RO unit is capable of producing 10 million gallons a day (MGD) of water and is permitted to discharge up to 6 MGD of effluent directly into the Wichita River. Typically, inland RO treatment units discharge concentrated dissolved constituents (i.e., brine reject) to surface water, sewers, deep wells, land application, or evaporation ponds. Aside from deep well injection, disposal options tend to increase the chloride load of surface soils and water, potentially decreasing soil fertility and/or downstream water quality (Brady et al. 2005).

The effects of discharges from RO treatment units have not previously been well documented in freshwaters, though aquatic organisms are known to respond to salinity gradients. Matthews (1998) described how salinity structures freshwater fish communities in the Red River of Texas and Oklahoma with few species in highly saline areas and increasing species richness as the salt load lessens. Echelle et al. (1972) identified groups of species that correspond to various ranges of salinity. Higgins and Wilde (2005) correlated the occurrence of species in the Red River system (including the Wichita and Little Wichita rivers) with salinity and concluded that salinity has been a dominant and persistent factor in affecting the structure of stream fish assemblages for the past 50 years. Nielsen et al. (2003) also observed that adult fishes could acclimate to elevated salinity, but eggs and juvenile life forms might be disproportionately affected, possibly eliminating them from an area. Nielsen et al. (2003), writing about effects of increasing salinity on freshwater ecosystems in Australia, concluded that macroinvertebrates were less susceptible to salinity than fishes. Kefford et al. (2003) suggested otherwise and developed LC50 values for macroinvertebrates in the Barwon River, Australia, with the least tolerant being baetid mayflies, followed by Chironomidae, and several soft-bodied, non-arthropods including members of Oligochaeta, Gastropoda, Nematomorpha, Tricladida, and Hirudinea.

The purpose of the present study was to evaluate whether the discharge from the RO unit influenced water quality and the macroinvertebrate and fish assemblages in the Wichita River.

STUDY AREA

The Wichita River, a tributary of the Red River, is formed by the confluence of the North and Middle forks of the Wichita River later joining with the South Fork of the Wichita River upstream of Lake Kemp. The study area lies within the Central Great Plains ecoregion (Level III) and Broken Red Plains Ecoregion (Level IV). As described by Omernik (2009), soils are red clay and sand and the line of 30 inches annual precipitation (or about the 98th meridian) marks the eastern limit of the distribution of mesquite and the eastern boundary of the ecoregion. The prairie type is transitional between tallgrass and shortgrass growth forms. Honey mesquite, wolfberry, sand sagebrush, yucca, and pricklypear cacti may be mixed with the grasses and riparian vegetation includes cottonwood, hackberry, cedar elm, pecan, and little walnut. Four sites (WR1-WR4) on the Wichita River in Wichita County, Texas were sampled during the time period of 2005, and 2008 to 2011 (Figure 1). All sites are downstream of lakes Kemp and Diversion. The center of the study reach is about 98 river km upstream from the confluence of the Wichita and Red rivers. The uppermost sampling site (WR1) is located 6.5 km upstream of the RO unit discharge, while the lowermost site (WR4) is 3.9 km downstream of the discharge point. Sampling events prior to discharge will be considered as 'pre-project' and the events after as 'post-project'.

METHODS

Each site was represented by a 500m reach with a goal of sampling once in spring, summer, and fall each year (2005, 2008, 2009, and 2010). Samples were collected during stable flow periods to increase the likelihood of including the full complement of benthic macroinvertebrate and fish resident species. To ensure this, sampling was delayed approximately four weeks following a flood pulse and two weeks following a high flow pulse with flow data being obtained from the U.S. Geological Survey (USGS) station (07312500) located 3.9 km downstream of WR4. Spring samples were not taken in 2009 because the plant had not been discharging for long and in 2010 because of high flow pulse events conflicting with sampling schedules (Figure 2). A spring sample was added in 2011 to supplement for the lack of one in prior years.

Physical habitat – Six cross-channel transects were established at 100 m intervals in each reach. Physical habitat data were collected and evaluated according to Texas Commission on Environmental Quality (TCEQ 2005), using a habitat quality index (HQI) to assign a corresponding aquatic life use (ALU) for each reach on each sampling date. Physical habitat data included stream width, depth, maximum pool width, maximum depth, dominant substrate type, percent gravel, instream cover types and percentages, bank erosion potential, bank slope, and a riparian characterization.

Water chemistry – To evaluate potential RO discharge influences on water chemistry, water samples, 24-hour multiprobe deployments, and monthly instantaneous measurements were taken. The water samples were collected at each site during each seasonal sampling event following TCEQ guidelines (TCEQ 2003) and were analyzed at the TPWD Contaminants Assessments Laboratory located at the AE Wood State Fish Hatchery, San Marcos, Texas, for total dissolved solids (TDS), chloride, sulfate, and selenium. A multiprobe datalogger (YSI 600 XLM) was deployed at the upstream area of each site during each seasonal sampling event to measure temperature, specific conductance, pH, and dissolved oxygen (DO) every hour for at least a 24-

hour period. The dataloggers were suspended where possible in flowing, non-turbulent water and were post-calibrated. Data were only accepted if they met established quality assurance guidelines (TCEQ 2003). In addition, monthly instantaneous measurements of temperature, specific conductance, pH, and DO were collected with a YSI 85 calibrated according to the manufacturer's directions. Means from multiprobes were combined with monthly instantaneous samples to evaluate trends, recognizing data gaps from instrument malfunction or failing quality assurance checks. The data were evaluated for differences using a two-way analysis of variance with factors including sites, and pre-/post- project discharge.

Continuous monitoring data from TCEQ stations (747, upstream from the discharge) and (746, downstream of the discharge) were also analyzed to look for RO discharge influences on water chemistry constituents, particularly specific conductance. Data were from June 2009 to October 2010 (the monitors were deactivated in November 2010). There were a number of gaps in the data record and observations were excluded from the analysis if either the up or downstream data were missing. In the water chemistry analyses, specific conductance was used as an indirect measure of the presence of dissolved solids such as chloride and sulfate. A paired sample t-test was used to compare upstream to downstream continuous monitoring data paired by hour. Significance for all statistical tests was set at 0.05. Specific conductance and stream discharge data from the downstream USGS gage were analyzed using regression to evaluate the relationship between the two variables using regression analysis.

Benthic macroinvertebrates – Macroinvertebrate samples were collected with kick-net and snag sampling protocols (TCEQ 2005) and were processed in the field, with a minimum of 140 individuals collected and preserved. Macroinvertebrates from each sample were identified to the lowest practical taxonomic level (generally to genus level) using different keys (Needham et al., 2000, Smith, 2001, Merritt et al., 2008, and Wiggins, 2009) and enumerated. Macroinvertebrates were assigned functional feeding groups (FFG) according to Merritt et al. (2008) and this information was used to calculate a 12-metric benthic index of biotic integrity (BIBI) that considers structural and functional attributes of the macroinvertebrate community (Harrison 1996, Davis 1997, Table B-11 TCEQ 2007). BIBI scoring criteria and aquatic life use point score ranges are for Kick Samples, Rapid Bioassessment Protocol, as outlined in Harrison (1996). Total BIBI scores were assigned an ALU for each reach for each sampling date. The 12 BIBI metrics were also tested individually against various factors (pre-/post-project, season, site, and pre-/post-project x site interaction) to check for differences using least squares fit. Assemblage responses to site, season, and year factors were analyzed using least squares fit analyses. Post-hoc test (Tukey's test) was conducted on responses that had significant differences, to evaluate the sources of the difference. Relationships between environmental factors and abundances were described with a multivariate ordination approach using canonical correspondence analysis (CCA). To understand the percentage of variance contributed by different factors, partial CCA was conducted on all environmental variables and macroinvertebrate abundance (Order level), along with dummy variable coding for the following factors: pre-/post-project, year, season, and site.

Fish assemblage – Mesohabitats were seined in proportion to their presence within each reach. A minimum of 10 seine hauls were taken, though sampling continued until no additional species were collected. The principal seine employed was 4.6 m x 1.8 m (4.8 mm ace weave mesh);

however, when needed to sample more effectively, additional size seines were also used: 1.8 m x 1.2 m (4.8 mm ace weave mesh) and 9.1 m x 1.8 m (6.4 mm ace weave mesh). Large-bodied fishes were also collected with a single, baited hoop-net deployed for 48 hours at each reach. Fishes easily identified in the field were enumerated, measured (total length), photographed (one fish of each species), and released. All other fish were preserved in 10% formalin and returned to the lab to be identified and enumerated. The principal taxonomic reference used for identifying fish was Hubbs et al. (2008), supplemented by Moore (1968), Douglas (1974), Pflieger (1975), Robison and Buchanan (1988), and Thomas et al. (2007). Scientific names follow Nelson et al. (2004). The index of biotic integrity (IBI) was calculated using the regionalized scoring criteria in Linam et al. (Table 7; 2002) for each site on each date and an ALU assigned. Fish assemblage responses were analyzed using three-way ANOVA and multivariate (ordination) analyses. To further assess changes in the fish assemblage, principal component analysis (PCA) was used to evaluate sample differences in relation to season, site, and pre- and post-project. CCA was performed to evaluate the relationship between possible differences among the fish samples and associated environmental data.

RESULTS

During the pre-project study period, mean annual flow at the USGS gage (#07312500) was 5.02 m^3/s for 2005 and 2.72 m^3/s for 2008 (Figure 2). During the post-project study period, mean annual flow was 1.81 m^3/s for 2009, 6.48 m^3/s for 2010 and 1.22 m^3/s for 2011. Mean discharge from the RO unit was 1.9 MGD in 2009 and 1.57 MGD in 2010, compared to the maximum permitted capacity of 6 MGD (Figure 3).

Physical habitat – Raw physical habitat data were summarized (Tables 1 and 2) and used to calculate HQI scores and an ALU category were assigned to each site (Tables 3 and 4). ALU classes varied from Intermediate to High. ANOVA results for RO project (pre-/post-) and site were not significant with P-values = 0.15 and 0.25 respectively. There was a significant seasonal variation in HQI scores with P-value = 0.03 (with fall scores being higher than summer score seen in Tukey’s test). Some variation in the average percent of substrate gravel or larger from event to event within each site was observed (Table 1 and 2).

Water chemistry – Self-reporting data from the Cypress Water Treatment Plant (Figure 3) demonstrates varying levels of RO unit discharge and constituents of interest from month to month. Combined data from short-term deployments and monthly instantaneous water quality measurements from this study are depicted in Figures 4–9 and Table 5. Temperature and pH were similar upstream and downstream, pre-/post-project. Specific conductance was significantly greater throughout the study area post-project, but there were no significant differences among sites upstream or downstream of the discharge and no significant interaction between the two factors analyzed (e.g., site and project presence). Similar results were observed for total dissolved solids (Figure 7). Chlorides and sulfates were not significantly different pre-/post-project or among sites (Figures 8 and 9), though variability was greater post-project. Site WR1, well upstream of the plant, demonstrated higher values than other sites on several dates. Selenium was less than detectable at all sites and in all samples (Table 5). TCEQ continuous monitoring data demonstrated significantly higher specific conductance downstream from the discharge with a mean difference of 547.7 µmhos/cm when compared to upstream, suggesting influence from the RO discharge.

Benthic macroinvertebrates – During the study, 9,055 benthic macroinvertebrates were collected, identified, and enumerated, representing 16 orders, 55 families, and 63 genera. Ephemeroptera comprised 32% of total abundance, followed by Trichoptera (21%), Diptera (14%), and Coleoptera (13%). Macroinvertebrate abundance data is depicted by season and site during the sampling period in Appendix 1a–1e. BIBI and ALU scores (Harrison 1996, Davis 1997, TCEQ 2007) were calculated for all four sites (Tables 6–10). ALU ratings for the four sites ranged from limited to exceptional (Figure 10, Tables 6–10), with most of the values falling within the intermediate and high categories. The BIBI scores for WR1 did not show any particular trend. WR2 showed a tight cluster between the pre- and post-project year BIBI scores, WR3 showed the highest variation, while WR4 had higher scores during the post-project period.

The total BIBI scores showed significant effects between the pre-/post- project time periods, and season (Table 11 (1)), however there was not a significant difference in the total BIBI scores among sites, or site and pre-/post-project interaction. Post-hoc test (Tukey's test, only mentioned in results section) showed the post-project total BIBI scores were significantly higher than the pre-project scores at all four sites. The total BIBI scores for summer samples were significantly higher than the spring samples. The significance tests for the 12 individual metrics contributing to the total BIBI score are summarized in Table 11 (2–13). The individual metrics with significant differences in pre- and post-project were taxa richness (greater in post- project), percent dominant functional feeding guild (FFG) being greater in pre-project, percentage of collector-gatherers (greater in pre-project), and percent of predators (greater in post-project).

Multivariate ordinate analysis (CCA) was conducted to explore the effects of environmental variables on fish assemblage. The environmental variables utilized in the CCA were pH, dissolved oxygen, specific conductance, temperature, streamflow, total dissolved solids (TDS), sulfate, chloride, and HQI (although some of these variables were correlated, they were retained in the analysis). Other environmental data collected was not used in the CCA because of high multicollinearity and insignificant t-values. Macroinvertebrate taxa used in this analysis were at the order level to keep the number of taxa at a manageable level on the CCA plot and also difference in sampling efficiency because of sampling personnel. The first two canonical axes explained over 65.1% of the total variance (Figure 11) with significant t-values for specific conductance, pH, temperature, and streamflow. Site scores, which represent the assemblage at a sampling location and date, showed a weak pre- and post-project grouping with the pre-project site scores spread throughout the CCA plot, and the post-project site scores having a tighter grouping on right half of the plot. Megaloptera, freshwater shrimp (Decapoda), and Amphipoda were positively associated to higher streamflow, higher temperatures, and higher total dissolved solids. Conversely, earthworms (Oligochaeta), water mites (Trombidiformes), and Physid snails (Limnophila) were negatively associated with streamflow. Mayflies and caddisflies were negatively associated with higher temperatures and higher total dissolved solids. Aquatic Lepidopterans and Podocopa were strongly associated with higher DO concentrations and higher HQI scores. The partial CCA results showed the full model explaining 46.26% (*P-value* = 0.06) of the total variance. Individual factors that contributed significantly to the model were season explaining 7.68% (*P-value* <0.01) of the total variance, year explaining 4.72% (*P-value* = 0.01), and pre- and post-project explaining 3.74% (*P-value* = 0.04). Sites explained very little of the variance (0.39%) and was not significant (*P-value* = 0.98).

Fish assemblage – In five years of seasonal sampling, a total of 41,796 fish were collected representing 35 species from 11 families. Two families comprised 98.49% of the total fish collected: Cyprinidae (14 species, 94.38%) and Poeciliidae (1 species, 4.11%). Of the cyprinids, red shiner *Cyprinella lutrensis* and bullhead minnow *Pimephales vigilax* comprised 73.77% and 16.30% of the total fish collected respectively. Appendix 2a–2e enumerates the species collected by season and site for each of the five years of the study.

Fish IBI scores and associated ALUs for each site and sampling event are presented in Tables 12–16. ALUs varied among years, sites, and seasons (Figure 12); no sites received an exceptional rating. There appear to be some differences in IBI total scores pre- versus post-project. The majority of the pre-project ALU designations were High and Intermediate and the majority of the post-project ALU designations were Intermediate and Limited with no samples in the High category although these differences were not significant ($p = 0.064$). There was a significant interaction between pre-/post-project IBI total scores and season, though differences among IBI scores when comparing upstream and downstream sites pre-/post-project were not significant.

In the PCA, principal component 1 (PC1 - 74.75%) and 2 (PC2 - 12.50%) combined to explain 87.25% of the variance in the fish assemblage data (Figure 13). The majority of the variance can be explained by seasonal differences in fish assemblage structure with seasonal sample groupings spread across PC1. Spring and summer sample differences appear to be driving the seasonal variation represented by a shift of high red shiner abundance in the spring samples to high bullhead minnow abundance in the summer samples. There appears to be a pre- and post-project effect with pre- and post-project sample groupings (open versus filled symbols in Figure 13) spread across PC2. Pre- and post-project sample differences appear to be driven by shifts in high western mosquitofish *Gambusia affinis* and freshwater drum *Aplodinotus grunniens* abundances in pre-project samples to high abundances of emerald shiner *Notropis atherinoides*, sand shiner *Notropis stramineus*, and ghost shiner *Notropis buchanani* in post-project samples. Samples were not significantly different between upstream samples sites versus downstream sample sites pre- or post-project.

Given that the changes in fish assemblage appear to be driven by seasonal factors and to a lesser extent the effects of RO unit discharge (lack of significant differences between upstream and downstream sites) for the study period, a CCA was performed to evaluate the relationship between differences in the fish samples and associated environmental data (same environmental variables as benthic macroinvertebrate CCA). The sum of the eigenvalues for axis CCA1 and CCA2 of the CCA combined to explain 16.89% of the variance (Figure 14). Summer samples exhibited higher TDS, temperature, and sulfate values; whereas, spring samples exhibited higher DO, pH, and chloride values (Figure 14a). When comparing samples between pre- and post-project, post-project samples appear to be associated with higher specific conductance (conductivity), TDS, and streamflow values (calculated during sampling event); whereas, pre-project samples are associated with lower specific conductance and TDS values, as well as higher DO, pH and chloride values (Figure 14b). Sample sites did not exhibit any patterns associated with environmental variables. Species-environmental correlations consist of chub shiner *Notropis potteri*, Gulf killifish *Fundulus grandis*, gizzard shad *Dorosoma cepedianum*, prairie chub *Macrhybopsis australis*, warmouth *Lepomis gulosus*, plains minnow *Hybognathus placitus*, Red River pupfish *Cyprinodon rubrofluviatilis*, and blue catfish *Ictalurus furcatus* correlated with high TDS, temperature, and sulfate; ghost shiner *Notropis buchanani*, emerald shiner *Notropis atherinoides*, sand shiner *Notropis stramineus*, and silver chub *Macrhybopsis storeriana* were correlated with high conductivity; white crappie *Pomoxis annularis*, freshwater drum *Aplodinotus grunniens*, and bluegill *Lepomis macrochirus* were correlated with high dissolved oxygen, pH, and chloride; fathead minnow *Pimephales promelas*, threadfin shad *Dorosoma petenense*, spotted gar *Lepisosteus oculatus*, and mosquito fish *Gambusia affinis* were correlated with low conductivity.

DISCUSSION

Downstream values for specific conductance, TDS, chloride, and sulfate concentrations from grab samples, instantaneous measurements, and short-term deployments were not significantly different than those upstream in the pre-project or post-project periods. However, continuous monitoring data did show significantly higher specific conductance values downstream, perhaps underscoring the difference between short-term samples and a fairly continuous record added to the varying volume of discharge. Values throughout the system were higher post-project, which likely relates to differences in streamflow. Regression analysis using the downstream USGS gage 30-minute water quality data (2007-2011) indicates that specific conductance was inversely related to streamflow (Figure 15), with higher streamflow resulting in lower specific conductance and vice versa. Seasonal patterns in streamflow were observed over the study period with lower mean flows in fall and winter compared with late spring and summer, a circumstance that may have influenced the biotic assemblages. USGS mean daily data (1998 to 2011) recorded at the downstream gage demonstrates long-term elevated but widely-fluctuating specific conductance values (Figure 16) with little indication of an overall increasing trend. Variation in average percent of substrate gravel or larger was observed between sampling events across sites and may be attributed to sediment movement due to pulse flow events in the Wichita River (Figure 2).

Significant effects of the RO unit discharge on the benthic macroinvertebrate assemblage were minimal in the study area over the study period. The lack of a significant difference between the upstream and downstream sites might be attributed to species mobility, connectivity of habitat patches, and proximity of the sites (about 10 km range of the sampled sites). Many of the macroinvertebrate species collected in the study have a terrestrial and aquatic component to their life cycle (Anderson and Wallace 1984); thus, are capable of migrating in and out of and repopulating (either by flight or drift) nearby sites (Williams et al. 2002). Significant differences in some IBI metrics between the pre- and post-project samples could be attributed to changes in water quality related to streamflow (and resulting specific conductance), interannual variation in assemblage structure, or differences in sampling efficiency resulting from different investigators.

Among the factors evaluated in this study, seasonal variation was the strongest factor structuring the macroinvertebrate assemblage (Tables 6-11). Abundances of taxa belonging to the Ephemeroptera, Plecoptera, and Trichoptera (EPT) orders showed a significant seasonal difference in abundance (Table 11), with highest numbers in summer and lower during fall and spring. Relatively short life cycles coupled with seasonal changes in habitat conditions (e.g., streamflow and resulting specific conductance) contribute to seasonal variability in macroinvertebrate assemblages (Hynes 1972; Williams et al. 1996; Linke et. al. 1999). Sprules (1947) also observed greater abundance and diversity of Ephemeroptera and Trichoptera during the warmer summer season.

Taxa that declined in abundance downstream of the RO unit discharge point during the post-project period were Baetidae (Ephemeroptera) and *Nectopsyche* spp. (see Appendix 1a-1e). Minshall et al. (2004) observed a decrease in Baetid mayflies at TDS levels above 1,500 mg/L (Figure 7). Although average TDS values in the Wichita River (Table 5) were higher than the threshold value to begin with, the greater variability in TDS levels during the post-project period can be attributed to having an effect on the above two taxa. Similar effects of higher TDS were observed in Trichopterans by Usis and Foote (1991). Previous studies have shown that the salinity tolerance level of the orders Ephemeroptera, Plecoptera, and Trichoptera (EPT) is low, and increase in salinity can influence their abundance (García-Criado et al. 1999; Kennedy et al. 2003; Hartman et al. 2005; Hassel et al. 2006; Pond et al. 2008; Pond 2010; Kefford et al. 2011; Cañedo-Argüelles et al. 2013). The absence of a significant effect from the RO unit discharge on the overall macroinvertebrate assemblage suggests a greater role for other environmental factors such as seasonal changes in hydrology and resulting water quality changes to be likely responsible for variability in abundance and species composition.

Similar to the benthic macroinvertebrate data, fish assemblage changes during this study also do not appear to be strongly influenced by RO unit discharge but rather seasonal differences, though this interpretation could be confounded by factors such as incomplete seasonal sampling (fewer post-project spring samples) and differences in hydrology between the two periods. Due to high flow pulses during spring 2010, only 12 total spring samples (8 pre-project vs. 4 post project) were collected compared to 16 summer and 16 fall samples. The significance of missing a spring sample is that Taylor et al. (1996) found that fish assemblage changes were greatest during the spring in other Red River tributaries which could confound interpretation of fish assemblage changes between pre- and post-project conditions. To further compare differences in hydrology between the two periods, daily discharge data from the USGS 07312500 gage station was analyzed with Indicators of Hydrologic Alteration (IHA) software (TNC 2009). IHA analysis indicated that the mean annual flow was greater in the pre-project period (2005-2008; 5.18 m^3/s) than the post-project period (2009-2011; 3.17 m^3/s). This difference in streamflow could play an important role in structuring the fish assemblage given that streamflow was found to be inversely related with specific conductance (Figure 15). The role of environmental conditions in structuring prairie stream fish assemblages has been well documented (Ross et al. 1985; Schlosser 1990), with salinity specifically identified as important in determining abundance and species richness in several studies (Echelle et al.1972; Taylor et al. 1993; Matthews 1998; Higgins and Wilde 2005). Another important hydrologic difference between the two periods was differences in median high flow pulse frequency which was lower during the pre-project years (9) than the post-project years (13). Hydrologic disturbances in the form of high flow pulses and floods have been shown to play an important role in structuring prairie stream fish assemblages (Schlosser 1991; Dodds et al. 2004) and could account for some of the fish assemblage differences observed in our study.

However, given the caveats of incomplete seasonal sampling and differences in hydrology between the two periods, the data suggests that variation in the fish assemblage was related to seasonal factors. PCA results (Figure 13) showed the greatest variance in samples resulted from seasonal differences in fish assemblage structure, specifically strong differences in spring and summer samples. Conversely, Ostrand and Wilde (2002) found in the upper Brazos River, Texas, a hypersaline river similar to the Wichita River, that changes in fish assemblages, although they varied seasonally, were more strongly correlated with environmental conditions. Species-environmental correlations from CCA results (Figure 14) showed similar species groupings as Echelle et al. (1972) and Higgins and Wilde (2005) in which salinity (specific conductance and TDS) was an important factor in structuring the fish assemblage. These species-environmental groupings consisted of species such as chub shiner, plains minnow, gulf killifish, prairie chub, and emerald shiner correlated with high salinities and species such as spotted gar, freshwater drum, smallmouth buffalo *Ictiobus bubalus*, and western mosquitofish correlated with lower salinities.

As noted previously, the Wichita River system has numerous natural sources of chlorides and other dissolved solids that maintain high salinity levels relative to many other rivers in Texas. This natural higher salinity loading provides a context for the potential influences of the RO discharge on riverine water quality and biotic responses. The minimal observed effects of the RO unit on biotic assemblages may be attributed to the fact that resident fauna (abundances and species composition) in the Wichita River are reflective of the historic water quality characteristics, which include a wide range of salinities. The principal variable influencing the concentration of salts throughout the system appears to be streamflow. During the study, the RO unit did not operate at full permitted capacity, as discharge volumes averaged less than 2.0 MGD (equivalent streamflow=0.0887 m^3/s) with some variability while mean annual streamflow ranged from 1.22 to 6.48 m^3/s. Chloride loadings from the discharge may have been within the range of the natural salinity characteristics of the Wichita River; thus our study may have revealed minimal biotic responses to the effluent since discharge began. Although the current study mainly documented seasonal changes in fish and benthic macroinvertebrate assemblages, the data will serve as a baseline that can be used for future assessments. Monitoring studies should be conducted following several additional years of RO unit discharge or when discharge volume substantially increases.

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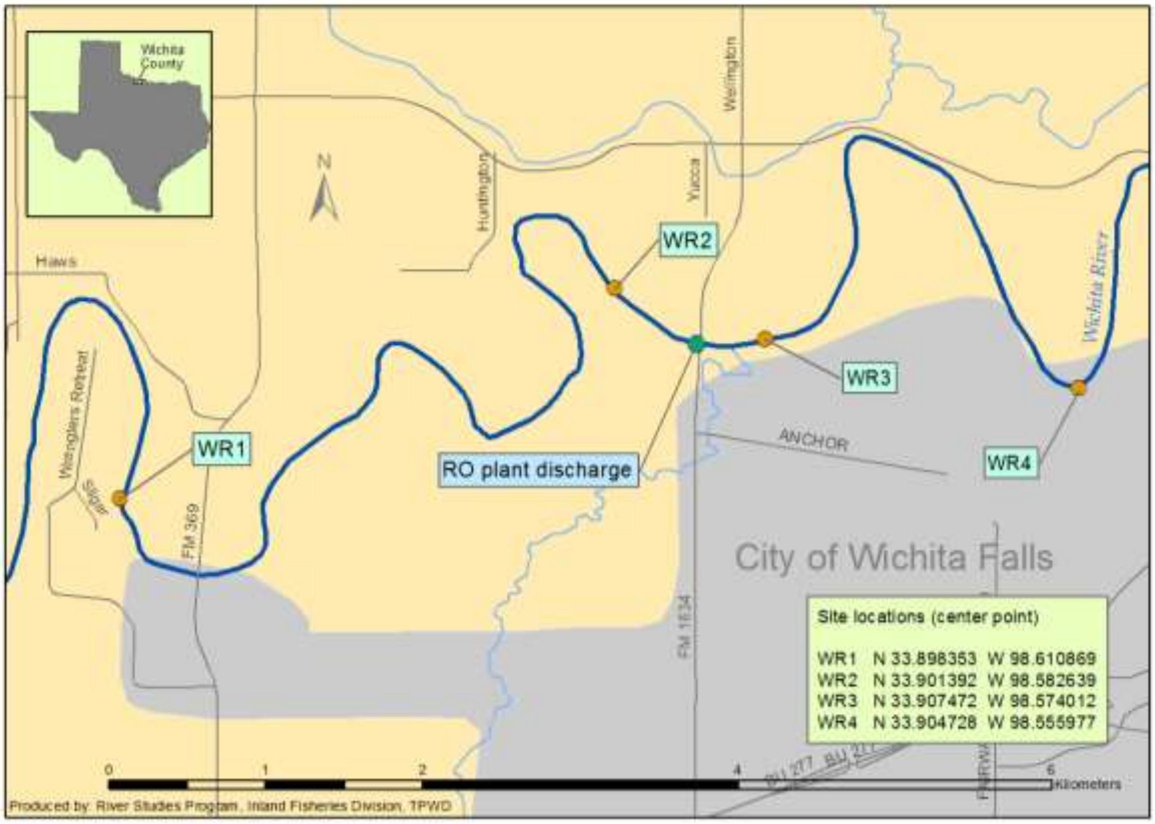


FIGURE 1. Wichita River study area showing sample sites (WR1–WR4) and location of the reverse osmosis (RO) unit discharge near Wichita Falls, Texas. Sites WR1 and WR2 are located upstream of the discharge while sites WR3 and WR4 are located downstream (USGS Gage# 7312500).

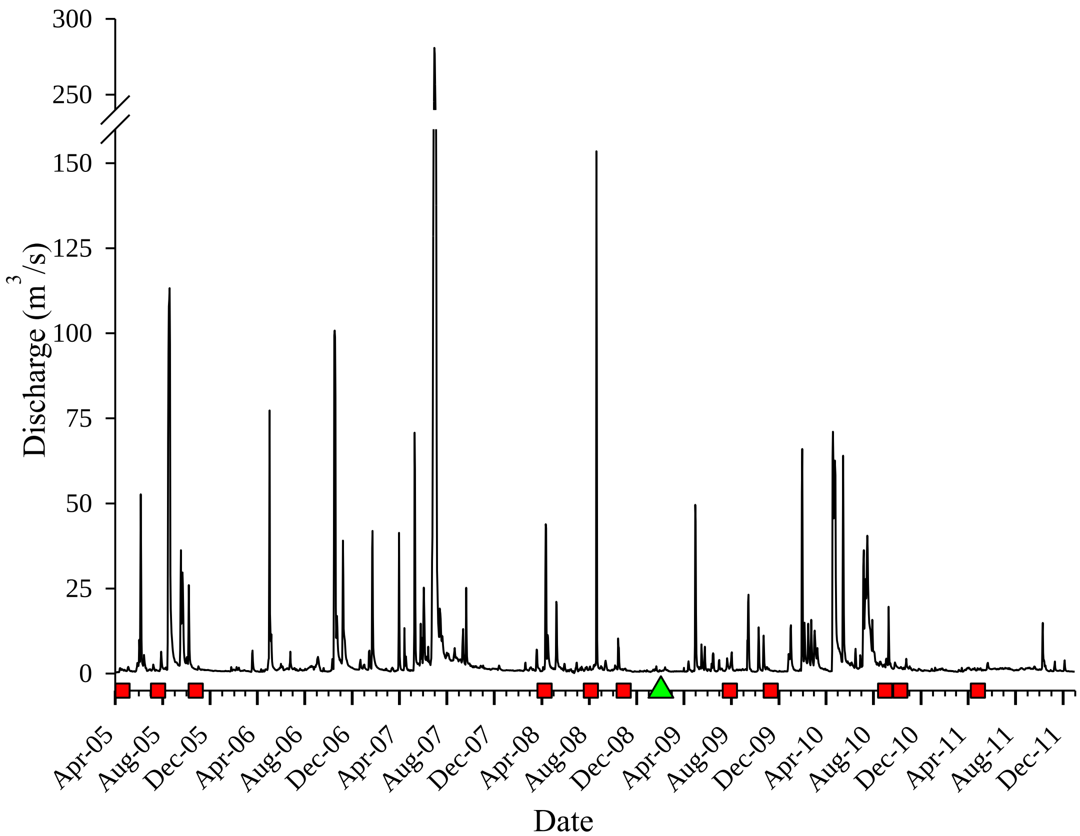
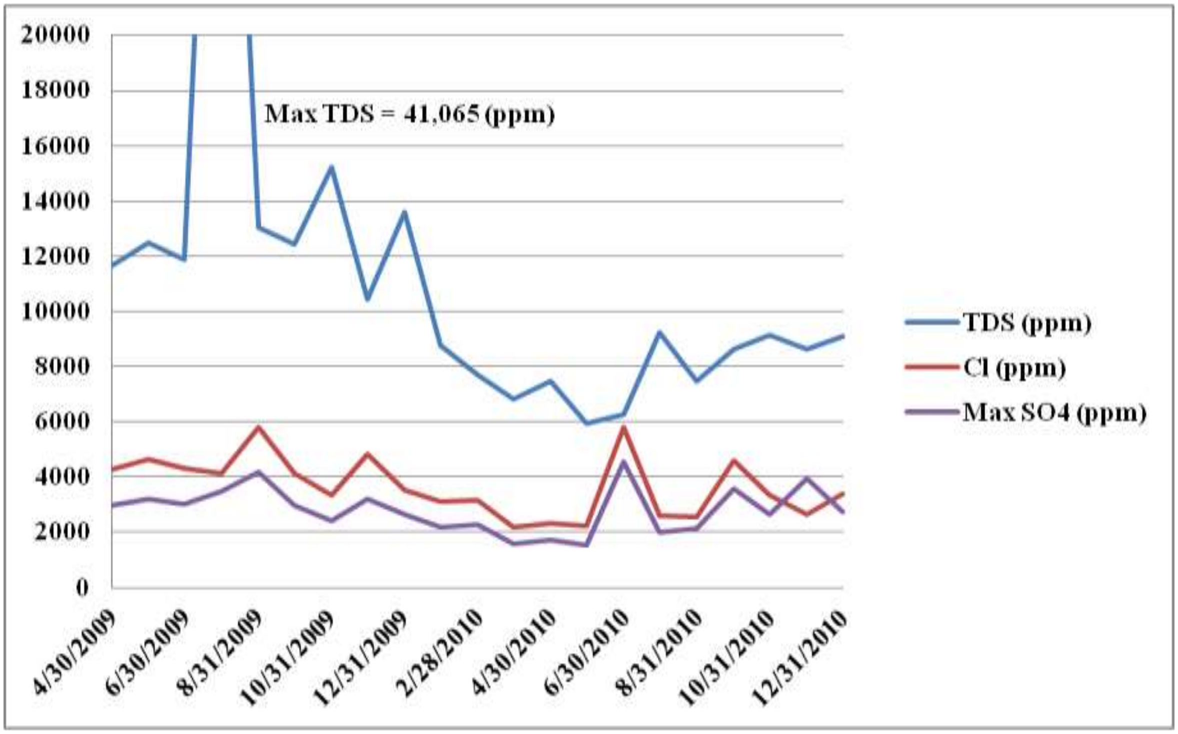


FIGURE 2. Streamflow (m^3/s) measured at the USGS gage #07312500 located downstream of the reverse osmosis unit discharge point on the Wichita River. The red squares on the horizontal axis correspond to sampling dates, and the green triangle indicates the start of reverse osmosis unit operation.



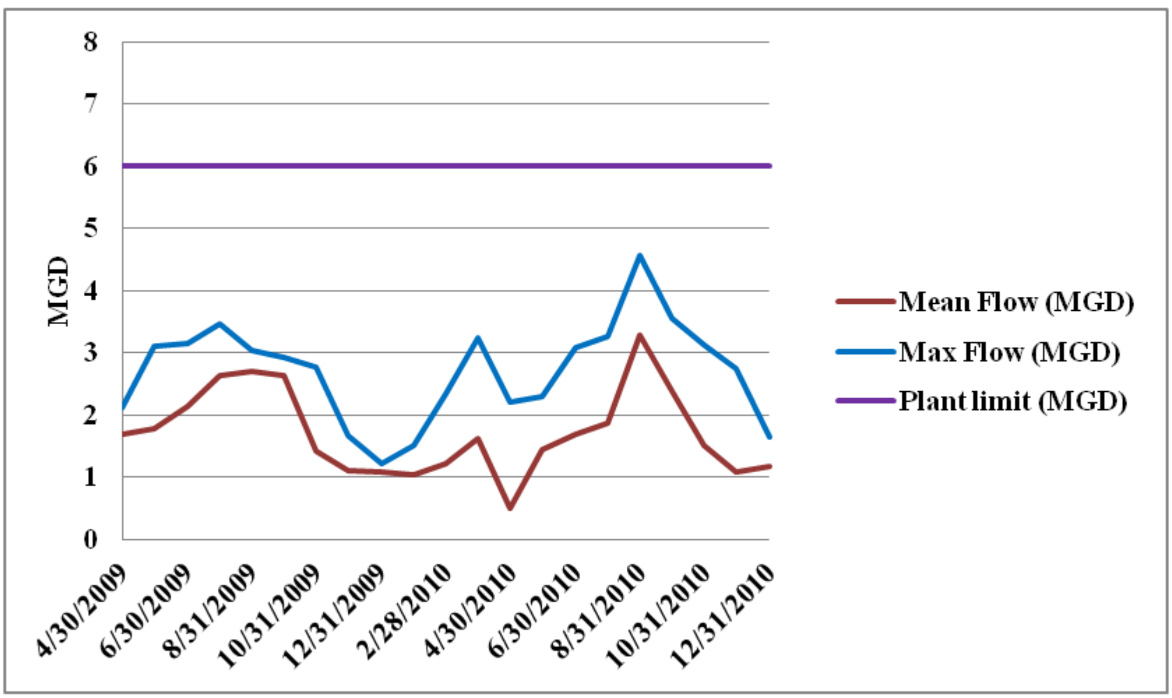


FIGURE 3. Effluent concentrations for total dissolved solids (TDS), sulfates (SO4), and chlorides (Cl) and mean and maximum monthly volume in million gallons per day (MGD) from a reverse osmosis unit discharge, 4/30/2009 to 12/31/2010, into the Wichita River. Source: http://iaspub.epa.gov/enviro/ICIS_DETAIL_REPORTS_NPDESID.icis_tst?npdesid=TX0124893&npvalue=1&npvalue=13&npvalue=14&npvalue=3&npvalue=4&npvalue=5&npvalue=6&rvalue=13&npvalue=2&npvalue=7&npvalue=8&npvalue=11&npvalue=12.

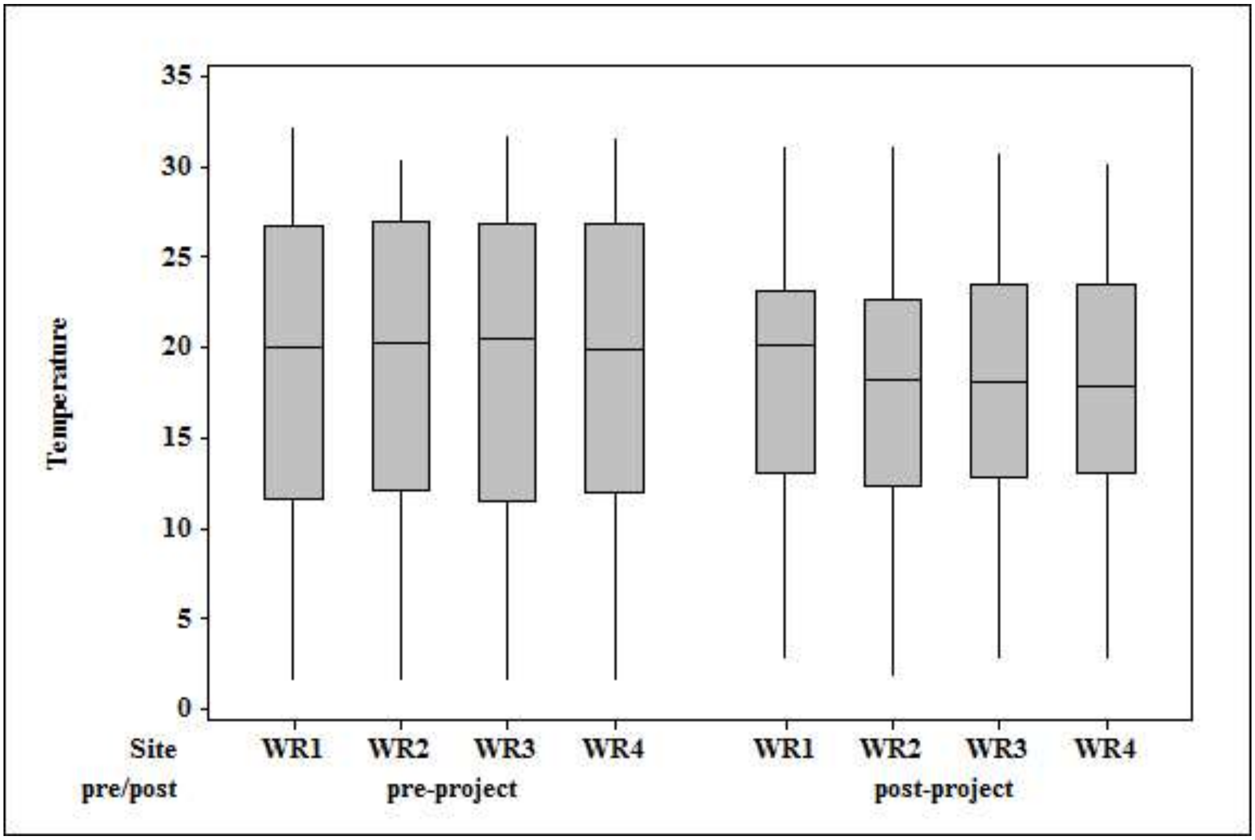


FIGURE 4. Water temperature (˚C) measured up- and downstream from a reverse osmosis unit discharge into the Wichita River, pre-project (2005, 2008) and post-project (2009 – 2011). Sites WR1 and WR2 are located upstream of the discharge while sites WR3 and WR4 are located downstream. Plots represent medians (-), quartiles (box), and range (whiskers) for monthly measurements.

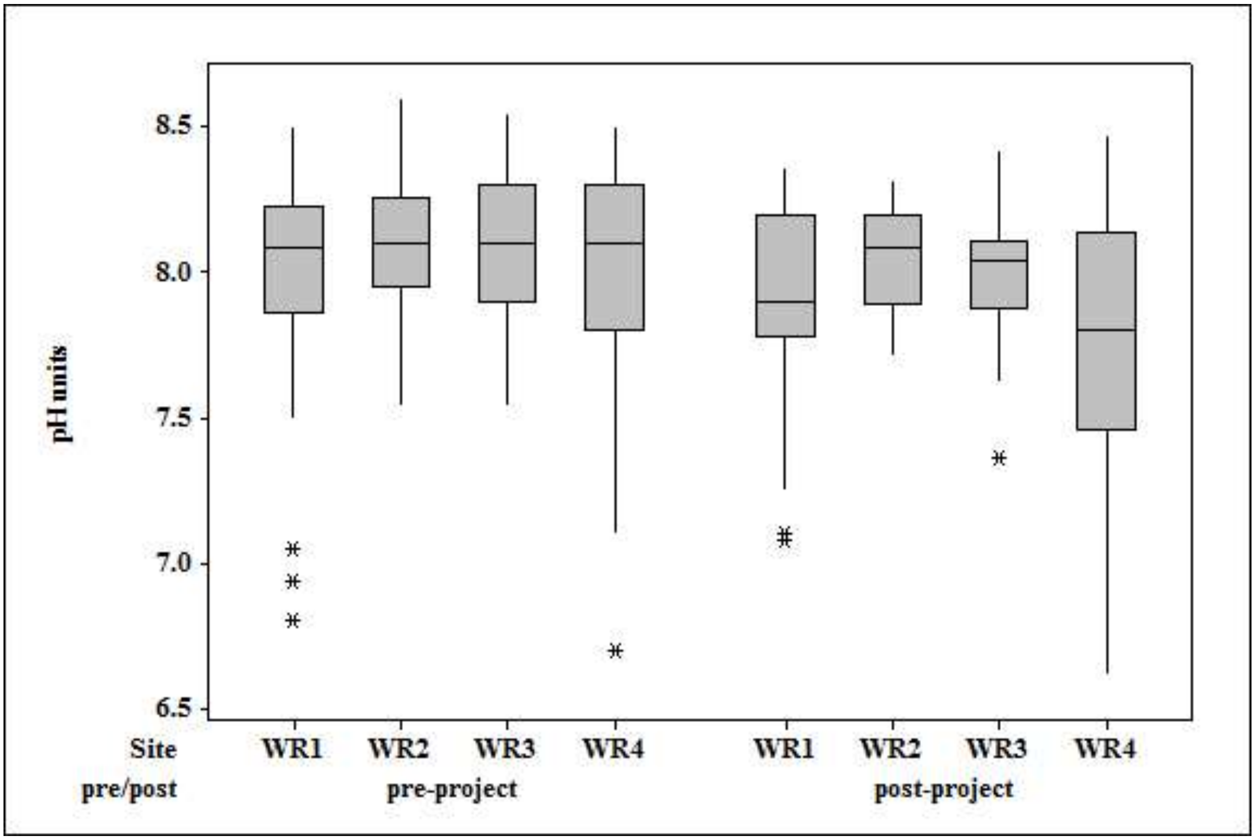


FIGURE 5. pH units measured up- and downstream from a reverse osmosis unit discharge into the Wichita River, pre-project (2005, 2008) and post-project (2009 – 2011) . Sites WR1 and WR2 are located upstream of the discharge while sites WR3 and WR4 are located downstream. Plots represent medians (-), quartiles (box), range (whiskers), and outliers (asterisk) for monthly measurements.

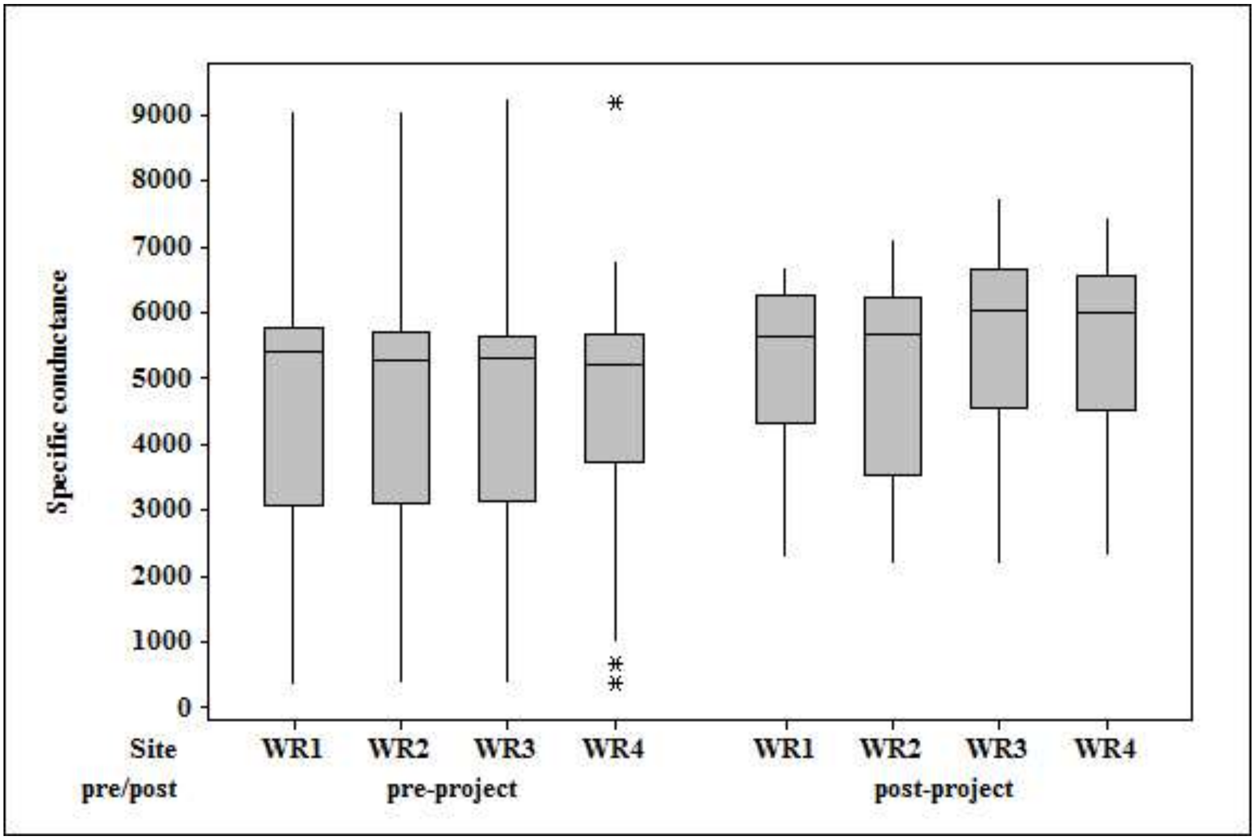


FIGURE 6. Specific conductance (µmhos/cm) measured up- and downstream from a reverse osmosis unit discharge into the Wichita River, pre-project (2005, 2008) and post-project (2009 – 2011). Sites WR1 and WR2 are located upstream of the discharge while sites WR3 and WR4 are located downstream. Plots represent medians (-), quartiles (box), range (whiskers), and outliers (asterisks) for monthly measurements.

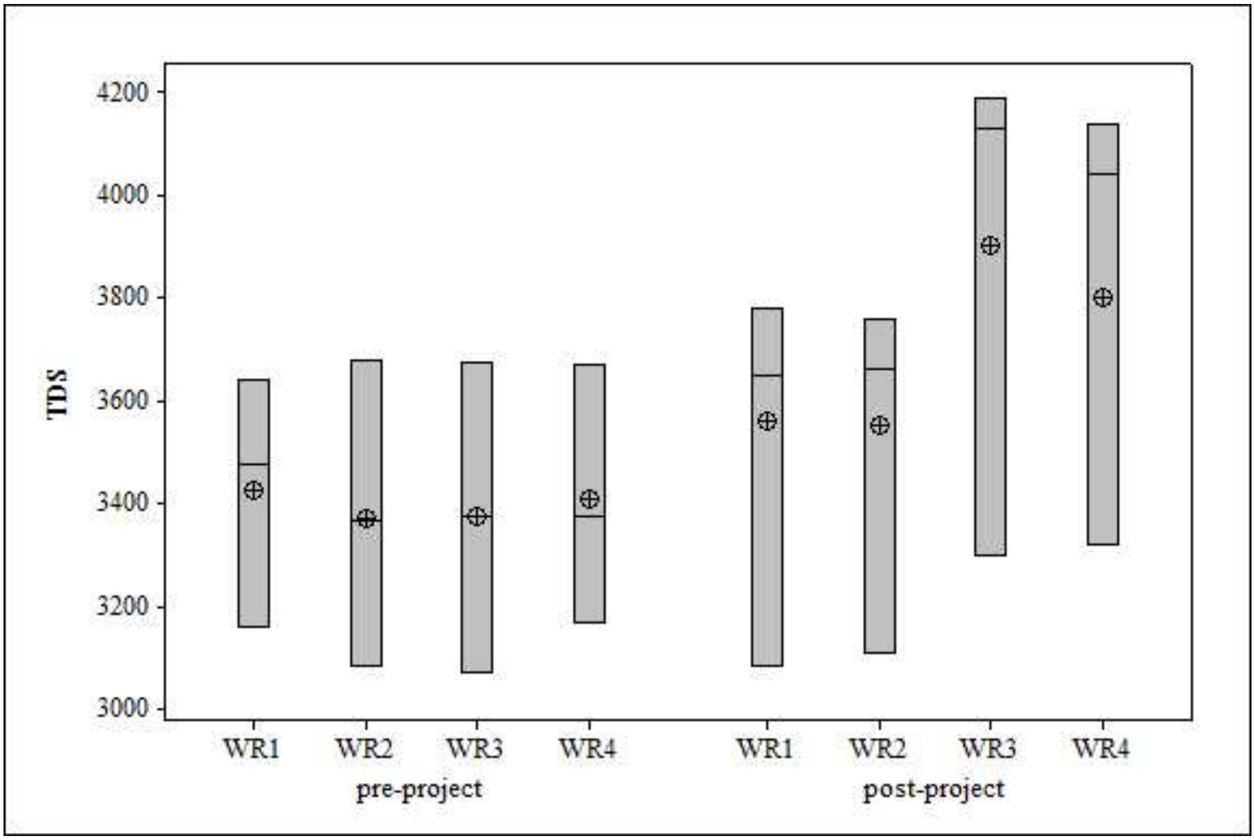


FIGURE 7. Total dissolved solids (TDS; in ppm) from grab samples collected up- and downstream from a reverse osmosis plant discharge into the Wichita River, pre-project (2005, 2008) and post-project (2009–2011). Sites WR1 and WR2 are located upstream of the discharge while sites WR3 and WR4 are located downstream. Plots represent medians (-), means (+), and 95% confidence intervals (box) for data collected at each sampling site.

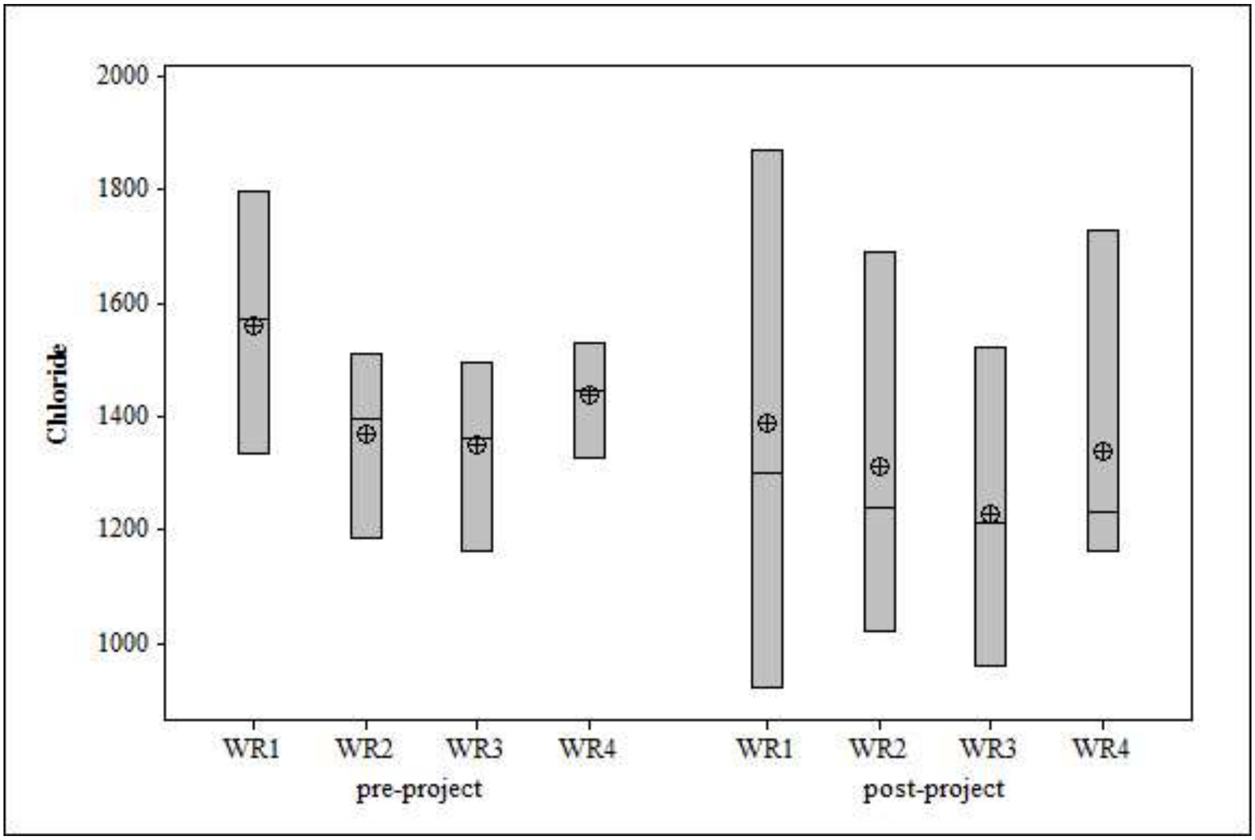


FIGURE 8. Chloride concentrations (ppm) from grab samples collected up- and downstream from a reverse osmosis plant discharge into the Wichita River, pre-project (2005, 2008) and post-project (2009 – 2011). Sites WR1 and WR2 are located upstream of the discharge while sites WR3 and WR4 are located downstream. Plots represent medians (-), means (+), and 95% confidence intervals (box) for data collected.

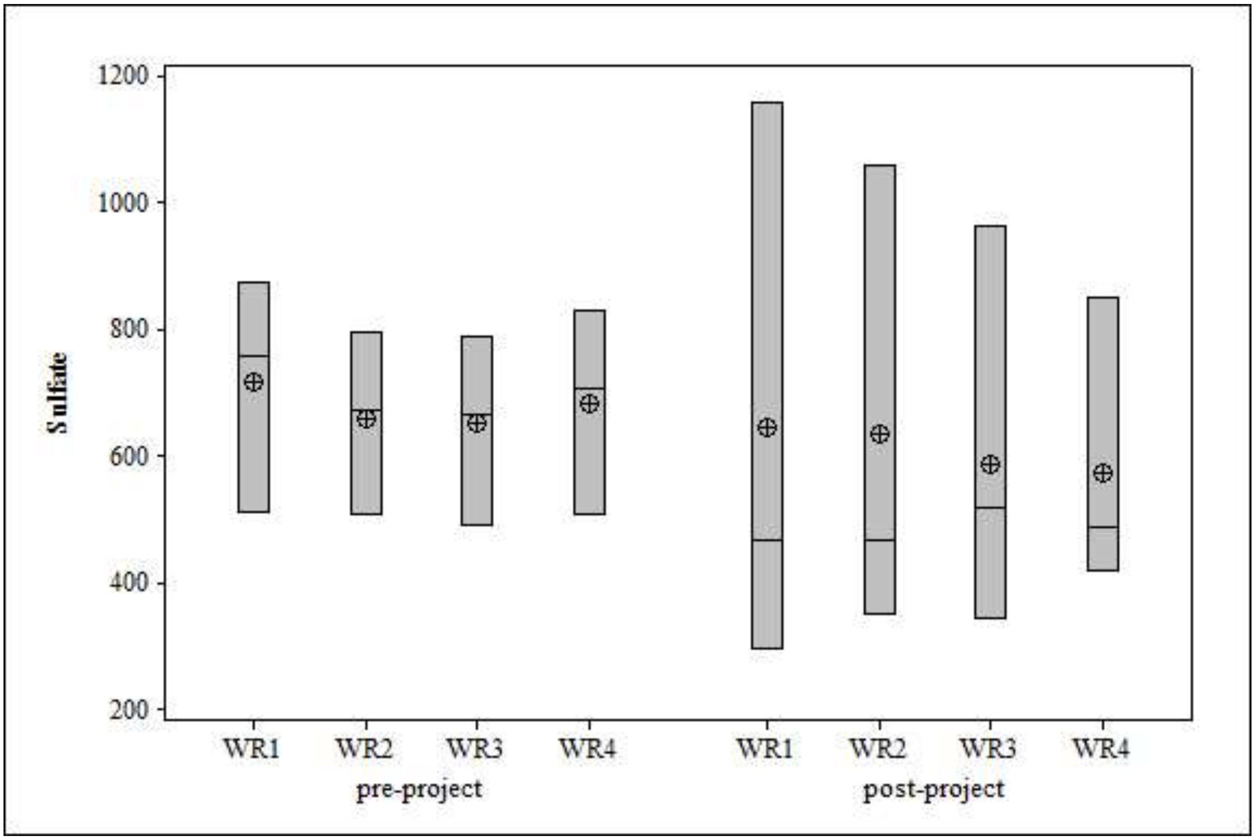


FIGURE 9. Sulfate concentrations (ppm) from grab samples collected up- and downstream from a reverse osmosis unit discharge into the Wichita River, pre-project (2005, 2008) and post-project (2009 – 2011). Sites WR1 and WR2 are located upstream of the discharge while sites WR3 and WR4 are located downstream. Plots represent medians (-), means (+), and 95% confidence intervals (box) for data collected.

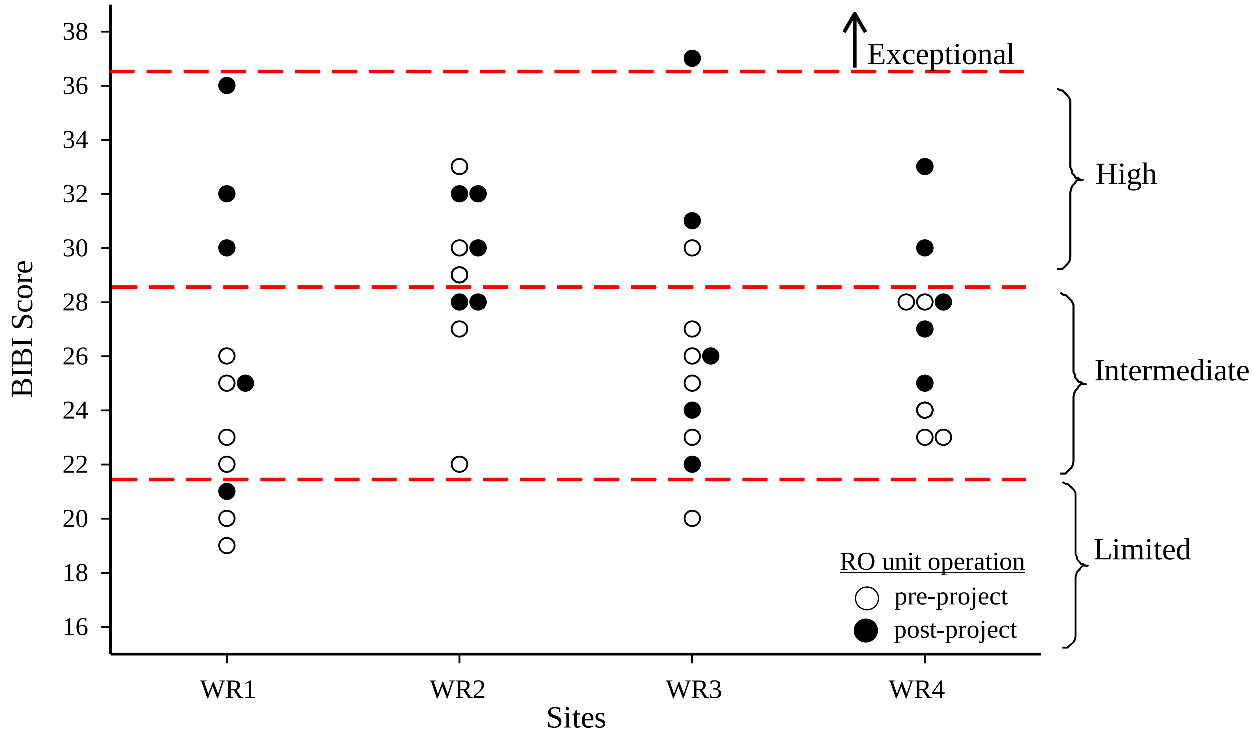


FIGURE 10. Benthic index of biotic integrity (BIBI) scores and associated aquatic life use categories from four sites on the Wichita River sampled pre- and post-operation of a reverse osmosis unit. Pre- and post-project samples were significantly different (*P*-value = 0.001, df = 1) with higher average scores in the post-project samples. The BIBI scores were not significantly different when tested across sites (*P*-value = 0.22, df = 3). Sites WR1 and WR2 are located upstream of the discharge while sites WR3 and WR4 are located downstream.

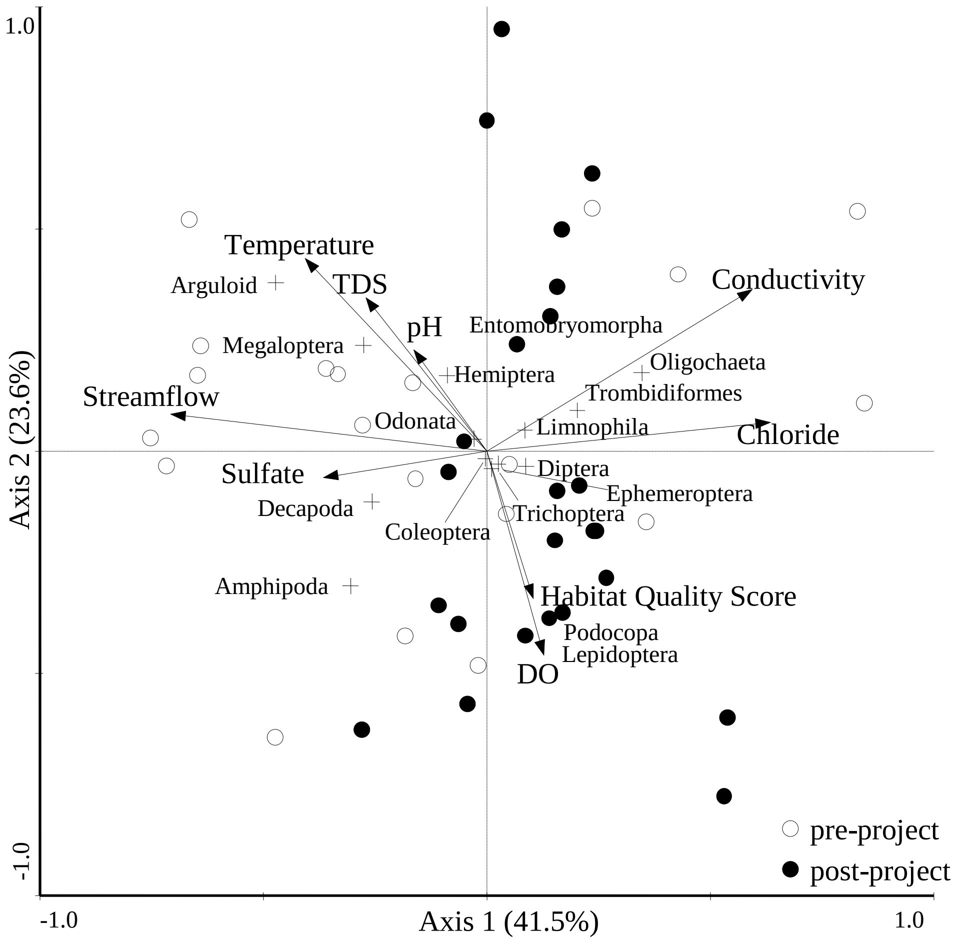


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FIGURE 11. First two axes of canonical correspondence analysis (CCA) for macroinvertebrate taxa collected from four Wichita River sites sampled from 2005, 2008, and 2009-2011. Site scores corresponding to pre- and post-operation of a reverse osmosis plant are coded as open and filled circles respectively.

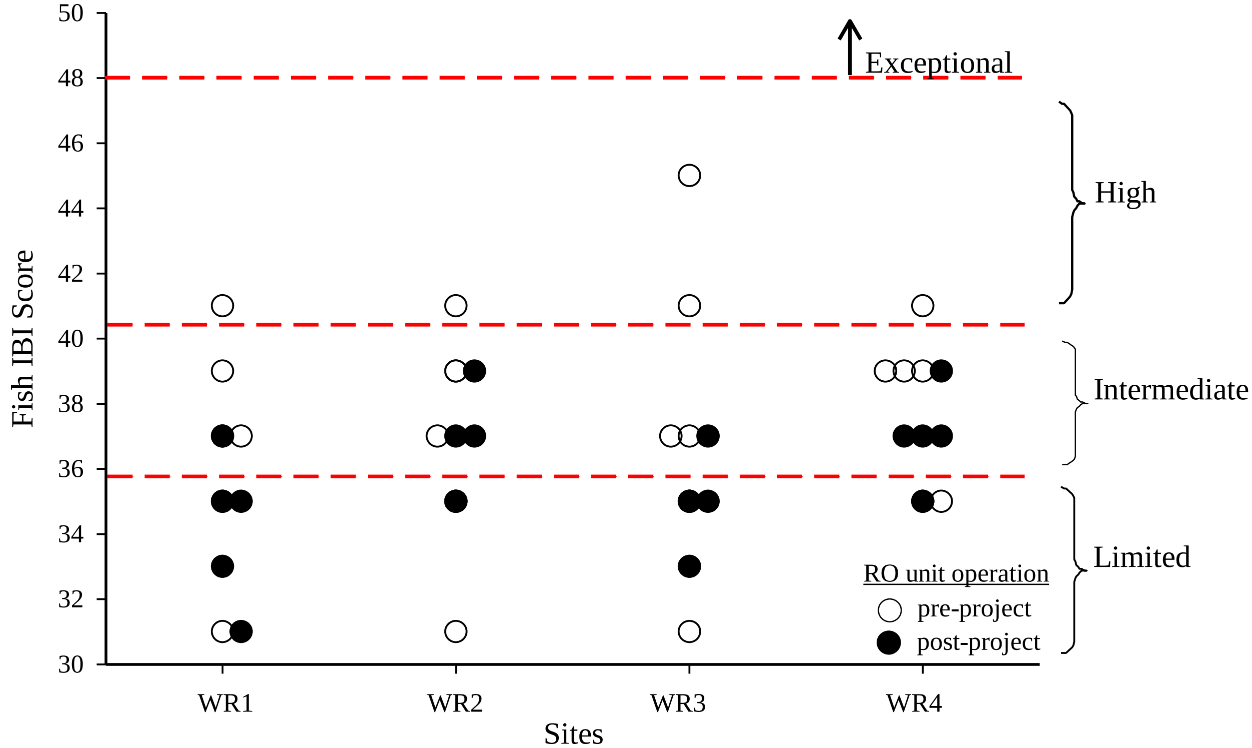

FIGURE 12. Index of biotic integrity (IBI) scores and associated aquatic life use categories for fish samples from four sites on the Wichita River sampled pre- and post-operation of a reverse osmosis plant. The fish IBI scores were not significantly different across sites (*P*-value = 0.47, df = 3). Sites WR1 and WR2 are located upstream of the discharge while sites WR3 and WR4 are located downstream. Open symbols indicate pre-project data, and the filled symbols indicate post-project data.

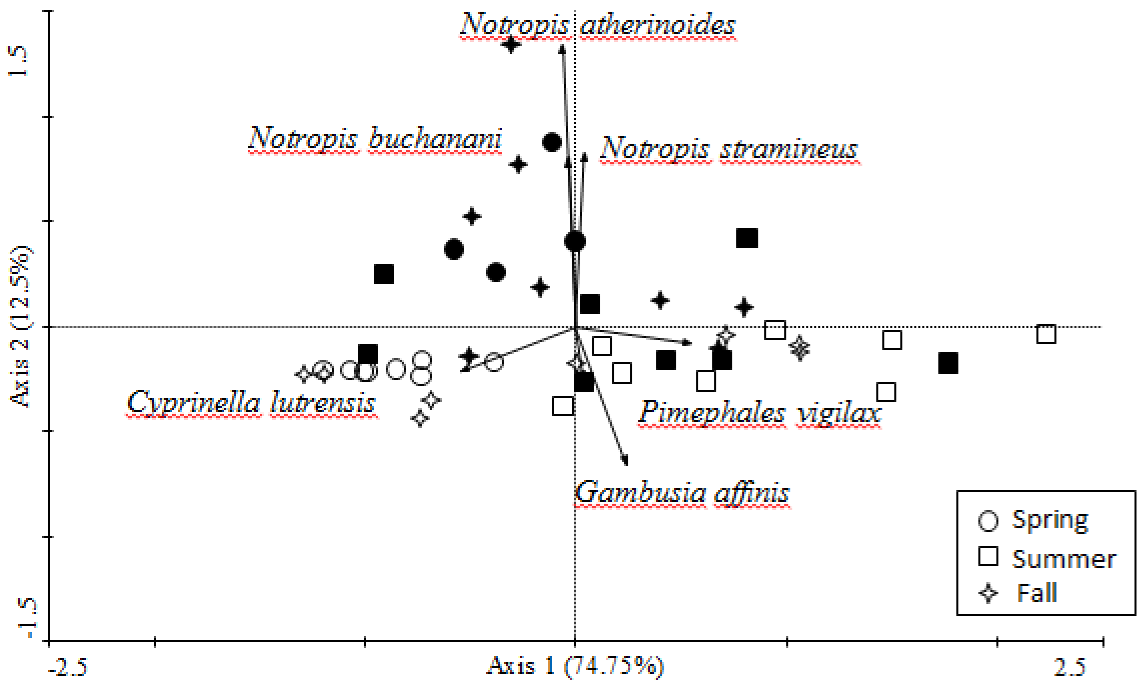

FIGURE 13 –First two axes of a principal components analysis (PCA) for fish data collected from four sites sampled from 2005, 2008, and 2009–2011 on the Wichita River.
Open symbols indicate pre-project data and filled symbols indicate post-project data.

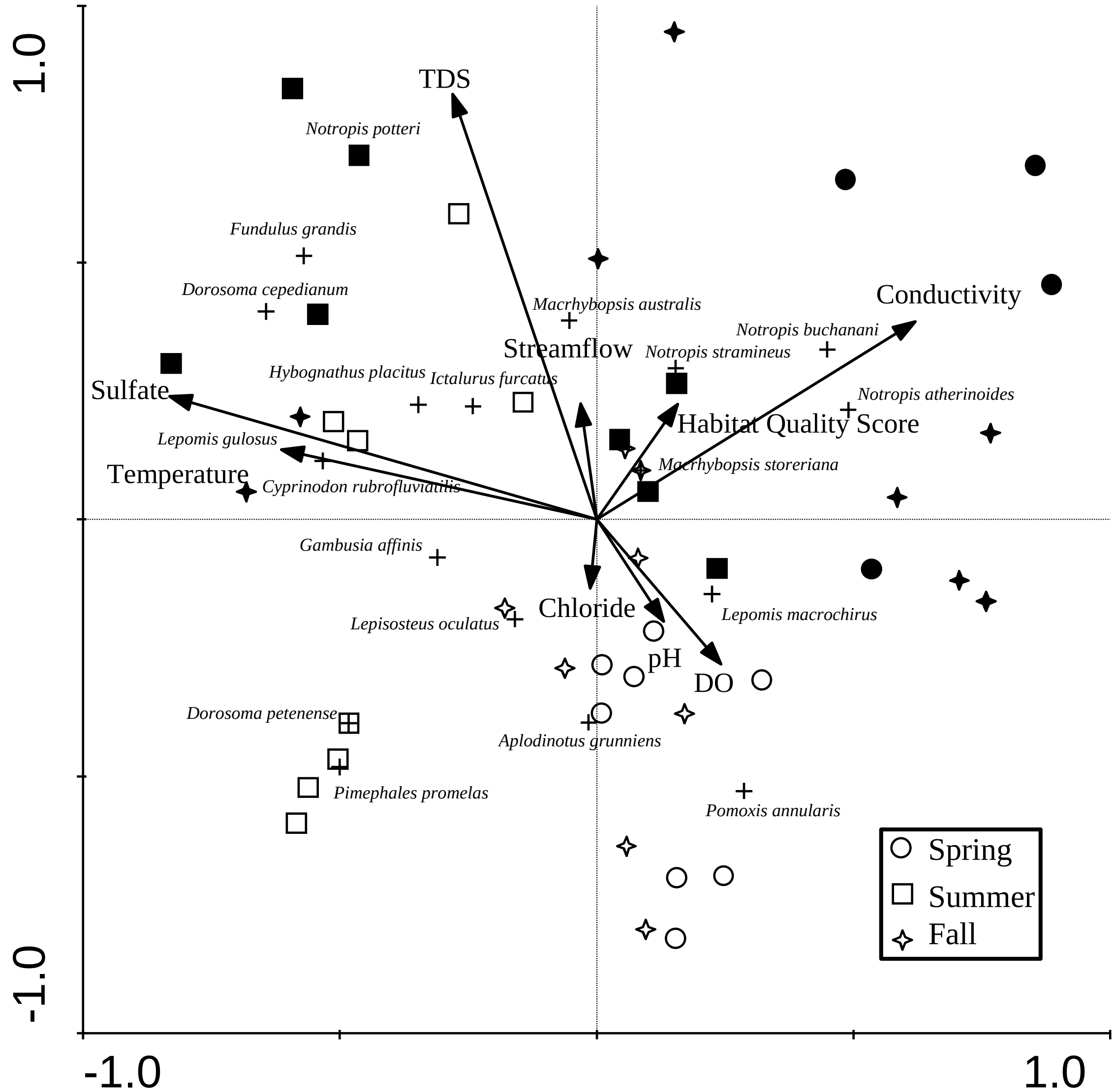

FIGURE 14. First two axes of canonical correspondence analysis for fish taxa from four sites sampled from 2005, 2008, and 2009–2011 on the Wichita River. The open symbols in the figure are pre-project site scores, and the filled symbols are post-project site scores.

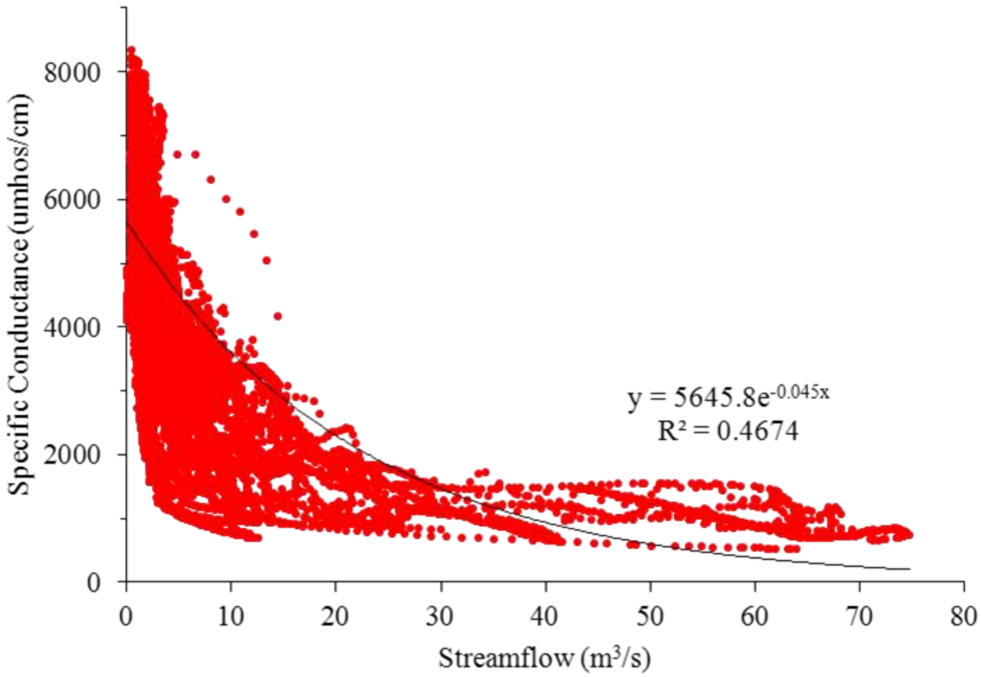

Figure 15. Regression of streamflow (m^3/s) and specific conductance (µmhos/cm) measured during water year 2007-2011 from USGS gage #07312500 located downstream of a reverse osmosis unit discharge on the Wichita River. If either streamflow or specific conductance data was missing, the corresponding value for the other variable was eliminated for analysis.

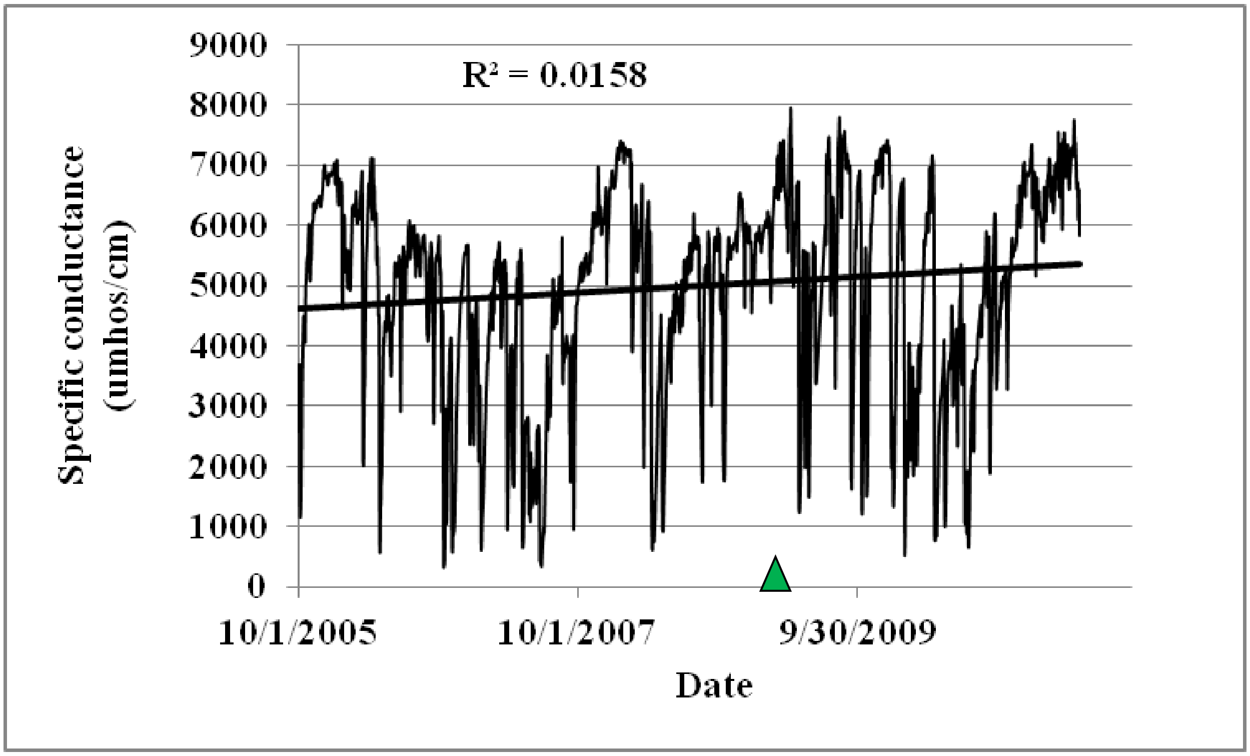

Figure 16. Plot of mean daily specific conductance (µmhos/cm) measured during years 2005-2011 at a USGS gage #07312500 located downstream of a reverse osmosis unit discharge on the Wichita River. The dark bar is a regression line and the green triangle indicates the commencement of the RO discharge.

TABLE 1. Site habitat summaries for 2005, 2008 prior to the beginning of reverse osmosis unit discharge into the Wichita River. Sites WR1 and WR2 are located upstream of the discharge while sites WR3 and WR4 are located downstream.

River characteristics	WR1			WR2			WR3			WR4		
	mean	min.	max.	mean	min.	max.	mean	min.	max.	mean	min.	max.
Average stream width (meters)	18.1	16.8	18.6	16.3	15.5	16.7	17.9	16.4	21.6	16.2	15.6	17.2
Average stream depth (meters)	0.39	0.36	0.42	0.32	0.28	0.38	0.39	0.35	0.46	0.52	0.44	0.61
Maximum pool width (meters)	16.0	14.2	18.4	16.0	14.2	18.4	15.1	13.9	18.4	15.1	13.9	18.4
Maximum pool depth (meters)	1.0	0.7	1.2	1.1	0.8	1.7	1.1	0.9	1.3	1.4	1.1	1.6
Dominant substrate type	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand
Average percent of substrate gravel or larger	10	4	19	4	0	6	3	0	6	20	12	29
Average percent instream cover	19.9	14.0	25.5	15.9	6.0	23.0	18.2	9.0	29.8	18.7	5.0	34.8
Number of cover types	5.0	3.0	8.0	4.2	3.0	6.0	4.3	3.0	6.0	5.3	4.0	7.0
Average percent stream bank erosion potential	24.6	12.0	48.0	20.4	15.5	25.0	23.2	14.6	32.0	24.6	15.0	32.0
Average stream bank slope (degrees)	41.8	30.0	58.0	55.5	45.4	65.0	53.4	38.5	65.0	51.3	23.0	85.0
Average width of natural buffer vegetation (meters)	21.1	20.0	26.0	30.1	29.0	31.0	29.7	29.0	33.5	36.6	24.5	50.0
Average percent tree canopy	50.1	20.4	65.0	44.4	38.0	56.0	45.3	21.0	63.0	51.4	41.0	68.0

TABLE 2. Site habitat summaries from 2009–2011 following the beginning of reverse osmosis unit discharge into the Wichita River. Sites WR1 and WR2 are located upstream of the discharge while sites WR3 and WR4 are located downstream.

River characteristics	WR1			WR2			WR3			WR4		
	mean	min.	max.	mean	min.	max.	mean	min.	max.	mean	min.	max.
Average stream width (meters)	18.2	17.6	18.5	16.2	15.7	16.8	16.1	15.5	16.7	16.5	16.0	16.8
Average stream depth (meters)	0.39	0.33	0.43	0.39	0.34	0.48	0.50	0.46	0.53	0.50	0.43	0.55
Maximum pool width (meters)	14.5	13.9	15.0	13.0	12.6	13.4	12.2	11.7	13.2	15.3	15.1	15.8
Maximum pool depth (meters)	1.1	1.1	1.2	1.1	0.9	1.2	1.2	1.0	1.4	1.3	1.1	1.4
Dominant substrate type	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand	sand
Average percent of substrate gravel or larger	8	2	14	11	1	24	20	5	35	28	21	42
Average percent instream cover	13.7	9.0	20.0	14.9	5.0	22.0	12.2	4.0	18.0	14.5	4.2	21.5
Number of cover types	4.2	3.0	6.0	4.4	2.0	7.0	4.0	3.0	5.0	4.6	3.0	6.0
Average percent stream bank erosion potential	30.7	18.5	42.0	18.7	16.0	22.5	28.6	19.0	36.7	28.0	25.0	30.0
Average stream bank slope (degrees)	49.8	43.0	64.0	52.1	42.0	66.6	53.0	47.0	61.0	56.8	41.0	73.2
Average width of natural buffer vegetation (meters)	20.1	20.0	20.4	30.0	30.0	30.2	29.2	29.0	29.8	54.1	45.0	60.5
Average percent tree canopy	57.1	52.0	59.5	48.2	45.0	56.0	54	46.0	64	64.8	58.0	81

TABLE 3. Habitat Quality Index metric scoring, total score, and aquatic life use designation for sites on the Wichita River prior to reverse osmosis unit discharge (2005 and 2008) by season. Sites WR1 and WR2 are located upstream of the discharge while sites WR3 and WR4 are located downstream. The ALU scale range is as follows: exceptional (E), high (H), intermediate (I), limited (L).

	Spring				Summer				Fall			
Sites	WR1	WR2	WR3	WR4	WR1	WR2	WR3	WR4	WR1	WR2	WR3	WR4
Year 2005												
Available instream cover (4,3,2,1)	2	2	2	3	2	2	2	3	2	2	2	3
Bottom substrate stability (4,3,2,1)	1	1	1	2	1	1	1	2	2	2	1	2
Number of riffles (4,3,2,1)	3	2	2	1	2	1	1	2	3	3	2	1
Dimensions of largest pool (4,3,2,1)	4	4	4	4	4	4	4	4	4	2	4	4
Channel flow status (3,2,1,0)	3	3	3	3	3	3	3	3	3	2	3	3
Bank stability (3,2,1,0)	1	1.5	2	1.5	2	1	1	2	2	1	2	2
Channel sinuosity (3,2,1,0)	1	1	1	1	1	2	1	1	1	2	1	1
Riparian buffer vegetation (3,2,1,0)	3	3	3	3	3	3	3	3	3	1	3	3
Aesthetics of reach (3,2,1,0)	2	2	2	1	2	2	2	1	2	3	2	1
Total score	20	19.5	20	19.5	20	19	18	21	22	18	20	20
Aquatic Life Use	H	I	H	I	H	I	I	H	H	I	H	H
Year 2008												
Available instream cover (4,3,2,1)	3	2	2	2	2	2	3	3	2	1	3	3
Bottom substrate stability (4,3,2,1)	2	1	1	2	1	1	1	2	2	1	1	2
Number of riffles (4,3,2,1)	3	2	2	2	3	2	1	2	3	2	2	2
Dimensions of largest pool (4,3,2,1)	3	3	3	4	4	3	4	4	4	3	4	4
Channel flow status (3,2,1,0)	3	3	3	3	3	3	3	3	3	3	3	3
Bank stability (3,2,1,0)	1	1	1	1	1	1	1	2	1	1	1	2
Channel sinuosity (3,2,1,0)	1	1	2	1	1	2	1	1	1	2	1	1
Riparian buffer vegetation (3,2,1,0)	3	3	3	3	3	3	3	3	3	3	3	3
Aesthetics of reach (3,2,1,0)	2	2	2	1	2	2	2	1	2	2	2	1
Total score	21	18	19	19	20	19	19	21	21	17	20	21
Aquatic Life Use	H	I	I	I	H	I	I	H	H	I	H	H

TABLE 4. Habitat Quality Index metric scoring, total score, and aquatic life use designation for sites on the Wichita River, 2009, 2010 and 2011 by season. The reverse osmosis unit became operational in February 2009. Sites WR1 and WR2 are located upstream of the discharge while sites WR3 and WR4 are located downstream. The ALU scale range is as follows: exceptional (E), high (H), intermediate (I), limited (L).

	Spring				Summer				Fall			
Sites	WR1	WR2	WR3	WR4	WR1	WR2	WR3	WR4	WR1	WR2	WR3	WR4
Year 2009												
Available instream cover (4,3,2,1)	--	--	--	--	2	2	3	3	2	3	3	2
Bottom substrate stability (4,3,2,1)	--	--	--	--	1	1	1	2	2	2	2	2
Number of riffles (4,3,2,1)	--	--	--	--	3	2	2	1	3	2	2	2
Dimensions of largest pool (4,3,2,1)	--	--	--	--	4	3	3	4	4	3	4	4
Channel flow status (3,2,1,0)	--	--	--	--	3	3	3	3	3	3	3	3
Bank stability (3,2,1,0)	--	--	--	--	2	2	1	1	1	2	2	1
Channel sinuosity (3,2,1,0)	--	--	--	--	1	2	1	1	1	2	1	1
Riparian buffer vegetation (3,2,1,0)	--	--	--	--	3	3	3	3	3	3	3	3
Aesthetics of reach (3,2,1,0)	--	--	--	--	2	2	2	1	2	2	2	1
Total score	--	--	--	--	21	21	19	19	21	22	22	19
Aquatic Life Use	--	--	--	--	H	H	I	I	H	H	H	I
Year 2010												
Available instream cover (4,3,2,1)	--	--	--	--	2	2	2	2	3	3	3	3
Bottom substrate stability (4,3,2,1)	--	--	--	--	1	1	2	2	2	2	3	3
Number of riffles (4,3,2,1)	--	--	--	--	2	2	2	2	2	2	2	2
Dimensions of largest pool (4,3,2,1)	--	--	--	--	4	4	4	4	4	4	4	4
Channel flow status (3,2,1,0)	--	--	--	--	3	3	3	3	3	3	3	3
Bank stability (3,2,1,0)	--	--	--	--	1	1	1	1	1	2	1	1
Channel sinuosity (3,2,1,0)	--	--	--	--	1	1	1	1	1	2	1	1
Riparian buffer vegetation (3,2,1,0)	--	--	--	--	3	2	2	3	3	3	3	3
Aesthetics of reach (3,2,1,0)	--	--	--	--	2	2	2	1	2	2	2	1
Total score	--	--	--	--	19	18	19	19	21	23	22	21
Aquatic Life Use	--	--	--	--	I	I	I	I	H	H	H	H
Year 2011												
Available instream cover (4,3,2,1)	2	2	2	3	--	--	--	--	--	--	--	--
Bottom substrate stability (4,3,2,1)	1	1	2	2	--	--	--	--	--	--	--	--
Number of riffles (4,3,2,1)	3	2	2	2	--	--	--	--	--	--	--	--
Dimensions of largest pool (4,3,2,1)	4	4	4	4	--	--	--	--	--	--	--	--
Channel flow status (3,2,1,0)	3	3	3	3	--	--	--	--	--	--	--	--
Bank stability (3,2,1,0)	1	1	1	2	--	--	--	--	--	--	--	--
Channel sinuosity (3,2,1,0)	1	2	1	1	--	--	--	--	--	--	--	--
Riparian buffer vegetation (3,2,1,0)	3	3	3	3	--	--	--	--	--	--	--	--
Aesthetics of reach (3,2,1,0)	2	2	2	1	--	--	--	--	--	--	--	--
Total score	20	20	18	21	--	--	--	--	--	--	--	--
Aquatic Life Use	H	H	I	H	--	--	--	--	--	--	--	--

TABLE 5. Water chemistry results from the Wichita River, TX, 2005, 2008, 2009, 2010 and 2011. Sites WR1 and WR2 are located upstream of the discharge point of a reverse osmosis unit which began discharging in February 2009, while sites WR3 and WR4 are located downstream.

	Spring				Summer				Fall			
Sites	WR1	WR2	WR3	WR4	WR1	WR2	WR3	WR4	WR1	WR2	WR3	WR4
Year 2005												
Total Dissolved Solids (ppm)	3,150	3,130	3,110	3,130	3,610	3,400	3,430	3,470	3,350	3,330	3,320	3,280
Chloride (ppm)	1,264	1,250	1,324	1,280	1,460	1,380	1,350	1,410	1,570	1,520	1,510	1,510
Sulfate (ppm)	593	567	605	576	710	740	720	780	894	606	610	633
Selenium (ppb)	< 1	< 1	< 1	< 1	1.3	1.2	< 1	< 1	< 1	< 1	< 1	< 1
Year 2008												
Total Dissolved Solids (ppm)	3,170	3,060	3,050	3,180	3,660	3,740	3,695	3,690	3,600	3,570	3,640	3,630
Chloride (ppm)	1,570	1,410	1,370	1,510	1,590	1,490	1,470	1,440	1,910	1,150	1,070	1,540
Sulfate (ppm)	467	473	426	493	805	817	813	806	844	756	742	841
Selenium (ppb)	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Year 2009												
Total Dissolved Solids (ppm)	--	--	--	--	3,740	3,730	4,190	4,140	3,780	3,760	4,130	4,060
Chloride (ppm)	--	--	--	--	1,301	1,200	1,300	1,226	1,870	1,240	1,210	1,230
Sulfate (ppm)	--	--	--	--	1,008	882	965	852	1,160	1,060	700	685
Selenium (ppb)	--	--	--	--	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Year 2010												
Total Dissolved Solids (ppm)	--	--	--	--	3,540	3,510	3,710	3,440	3,085	3,110	3,300	3,320
Chloride (ppm)	--	--	--	--	1,110	1,020	1,150	1,160	920	1,690	957	1,350
Sulfate (ppm)	--	--	--	--	298	467	403	418	297	349	345	430
Selenium (ppb)	--	--	--	--	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Year 2011												
Total Dissolved Solids (ppm)	3,650	3,660	4,180	4,040	--	--	--	--	--	--	--	--
Chloride (ppm)	1,730	1,400	1,520	1,730	--	--	--	--	--	--	--	--
Sulfate (ppm)	466	415	517	489	--	--	--	--	--	--	--	--
Selenium (ppb)	< 1	< 1	< 1	< 1	--	--	--	--	--	--	--	--

TABLE 6. Macroinvertebrate BIBI scores for the year 2005. Metrics and scoring criteria for benthic invertebrates collected using Rapid Bioassessment protocol. In parentheses are the scores to the corresponding values assigned based on TCEQ SWQM vol. II ch. 5.

	Spring				**Summer**				**Fall**			
Metrics	**WR1**	**WR2**	**WR3**	**WR4**	**WR1**	**WR2**	**WR3**	**WR4**	**WR1**	**WR2**	**WR3**	**WR4**
Taxa richness (Genus)	15 (3)	18 (3)	14 (2)	16 (3)	15 (3)	16 (3)	14 (2)	21 (3)	15 (3)	12 (2)	11 (2)	11 (2)
EPT[1] taxa abundance	6 (2)	7 (3)	4 (2)	5 (2)	9 (3)	7 (3)	6 (2)	7 (3)	10 (4)	5 (2)	6 (2)	7 (3)
Biotic index (HBI)	6 (1)	5 (2)	5 (2)	5 (2)	6 (1)	5 (2)	5 (2)	5 (2)	6 (1)	4 (3)	5 (2)	6 (1)
% Chironomidae	38 (1)	29 (1)	23 (1)	29 (1)	6 (3)	5 (3)	5 (3)	12 (2)	11 (2)	6 (3)	19 (1)	16 (2)
% Dominant taxon	48 (1)	29 (3)	54 (1)	28 (3)	33 (2)	28 (3)	28 (3)	21 (4)	44 (1)	28 (3)	19 (4)	20 (4)
%Dominant FFG[2]	42 (3)	40 (3)	46 (2)	44 (3)	60 (1)	39 (3)	49 (2)	61 (1)	53 (2)	63 (1)	45 (3)	48 (2)
% Predators	40 (1)	27 (2)	46 (1)	38 (1)	12 (4)	10 (4)	21 (3)	9 (4)	4 (1)	16 (3)	11 (4)	6 (4)
Ratio of intolerant:tolerant taxa	0 (1)	1 (1)	1 (1)	1 (1)	1 (1)	10 (4)	4 (3)	2 (2)	1 (1)	7 (4)	3 (2)	1 (1)
% of total trichoptera as Hydropsychidae	0 (1)	64 (2)	11 (4)	0 (1)	57 (2)	80 (1)	6 (4)	100 (1)	97 (1)	33 (3)	100 (1)	100 (1)
# of non-insect taxa	1 (1)	3 (2)	2 (2)	1 (1)	0 (1)	1 (1)	1 (1)	3 (2)	1 (1)	1 (1)	1 (1)	0 (1)
% Collector-gatherers	42 (1)	28 (3)	42 (1)	44 (1)	60 (1)	39 (2)	49 (1)	61 (1)	53 (1)	63 (1)	45 (1)	48 (1)
% of total number as Elmidae	3 (4)	1 (4)	0 (1)	5 (4)	18 (3)	2 (4)	2 (4)	13 (3)	44 (1)	2 (4)	5 (4)	21 (2)
Total Score	20	29	20	23	25	33	30	28	19	30	27	24
Aquatic Life Use	L	H	L	I	I	H	H	I L	L	H	I	I

[1]EPT = Ephemeroptera, Plecoptera, Trichoptera; [2]FFG = Functional feeding group; Aquatic Life Use: >36 Exceptional; 29-36 High; 22-28 Intermediate; <22 Limited

TABLE 7. Macroinvertebrate BIBI scores for the year 2008. Metrics and scoring criteria for benthic invertebrates collected using Rapid Bioassessment protocol. In parentheses are the scores to the corresponding values assigned based on TCEQ SWQM vol. II ch. 5.

	Spring				**Summer**				**Fall**			
Metrics	**WR1**	**WR2**	**WR3**	**WR4**	**WR1**	**WR2**	**WR3**	**WR4**	**WR1**	**WR2**	**WR3**	**WR4**
Taxa richness (Genus)	7 (1)	14 (2)	18 (3)	20 (3)	14 (2)	19 (3)	9 (2)	14 (2)	22 (4)	10 (2)	12 (2)	10 (2)
EPT[1] taxa abundance	4 (2)	8 (3)	8 (3)	6 (2)	8 (3)	8 (3)	7 (3)	8 (3)	9 (3)	4 (2)	3 (1)	4 (2)
Biotic index (HBI)	6 (1)	5 (1)	5 (2)	5 (2)	5 (2)	5 (2)	4 (3)	6 (1)	6 (1)	6 (1)	4 (3)	5 (2)
% Chironomidae	24 (1)	1 (4)	19 (1)	20 (1)	2 (4)	0 (1)	1 (4)	5 (3)	18 (1)	59 (1)	10 (2)	23 (1)
% Dominant taxon	24 (3)	23 (3)	26 (3)	25 (3)	33 (2)	30 (3)	38 (2)	38 (2)	28 (3)	59 (1)	36 (2)	43 (1)
%Dominant FFG[2]	44 (3)	32 (4)	46 (2)	32 (4)	56 (1)	50 (2)	51 (2)	45 (3)	41 (3)	33 (4)	56 (1)	49 (2)
% Predators	9 (4)	24 (3)	20 (3)	15 (3)	4 (1)	8 (4)	2 (1)	3 (1)	30 (2)	25 (3)	22 (3)	19 (3)
Ratio of intolerant:tolerant taxa	1 (1)	1 (1)	2 (2)	2 (1)	1 (1)	4 (3)	2 (2)	1 (1)	1 (1)	0 (1)	5 (3)	2 (2)
% of total trichoptera as Hydropsychidae	100 (1)	98 (1)	77 (1)	100 (1)	76 (1)	98 (1)	88 (1)	93 (1)	89 (1)	100 (1)	0 (1)	77 (1)
# of non-insect taxa	0 (1)	0 (1)	0 (1)	3 (2)	0 (1)	1 (1)	0 (1)	1 (1)	1 (1)	0 (1)	2 (2)	1 (1)
% Collector-gatherers	27 (3)	32 (2)	46 (1)	31 (2)	56 (1)	24 (3)	51 (1)	45 (1)	41 (2)	33 (2)	56 (1)	22 (3)
% of total number as Elmidae	31 (1)	25 (2)	3 (4)	7 (4)	3 (4)	13 (3)	0 (1)	8 (4)	1 (4)	13 (3)	2 (4)	8 (4)
Total Score	22	27	26	28	23	29	23	23	26	22	25	24
Aquatic Life Use	I	I	I	I	I	H	I	I L	I	I	I	I

[1]EPT = Ephemeroptera, Plecoptera, Trichoptera; [2]FFG = Functional feeding group; Aquatic Life Use: >36 Exceptional; 29-36 High; 22-28 Intermediate; <22 Limited

TABLE 8. Macroinvertebrate BIBI scores for the year 2009. Metrics and scoring criteria for benthic invertebrates collected using Rapid Bioassessment protocol. In parentheses are the scores to the corresponding values assigned based on TCEQ SWQM vol. II ch. 5.

	Spring				Summer				Fall			
Metrics	**WR1**	**WR2**	**WR3**	**WR4**	**WR1**	**WR2**	**WR3**	**WR4**	**WR1**	**WR2**	**WR3**	**WR4**
Taxa richness (Genus)	--	--	--	--	27 (4)	29 (4)	20 (3)	26 (4)	19 (3)	17 (3)	25 (4)	21 (3)
EPT[1] taxa abundance	--	--	--	--	8 (3)	7 (3)	8 (3)	8 (3)	7 (3)	6 (2)	9 (3)	8 (3)
Biotic index (HBI)	--	--	--	--	5 (2)	5 (2)	5 (2)	6 (1)	5 (1)	4 (3)	5 (2)	5 (2)
% Chironomidae	--	--	--	--	1 (4)	0 (1)	3 (4)	0 (1)	23 (1)	7 (3)	40 (1)	24 (1)
% Dominant taxon	--	--	--	--	19 (4)	27 (3)	58 (1)	18 (4)	23 (3)	60 (1)	40 (2)	24 (3)
%Dominant FFG[2]	--	--	--	--	30 (4)	46 (2)	47 (2)	41 (3)	37 (3)	68 (1)	40 (3)	32 (4)
% Predators	--	--	--	--	30 (2)	42 (1)	36 (2)	41 (1)	34 (2)	11 (4)	36 (1)	17 (3)
Ratio of intolerant:tolerant taxa	--	--	--	--	2 (2)	2 (2)	3 (2)	1 (1)	1 (1)	5 (3)	1 (1)	1 (1)
% of total trichoptera as Hydropsychidae	--	--	--	--	53 (2)	42 (3)	90 (1)	56 (2)	100 (1)	86 (1)	54 (2)	98 (1)
# of non-insect taxa	--	--	--	--	3 (2)	2 (2)	2 (2)	1 (1)	2 (2)	2 (2)	1 (1)	3 (2)
% Collector-gatherers	--	--	--	--	24 (3)	46 (1)	47 (1)	30 (3)	37 (2)	68 (1)	40 (2)	32 (2)
% of total number as Elmidae	--	--	--	--	6 (4)	3 (4)	1 (1)	18 (3)	12 (3)	3 (4)	1 (4)	16 (3)
Total Score	--	--	--	--	36	28	24	27	25	28	26	28
Aquatic Life Use	--	--	--	--	H	I	I	I	I	I	I	I

[1]EPT = Ephemeroptera, Plecoptera, Trichoptera; [2]FFG = Functional feeding group; Aquatic Life Use: >36 Exceptional; 29-36 High; 22-28 Intermediate; <22 Limited

TABLE 9. Macroinvertebrate BIBI scores for the year 2010, sampling not conducted during spring season. Metrics and scoring criteria for benthic invertebrates collected using Rapid Bioassessment protocol. In parentheses are the scores to the corresponding values assigned based on TCEQ SWQM vol. II ch. 5.

	Spring				Summer				Fall			
Metrics	**WR1**	**WR2**	**WR3**	**WR4**	**WR1**	**WR2**	**WR3**	**WR4**	**WR1**	**WR2**	**WR3**	**WR4**
Taxa richness (Genus)	--	--	--	--	18 (3)	21 (3)	23 (4)	19 (3)	15 (3)	23 (4)	14 (2)	21 (3)
EPT[1] taxa abundance	--	--	--	--	9 (3)	9 (3)	10 (4)	11 (4)	8 (3)	10 (4)	7 (3)	7 (3)
Biotic index (HBI)	--	--	--	--	5 (2)	4 (3)	4 (3)	5 (2)	4 (3)	5 (2)	4 (3)	5 (2)
% Chironomidae	--	--	--	--	4 (4)	3 (4)	2 (4)	5 (3)	2 (4)	12 (2)	3 (4)	8 (3)
% Dominant taxon	--	--	--	--	42 (1)	30 (3)	42 (1)	38 (2)	28 (3)	22 (3)	52 (1)	43 (1)
%Dominant FFG[2]	--	--	--	--	45 (3)	46 (2)	32 (4)	51 (2)	45 (2)	42 (3)	39 (3)	42 (3)
% Predators	--	--	--	--	12 (4)	29 (2)	32 (2)	8 (4)	4 (1)	12 (4)	27 (2)	7 (4)
Ratio of intolerant:tolerant taxa	--	--	--	--	3 (3)	5 (3)	5 (4)	6 (4)	6 (4)	3 (3)	3 (2)	5 (4)
% of total trichoptera as Hydropsychidae	--	--	--	--	85 (1)	38 (3)	33 (3)	98 (1)	97 (1)	83 (1)	8 (4)	100 (1)
# of non-insect taxa	--	--	--	--	1 (1)	1 (1)	0 (1)	0 (1)	0 (1)	1 (1)	1 (1)	1 (1)
% Collector-gatherers	--	--	--	--	25 (3)	46 (1)	23 (3)	23 (3)	45 (1)	42 (1)	39 (2)	42 (1)
% of total number as Elmidae	--	--	--	--	3 (4)	4 (4)	4 (4)	5 (4)	8 (4)	3 (4)	4 (4)	2 (4)
Total Score	--	--	--	--	32	32	37	33	30	32	31	30
Aquatic Life Use	--	--	--	--	H	H	E	H L	H	H	H	H

[1]EPT = Ephemeroptera, Plecoptera, Trichoptera; [2]FFG = Functional feeding group; Aquatic Life Use: >36 Exceptional; 29-36 High; 22-28 Intermediate; <22 Limited

TABLE 10. Macroinvertebrate BIBI scores for the year 2011, sampling was concluded in Spring 2011. Metrics and scoring criteria for benthic invertebrates collected using Rapid Bioassessment protocol. In parentheses are the scores to the corresponding values assigned based on TCEQ SWQM vol. II ch. 5.

	Spring				Summer				Fall			
Metrics	**WR1**	**WR2**	**WR3**	**WR4**	**WR1**	**WR2**	**WR3**	**WR4**	**WR1**	**WR2**	**WR3**	**WR4**
Taxa richness (Genus)	11 (2)	32 (4)	15 (3)	19 (3)	--	--	--	--	--	--	--	--
EPT[1] taxa abundance	5 (2)	6 (2)	2 (1)	7 (3)	--	--	--	--	--	--	--	--
Biotic index (HBI)	6 (1)	5 (2)	4 (3)	5 (1)	--	--	--	--	--	--	--	--
% Chironomidae	42 (1)	33 (1)	12 (2)	35 (1)	--	--	--	--	--	--	--	--
% Dominant taxon	42 (1)	33 (2)	60 (1)	35 (2)	--	--	--	--	--	--	--	--
%Dominant FFG[2]	39 (3)	30 (4)	40 (3)	35 (4)	--	--	--	--	--	--	--	--
% Predators	19 (3)	30 (2)	40 (1)	20 (3)	--	--	--	--	--	--	--	--
Ratio of intolerant:tolerant taxa	1 (1)	1 (1)	3 (2)	1 (1)	--	--	--	--	--	--	--	--
% of total trichoptera as Hydropsychidae	100 (1)	27 (3)	0 (1)	94 (1)	--	--	--	--	--	--	--	--
# of non-insect taxa	1 (1)	3 (2)	3 (2)	1 (1)	--	--	--	--	--	--	--	--
% Collector-gatherers	34 (2)	30 (3)	33 (2)	35 (2)	--	--	--	--	--	--	--	--
% of total number as Elmidae	11 (3)	2 (4)	0 (1)	18 (3)	--	--	--	--	--	--	--	--
Total Score	21	30	22	25	--	--	--	--	--	--	--	--
Aquatic Life Use	L	H	I	I	--	--	--	--	--	--	--	--

[1]EPT = Ephemeroptera, Plecoptera, Trichoptera; [2]FFG = Functional feeding group; Aquatic Life Use: >36 Exceptional; 29-36 High; 22-28 Intermediate; <22 Limited

TABLE 11. Comparison of least-squares fits for pre- and post-project, season, and site variables on Total BIBI score (1) and BIBI individual metrics (2-13) of macroinvertebrate assemblage. Values in bold are significant *P*-values. (FFG = functional feeding guild).

Source	dF	Sum of Squares	F Ratio	*P*-value
1) Total BIBI Score				
Pre- and post-	1	110.51	8.96	**0.005**
Season	2	110.27	4.47	**0.02**
Site	3	73.32	1.98	0.14
Pre-/Post- x Site	3	31.68	0.86	0.47
2) Taxa Richness (Genus)				
Pre- and post	1	422.94	21.47	**<.0001**
Season	2	69.04	1.75	0.19
Site	3	88.10	1.49	0.23
Pre-/Post- x Site	3	53.64	0.91	0.45
3) EPT Taxa Abundance				
Pre- and post	1	8.17	2.72	0.11
Season	2	36.80	6.12	**0.005**
Site	3	6.89	0.76	0.52
Pre-/Post- x Site	3	7.98	0.89	0.46
4) Hilsenhoff Biotic Index				
Pre- and post	1	1.07	3.42	0.07
Season	2	0.33	0.53	0.59
Site	3	5.52	5.89	**0.002**
Pre-/Post- x Site	3	0.69	0.73	0.54
5) Percent Chironomidae				
Pre- and post	1	10.00	0.07	0.79
Season	2	3468.79	12.49	**<.0001**
Site	3	84.79	0.20	0.89
Pre-/Post- x Site	3	34.75	0.08	0.97
6) Percent Dominant Taxon				
Pre- and post	1	216.40	1.65	0.21
Season	2	110.85	0.42	0.66
Site	3	819.86	2.09	0.12
Pre-/Post- x Site	3	659.83	1.68	0.19
7) Percent Dominant FFG				
Pre-/post	1	470.61	7.29	**0.01**
Season	2	591.20	4.58	**0.02**
Site	3	9.51	0.05	0.99
Pre-/post x Site	3	321.37	1.66	0.19

Source	dF	Sum of Squares	F Ratio	*P*-value
8) Percent Predators				
Pre- and post	1	727.12	5.44	**0.03**
Season	2	969.76	3.62	**0.04**
Site	3	715.68	1.78	0.17
Pre-/Post- x Site	3	196.20	0.49	0.69
9) Ratio of Intolerant : Tolerant taxa				
Pre- and post	1	1.71	0.46	0.50
Season	2	27.24	3.68	**0.04**
Site	3	20.34	1.83	0.16
Pre-/Post- x Site	3	9.28	0.84	0.48
10) Percent of total Trichoptera as Hydropsychidae				
Pre- and post	1	141.65	0.13	0.72
Season	2	2995.58	1.37	0.27
Site	3	11302.96	3.44	**0.03**
Pre-/Post- x Site	3	2888.65	0.88	0.46
11) Number of Non-Insect Taxa				
Pre- and post	1	2.84	2.76	0.11
Season	2	2.10	1.02	0.37
Site	3	1.34	0.43	0.73
Pre-/Post- x Site	3	2.43	0.79	0.51
12) Percent Collector-Gatherers				
Pre- and post	1	570.63	5.28	**0.03**
Season	2	679.75	3.15	0.06
Site	3	170.26	0.53	0.67
Pre-/Post- x Site	3	963.44	2.97	**0.05**
13) Percent of Total Number as Elmidae				
Pre- and post	1	116.25	1.60	0.21
Season	2	58.25	0.40	0.67
Site	3	734.10	3.37	**0.03**
Pre-/Post- x Site	3	190.00	0.87	0.46

TABLE 12. Index of biotic integrity (IBI) results from four sites in the Wichita River during 2005 prior to discharge from a reverse osmosis plant that began in February 2009. IBI scores are presented as raw values and IBI score in parentheses (Aquatic life use codes: L = Limited, I = Intermediate, H = High).

	Spring				Summer				Fall			
Metrics	WR1	WR2	WR3	WR4	WR1	WR2	WR3	WR4	WR1	WR2	WR3	WR4
Total Number of Fish Species	8 (3)	12 (3)	12 (3)	10 (3)	16 (5)	16 (5)	17 (5)	21 (5)	10 (3)	7 (1)	8 (3)	7 (1)
Number of Native Cyprinid Species	5 (5)	4 (5)	4 (5)	4 (5)	6 (5)	6(5)	7 (5)	8 (5)	2 (3)	3 (3)	3 (3)	4 (5)
Number of Benthic Invertivore Species	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)
Number of Sunfish Species	2 (3)	1 (1)	2 (3)	2(3)	2 (3)	2 (3)	4 (5)	3 (3)	1 (1)	1 (1)	1 (1)	1 (1)
% of Individuals as Tolerant Species	96.2 (1)	93.5 (1)	89.2 (1)	94.7 (1)	72.9 (1)	64.3 (1)	47.7 (3)	72.4 (1)	82.6 (1)	98.0 (1)	81.9 (1)	96.4 (1)
% of Individuals as Omnivores	0.2(5)	0.4 (5)	1.5 (5)	0.1 (5)	0.8 (5)	6.3 (5)	2.1 (5)	6.3 (5)	1.7 (5)	0.4 (5)	0.8 (5)	0.0 (5)
% of Individuals as Invertivores	99.8 (5)	99.3 (5)	97.8 (5)	99.8 (5)	98.9 (5)	92.8 (5)	97.8 (5)	93.1 (5)	95.9 (5)	99.6 (5)	99.2 (5)	100.0 (5)
% of Individuals as Piscivores	0.0 (1)	0.4 (1)	0.7 (1)	0.1 (1)	0.3 (1)	0.9 (1)	0.1 (1)	0.6 (1)	2.3 (1)	0.0 (1)	0.0 (1)	0.0 (1)
Number of Individuals/seine haul	109.9 (5)	140.5 (5)	40.7 (3)	109.2 (5)	189.6 (5)	57.2 (3)	201.7 (5)	112.2 (5)	14.9 (1)	65.0 (3)	30.8 (1)	102.0 (5)
% of Individuals as Non-native Species	0.0 (5)	0.1 (5)	0.2 (5)	0.0 (5)	0.0 (5)	0.0 (5)	0.0 (5)	0.0 (5)	0.0 (5)	0.0 (5)	0.5 (5)	0.0 (5)
% of Individuals With Disease/Anomaly	0.0 (5)	0.0 (5)	0.0 (5)	0.0 (5)	0.0 (5)	0.0 (5)	0.0 (5)	0.0 (5)	0.0 (5)	0.0 (5)	0.0 (5)	0.0 (5)
Total IBI Score	39	37	37	39	41	39	45	41	31	31	31	35
Aquatic Life Use	I	I	I	I	H	I	H	H	L	L	L	I

TABLE 13. Index of biotic integrity (IBI) results from four sites in the Wichita River during 2008 prior to discharge from a reverse osmosis plant that began in February 2009. IBI scores are presented as raw values and IBI score in parentheses (Aquatic life use codes: I = Intermediate, H = High). WR1 and WR2 are upstream and WR3 and WR4 downstream from a reverse osmosis plant that began discharging in February 2009.

	Spring				Summer				Fall			
Metrics	WR1	WR2	WR3	WR4	WR1	WR2	WR3	WR4	WR1	WR2	WR3	WR4
Total Number of Fish Species	11 (3)	12 (3)	9 (3)	11 (3)	11 (3)	17 (5)	15 (5)	16 (5)	11 (3)	15 (5)	14 (3)	15 (5)
Number of Native Cyprinid Species	5 (5)	4 (5)	3 (3)	2 (3)	5 (5)	7 (5)	5 (5)	6 (5)	5 (5)	6 (5)	6 (5)	7 (5)
Number of Benthic Invertivore Species	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	1 (0)	0 (1)	0 (1)	0 (1)
Number of Sunfish Species	2 (3)	2 (3)	2 (3)	3 (3)	1 (1)	3 (3)	2 (3)	2 (3)	1 (1)	1 (1)	1 (1)	3 (3)
% of Individuals as Tolerant Species	85.1 (1)	90.1 (1)	88.8 (1)	93.9 (1)	52.1 (1)	78.4 (1)	42.3 (3)	63.0 (1)	77.8 (1)	61.4 (1)	60.0 (1)	66.8 (1)
% of Individuals as Omnivores	0.6 (5)	1.8 (5)	0.4 (5)	0.5 (5)	1.8 (5)	8.0 (5)	8.4 (5)	5.8 (5)	0.8 (5)	1.7 (5)	0.9 (5)	1.7 (5)
% of Individuals as Invertivores	99.1 (5)	97.0 (5)	99.5 (5)	99.2 (5)	96.1 (5)	90.8 (5)	91.0 (5)	93.5 (5)	99.2 (5)	98.1 (5)	98.9 (5)	98.2 (5)
% of Individuals as Piscivores	0.2 (1)	1.3 (1)	0.1 (1)	0.3 (1)	2.1 (1)	1.2 (1)	0.6 (1)	0.7 (1)	0.0 (1)	0.3 (1)	0.2 (1)	0.1 (1)
Number of Individuals/seine haul	85.2 (3)	32.2 (1)	66.4 (3)	84.8 (3)	43.2 (3)	126.4 (5)	83.0 (3)	67.8 (3)	134.0 (5)	167.9 (5)	121.0 (5)	69.3 (3)
% of Individuals as Non-native Species	0.0 (5)	0.0 (5)	0.0 (5)	0.1 (5)	0.0 (5)	0.0 (5)	0.2 (5)	0.7 (5)	0.0 (5)	0.1 (5)	0.1 (5)	0.0 (5)
% of Individuals With Disease/Anomaly	0.0 (5)	0.0 (5)	0.0 (5)	0.0 (5)	0.0 (5)	0.0 (5)	0.0 (5)	0.1 (5)	0.0 (5)	0.0 (5)	0.0 (5)	0.0 (5)
Total IBI Score	37	35	35	35	35	41	41	39	37	39	37	39
Aquatic Life Use	I	I	I	I	I	H	H	I	I	I	I	I

TABLE 14. Index of biotic integrity (IBI) results from four sites in the Wichita River during 2009. IBI scores are presented as raw values and IBI score in parentheses (Aquatic life use codes: L = Limited, I = Intermediate). WR1 and WR2 are upstream and WR3 and WR4 downstream from a reverse osmosis plant that began discharging in February 2009.

	Spring				Summer				Fall			
Metrics	WR1	WR2	WR3	WR4	WR1	WR2	WR3	WR4	WR1	WR2	WR3	WR4
Total Number of Fish Species	--	--	--	--	12 (3)	13 (3)	16(5)	15 (5)	9 (3)	16 (5)	11 (3)	11 (3)
Number of Native Cyprinid Species	--	--	--	--	5 (5)	4 (5)	5 (5)	7 (5)	5 (5)	8 (5)	5 (5)	6 (5)
Number of Benthic Invertivore Species	--	--	--	--	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)
Number of Sunfish Species	--	--	--	--	0 (1)	2 (3)	2 (3)	1 (1)	0 (1)	1 (1)	1 (1)	2 (3)
% of Individuals as Tolerant Species	--	--	--	--	48.8 (3)	72.5 (1)	66.1 (1)	70.2 (1)	65.3 (1)	65.8 (1)	61.5 (1)	75.3 (1)
% of Individuals as Omnivores	--	--	--	--	10.4 (3)	7.7 (5)	12.2 (3)	6.6 (5)	0.6 (5)	1.1 (5)	0.7 (5)	0.1 (5)
% of Individuals as Invertivores	--	--	--	--	88.0 (5)	91.9 (5)	87.4 (5)	92.6 (5)	99.2 (5)	98.7 (5)	99.3 (5)	99.9 (5)
% of Individuals as Piscivores	--	--	--	--	1.7 (1)	0.4 (1)	0.5 (1)	0.8 (1)	0.3 (1)	0.2 (1)	0.0 (1)	0.0 (1)
Number of Individuals/seine haul	--	--	--	--	29.4 (1)	46.4 (3)	34.2 (1)	47.5 (3)	72.3 (3)	92.3 (5)	78.6 (3)	133.5 (5)
% of Individuals as Non-native Species	--	--	--	--	0.0 (5)	0.0 (5)	0.2 (5)	0.2 (5)	0.0 (5)	0.1 (5)	0.1 (5)	0.0 (5)
% of Individuals With Disease/Anomaly	--	--	--	--	0.3 (5)	0.6 (5)	0.5 (5)	0.6 (5)	0.3 (5)	0.2 (5)	0.2 (5)	0.1 (5)
Total IBI Score	--	--	--	--	33	35	35	35	35	39	35	39
Aquatic Life Use	--	--	--	--	L	I	I	I	I	I	I	I

TABLE 15. Index of biotic integrity (IBI) results from four sites in the Wichita River during 2010. IBI scores are presented as raw values and IBI score in parentheses (Aquatic life use codes: L = Limited, I = Intermediate). WR1 and WR2 are upstream and WR3 and WR4 downstream from a reverse osmosis plant that began discharging in February 2009.

	Spring				Summer				Fall			
Metrics	WR1	WR2	WR3	WR4	WR1	WR2	WR3	WR4	WR1	WR2	WR3	WR4
Total Number of Fish Species	--	--	--	--	10 (3)	9 (3)	12 (3)	14 (3)	11 (3)	14 (3)	11 (3)	10 (3)
Number of Native Cyprinid Species	--	--	--	--	3 (3)	6 (5)	6 (5)	6 (5)	6 (5)	8 (5)	5 (5)	8 (5)
Number of Benthic Invertivore Species	--	--	--	--	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)
Number of Sunfish Species	--	--	--	--	0 (1)	0 (1)	0 (1)	2 (3)	1 (1)	0 (1)	0 (1)	0 (1)
% of Individuals as Tolerant Species	--	--	--	--	93.4 (1)	87.8 (1)	58.9 (1)	70.6 (1)	84.7 (1)	74.5 (1)	71.4 (1)	64.5 (1)
% of Individuals as Omnivores	--	--	--	--	0.9 (5)	3.3 (5)	2.5 (5)	1.2 (5)	0.3 (5)	0.5 (5)	0.3 (5)	0.1 (5)
% of Individuals as Invertivores	--	--	--	--	97.6 (5)	96.2 (5)	95.6 (5)	98.5 (5)	99.7 (5)	99.3 (5)	99.3 (5)	99.9 (5)
% of Individuals as Piscivores	--	--	--	--	1.5 (1)	0.5 (1)	1.9 (1)	0.3 (1)	0.0 (1)	0.2 (1)	0.3 (1)	0.0 (1)
Number of Individuals/seine haul	--	--	--	--	33.2 (1)	36.6 (3)	15.5 (1)	68.0 (3)	119.5 (5)	173.3 (5)	116.8 (5)	168.9 (5)
% of Individuals as Non-native Species	--	--	--	--	0.0 (5)	0.0 (5)	0.0 (5)	0.3 (5)	0.1 (5)	0.0 (5)	0.1 (5)	0.0 (5)
% of Individuals With Disease/Anomaly	--	--	--	--	0.0 (5)	0.0 (5)	0.0 (5)	0.0 (5)	0.0 (5)	0.1 (5)	0.1 (5)	0.1 (5)
Total IBI Score	--	--	--	--	31	35	33	37	37	37	37	37
Aquatic Life Use	--	--	--	--	L	I	L	I	I	I	I	I

TABLE 16. Index of biotic integrity (IBI) results from four sites in the Wichita River during 2011. IBI scores are presented as raw values and IBI scores in parentheses (Aquatic life use code: I = Intermediate). WR1 and WR2 are upstream and WR3 and WR4 downstream from a reverse osmosis plant that began discharging in February 2009.

	Spring				Summer				Fall			
Metrics	WR1	WR2	WR3	WR4	WR1	WR2	WR3	WR4	WR1	WR2	WR3	WR4
Total Number of Fish Species	9 (3)	13 (3)	9 (3)	13 (3)	--	--	--	--	--	--	--	--
Number of Native Cyprinid Species	5 (5)	7 (5)	5 (5)	7 (5)	--	--	--	--	--	--	--	--
Number of Benthic Invertivore Species	0 (1)	0 (1)	0 (1)	0 (1)	--	--	--	--	--	--	--	--
Number of Sunfish Species	1 (1)	1 (1)	0 (1)	1 (1)	--	--	--	--	--	--	--	--
% of Individuals as Tolerant Species	72.8 (1)	65.2 (1)	80.0 (1)	77.7 (1)	--	--	--	--	--	--	--	--
% of Individuals as Omnivores	0.8 (5)	0.3 (5)	0.4 (5)	0.1 (5)	--	--	--	--	--	--	--	--
% of Individuals as Invertivores	98.9 (5)	98.9 (5)	99.3 (5)	99.6 (5)	--	--	--	--	--	--	--	--
% of Individuals as Piscivores	0.4 (1)	0.9 (1)	0.3 (1)	0.2 (1)	--	--	--	--	--	--	--	--
Number of Individuals/seine haul	52.8 (3)	139.5 (5)	64.9 (3)	164.2 (5)	--	--	--	--	--	--	--	--
% of Individuals as Non-native Species	0.0 (5)	0.0 (5)	0.0 (5)	0.0 (5)	--	--	--	--	--	--	--	--
% of Individuals With Disease/Anomaly	0.2 (5)	0.1 (5)	0.1 (5)	0.0 (5)	--	--	--	--	--	--	--	--
Total IBI Score	35	37	35	37	--	--	--	--	--	--	--	--
Aquatic Life Use	I	I	I	I	--	--	--	--	--	--	--	--

Appendix 1a. Benthic macroinvertebrates collected from four sites in the Wichita River in 2005. WR1 and WR2 are upstream and WR3 and WR4 downstream from a reverse osmosis plant that began discharging in February 2009.

			Spring				Summer				Fall			
Order	Family	Genus	WR1	WR2	WR3	WR4	WR1	WR2	WR3	WR4	WR1	WR2	WR3	WR4
Amphipoda	Dogielinotidae	*Hyalella*	1	--	--	--	--	--	--	--	--	--	--	--
Coleoptera	Elmidae	*Dubiraphia*	--	1	--	1	--	--	--	3	--	--	--	1
		Stenelmis	133	1	3	41	5	2	--	1	28	3	3	53
	Hydrophilidae	*Berosus*	--	--	--	--	--	--	--	1	--	1	3	--
Collembolla	Isotomidae		--	--	--	--	--	1	--	--	--	--	--	--
Decapoda	Palaemonidae	*Palaemonetes*	--	22	2	--	--	5	--	4	--	2	4	--
Diptera	Ceratopogonidae		1	--	--	--	1	--	8	1	--	--	--	1
	Chironomidae		33	6	12	32	67	45	48	25	10	9	7	48
	Dolichopodidae		--	--	--	--	--	--	1	--	--	--	--	--
	Simuliidae	*Simulium*	--	--	--	--	--	38	--	--	--	--	--	--
	Tabanidae		--	--	--	--	--	--	--	1	--	--	--	--
	Tipulidae		--	--	--	--	--	--	--	1	--	--	--	--
Ephemeroptera	Baetidae		26	--	12	9	--	--	--	8	10	48	39	37
	Caenidae	*Brachycercus*	--	1	--	--	--	--	--	--	--	1	3	86
		Caenis	--	--	--	39	2	1	1	--	20	1	13	20
	Ephemerellidae		--	--	1	--	--	--	--	--	--	--	--	--
	Heptageniidae	*Stenonema*	7	--	--	10	1	1	1	1	7	--	--	10
	Leptophlebiidae		7	--	3	13	1	2	--	1	8	--	--	15
	Tricorythidae	*Tricorythodes*	62	27	12	30	2	1	--	4	52	30	19	69
Gastropoda	Physidae	*Physa*	--	--	--	--	--	3	3	--	--	--	--	--
Hemiptera	Corixidae	*Trichocorixa*	--	2	--	--	84	37	117	24	7	1	1	8
	Gerridae	*Rheumatobates*	--	--	--	--	--	--	--	--	--	--	--	1
Hydracarina			--	--	--	--	--	--	--	--	--	--	--	1
Lepidoptera	Pyralidae		--	--	--	--	--	--	--	--	--	--	--	1
Odonata	Calopterygidae	*Hetaerina*	--	4	--	--	1	1	--	3	1	1	--	--
	Coenogrionidae	*Argia*	2	--	2	1	1	1	1	--	9	1	--	4
	Gomphidae	*Dromogomphus*	--	--	--	--	--	1	--	--	--	--	--	--
		Erpetogomphus	--	2	--	--	--	4	--	6	1	3	4	--
		Phyllogomphoides	--	--	--	--	--	--	7	--	--	--	--	7
		Progomphus	--	--	1	--	3	--	7	--	--	3	8	2
	Libellulidae		--	--	--	--	1	--	--	--	--	--	--	--
	Macromidae	Macromia	--	--	--	--	--	--	--	--	--	--	1	--
Oligochaeta	Oligochaeta		--	--	--	--	3	--	5	--	--	--	--	2
Ostracoda			--	--	--	--	--	--	--	--	--	--	--	1
Trichoptera	Glossosomatidae		--	--	--	--	3	--	--	--	1	--	--	--
	Hydropsychidae	Ceratopsyche	17	--	8	--	--	--	--	--	--	--	--	--
		Cheumatopsyche	1	1	--	--	--	1	--	--	--	--	--	--
		Hydropsyche	1	--	6	24	--	--	--	--	3	28	2	--
		Potamyia	4	9	--	2	--	8	1	--	1	27	--	36
		Smicridea	5	--	--	--	--	--	--	--	--	--	--	--
	Hydroptilidae	Ithytrichia	--	--	--	--	1	--	--	--	--	--	--	--
		Stactobiella	1	--	--	--	--	--	--	--	--	--	--	--
	Leptoceridae	Nectopsyche	--	20	--	--	--	5	8	1	2	14	34	--
		Total	301	96	62	202	176	157	208	85	160	173	141	403

Appendix 1b. Benthic macroinvertebrates collected from four sites in the Wichita River in 2008. WR1 and WR2 are upstream and WR3 and WR4 downstream from a reverse osmosis plant that began discharging in February 2009.

			Spring				Summer				Fall			
Order	Family	Genus	WR1	WR2	WR3	WR4	WR1	WR2	WR3	WR4	WR1	WR2	WR3	WR4
Coleoptera	Dryopidae	*Helichus*	- -	2	- -	- -	- -	27	11	2	- -	31	- -	- -
	Dytiscidae		- -	1	1	- -	- -	- -	- -	- -	- -	- -	- -	- -
	Elmidae	*Stenelmis*	2	19	2	3	38	60	6	17	9	33	- -	22
	Gyrinidae	*Gyretes*	- -	- -	- -	- -	- -	1	- -	2	2	2	- -	- -
	Halipilidae	*Peltodytes*	2	- -	- -	- -	- -	- -	- -	2	- -	- -	- -	- -
	Hydrophilidae		9	- -	4	1	- -	- -	- -	- -	- -	- -	- -	2
	Scirtidae	*Scirtes*	- -	- -	3	- -	- -	- -	- -	- -	- -	- -	- -	- -
	Staphylinidae		2	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Decapoda	Palaemonidae	*Palaemonetes*	- -	- -	32	- -	- -	- -	- -	5	- -	- -	- -	- -
Diptera	Ceratopogonidae		1	- -	- -	- -	- -	- -	1	1	- -	- -	- -	- -
	Chironomidae	*Tanypodinae*	- -	- -	- -	- -	- -	- -	11	- -	- -	- -	- -	- -
			33	86	9	9	30	3	33	48	5	1	3	14
	Simuliidae	*Simulium*	- -	- -	- -	- -	- -	- -	3	- -	- -	- -	- -	- -
Ephemeroptera	Baetidae		21	- -	- -	- -	1	2	34	14	31	13	9	50
	Caenidae	*Caenis*	8	1	1	- -	- -	5	11	7	89	2	79	102
	Ephemeridae	*Hexagenia*	1	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
	Heptageniidae	*Stenonema*	4	- -	- -	1	- -	6	- -	7	6	- -	31	13
	Isonythidae	*Isonychia*	- -	- -	- -	- -	- -	- -	3	- -	- -	6	- -	- -
	Leptophlebiidae		8	16	2	1	9	24	5	20	46	15	94	23
	Tricorythidae	*Tricorythodes*	10	- -	- -	- -	- -	14	62	13	58	13	17	8
Gastropoda	Physidae	*Physa*	5	- -	3	- -	- -	- -	- -	17	- -	1	- -	2
Hemiptera	Belostomatida	*Belostoma*	- -	- -	2	- -	- -	- -	- -	1	- -	- -	- -	- -
	Corixidae	*Trichocorixa*	- -	- -	- -	- -	- -	- -	- -	6	- -	- -	- -	- -
			51	- -	1	- -	- -	- -	- -	- -	- -	1	- -	- -
	Mesoveliidae	*Mesovelia*	2	- -	- -	- -	- -	- -	- -	2	- -	- -	- -	- -
	Notonectidae	*Notonecta*	1	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
	Veliidae	*Rhagovelia*	- -	- -	- -	- -	- -	- -	- -	- -	- -	1	- -	- -
Megaloptera	Corydalidae	*Corydalus*	- -	- -	- -	- -	- -	- -	- -	1	- -	6	- -	- -
Odonata	Calopterygidae	*Hetaerina*	- -	- -	- -	1	- -	- -	14	- -	- -	5	- -	- -
	Coenogrionidae	*Argia*	- -	6	- -	1	1	55	6	10	3	4	4	1
	Gomphidae	*Erpetogomphus*	3	1	- -	- -	- -	1	1	- -	2	- -	- -	- -
		Gomphus	1	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
		Progomphus	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1
		Stylurus	2	- -	- -	- -	- -	- -	1	- -	1	1	- -	- -
Oligochaeta	Oligochaeta		- -	- -	- -	1	- -	- -	- -	1	- -	- -	- -	- -
Trichoptera	Hydropsychidae	Ceratopsyche	- -	5	- -	- -	5	30	23	- -	11	45	7	25
		Hydropsyche	16	9	- -	17	40	11	4	60	2	77	- -	- -
	Hydroptilidae	Ithytrichia	- -	- -	- -	- -	- -	1	- -	- -	- -	- -	- -	1
			1	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1
	Leptoceridae	Nectopsyche	1	- -	29	5	- -	- -	8	- -	4	2	- -	- -
	Polycentropodidae	Cyrnellus	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1	- -
		Total	184	146	89	40	124	240	237	236	269	259	245	265

Appendix 1c. Benthic macroinvertebrates collected from four sites in the Wichita River in 2009. WR1 and WR2 are upstream and WR3 and WR4 downstream from a reverse osmosis plant that began discharging in February 2009.

			Spring				Summer				Fall			
Order	Family	Genus	WR1	WR2	WR3	WR4	WR1	WR2	WR3	WR4	WR1	WR2	WR3	WR4
Amphipoda	Dogielinotidae	*Hyalella*	- -	- -	- -	- -	1	1	- -	- -	1	- -	- -	- -
Arguloida	Argulidae	*Argulus*	- -	- -	- -	- -	- -	- -	- -	1	- -	- -	2	- -
Coleoptera	Chrysomelidae		- -	- -	- -	- -	- -	- -	- -	- -	- -	1	- -	- -
	Curculionidae		- -	- -	- -	- -	1	- -	- -	- -	- -	- -	- -	- -
	Dryopidae	*Helichus*	- -	- -	- -	- -	23	- -	10	28	11	3	- -	4
	Dytiscidae		- -	- -	- -	- -	- -	- -	- -	- -	- -	1	1	- -
	Elmidae	*Dubiraphia*	- -	- -	- -	- -	- -	1	- -	- -	- -	- -	- -	- -
		Stenelmis	- -	- -	- -	- -	30	5	2	37	14	7	2	52
	Gyrinidae	*Dineutus*	- -	- -	- -	- -	- -	- -	2	- -	- -	- -	- -	- -
		Gyretes	- -	- -	- -	- -	- -	- -	1	- -	2	3	2	3
	Halipilidae	*Brychius*	- -	- -	- -	- -	- -	- -	- -	- -	- -	1	- -	2
		Peltodytes	- -	- -	- -	- -	- -	- -	- -	- -	20	2	- -	6
	Hydrochidae	*Hydrochus*	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1
	Hydrophilidae	*Tropisternus*	- -	- -	- -	- -	- -	- -	1	- -	- -	- -	- -	- -
	Scirtidae	*Scirtes*	- -	- -	- -	- -	- -	- -	- -	- -	1	- -	- -	- -
Decapoda	Palaemonidae	*Palaemonetes*	- -	- -	- -	- -	- -	113	39	1	4	55	1	8
Diptera	Ceratopogonidae		- -	- -	- -	- -	- -	- -	2	- -	- -	- -	- -	- -
	Chironomidae		- -	- -	- -	- -	58	13	88	55	2	1	6	- -
	Ephydridae		- -	- -	- -	- -	- -	- -	- -	- -	1	- -	- -	- -
	Simuliidae	*Simulium*	- -	- -	- -	- -	1	23	- -	1	- -	- -	- -	- -
			- -	- -	- -	- -	- -	- -	4	- -	- -	- -	- -	- -
Ephemeroptera	Baetidae		- -	- -	- -	- -	4	2	1	10	14	3	18	8
	Caenidae	*Caenis*	- -	- -	- -	- -	2	1	6	4	6	2	7	8
	Ephemeridae	*Hexagenia*	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1
	Heptageniidae	*Stenonema*	- -	- -	- -	- -	6	- -	1	1	2	1	18	- -
	Leptophlebiidae		- -	- -	- -	- -	10	- -	1	19	1	- -	11	1
	Tricorythidae	*Tricorythodes*	- -	- -	- -	- -	36	5	6	3	9	5	12	8
Gastropoda	Physidae	*Physa*	- -	- -	- -	- -	- -	- -	- -	- -	3	2	- -	- -
Hemiptera	Belostomatida	*Belostoma*	- -	- -	- -	- -	- -	- -	- -	- -	4	7	- -	- -
	Corixidae	*Trichocorixa*	- -	- -	- -	- -	- -	- -	- -	- -	3	44	139	48
			- -	- -	- -	- -	- -	- -	- -	1	- -	- -	- -	- -
	Gerridae	*Metrobates*	- -	- -	- -	- -	1	- -	3	1	2	11	1	17
		Rheumatobates	- -	- -	- -	- -	- -	- -	- -	- -	- -	1	- -	- -
	Mesoveliidae	*Mesovelia*	- -	- -	- -	- -	- -	- -	- -	- -	- -	1	- -	- -
	Nepidae	*Ranatra*	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1
	Saldidae		- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1	- -
	Veliidae	*Platyvelia*	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1
		Rhagovelia	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	4
Megaloptera	Corydalidae	*Corydalus*	- -	- -	- -	- -	- -	- -	- -	3	5	1	1	- -
Odonata	Calopterygidae	*Hetaerina*	- -	- -	- -	- -	7	8	7	- -	10	8	- -	6
	Coenogrionidae	*Argia*	- -	- -	- -	- -	45	5	15	8	14	19	4	16
	Gomphidae	*Arigomphus*	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2
		Dromogomphus	- -	- -	- -	- -	- -	- -	4	- -	- -	1	- -	- -
		Erpetogomphus	- -	- -	- -	- -	13	1	12	6	- -	- -	- -	- -
		Gomphus	- -	- -	- -	- -	2	1	- -	- -	- -	2	2	20
		Progomphus	- -	- -	- -	- -	- -	- -	- -	1	- -	1	- -	- -
		Stylurus	- -	- -	- -	- -	- -	1	2	- -	1	3	- -	4
	Libellulidae	Pantala	- -	- -	- -	- -	- -	- -	- -	- -	1	- -	- -	- -
	Macromidae	Macromia	- -	- -	- -	- -	- -	- -	- -	- -	2	- -	- -	7
		Macromiinae	- -	- -	- -	- -	- -	- -	1	- -	- -	- -	- -	- -
Oligochaeta	Oligochaeta		- -	- -	- -	- -	2	- -	- -	1	- -	- -	- -	- -
Trichoptera	Hydropsychidae	Ceratopsyche	- -	- -	- -	- -	12	4	5	42	16	6	8	26
		Hydropsyche	- -	- -	- -	- -	1	2	2	2	33	2	1	6
	Hydroptilidae	Hydroptila	- -	- -	- -	- -	- -	- -	- -	1	- -	- -	- -	- -
			- -	- -	- -	- -	- -	- -	1	- -	- -	- -	- -	- -
	Leptoceridae	Nectopsyche	- -	- -	- -	- -	- -	1	5	- -	44	11	1	25
		Total					255	187	221	226	226	205	238	285

Appendix 1d. Benthic macroinvertebrates collected from four sites in the Wichita River in 2010. WR1 and WR2 are upstream and WR3 and WR4 downstream from a reverse osmosis plant that began discharging in February 2009.

			Spring				Summer				Fall			
Order	Family	Genus	WR1	WR2	WR3	WR4	WR1	WR2	WR3	WR4	WR1	WR2	WR3	WR4
Coleoptera	Dryopidae	*Helichus*	--	--	--	--	1	3	--	8	--	2	1	4
	Dytiscidae		--	--	--	--	--	--	--	--	--	--	10	--
	Elmidae	*Dubiraphia*	--	--	--	--	--	--	--	1	--	1	--	--
		Heterelmis	--	--	--	--	1	--	--	--	--	--	--	--
		Stenelmis	--	--	--	--	18	7	8	4	8	8	9	10
	Gyrinidae	*Gyretes*	--	--	--	--	--	1	--	2	8	18	5	--
	Hydrochidae	*Hydrochus*	--	--	--	--	--	--	--	--	--	--	2	--
	Hydrophilidae	*Berosus*	--	--	--	--	--	1	--	--	--	--	--	--
		Tropisternus	--	--	--	--	--	1	--	--	--	--	--	--
	Scirtidae	*Scirtes*	--	--	--	--	--	--	--	--	--	--	3	--
Decapoda	Palaemonidae	*Palaemonetes*	--	--	--	--	--	3	5	--	--	64	--	--
Diptera	Ceratopogonidae		--	--	--	--	--	--	1	1	--	--	--	--
	Chironomidae		--	--	--	--	5	27	6	22	9	6	4	10
Ephemeroptera	Baetidae		--	--	--	--	30	50	10	118	15	14	8	34
	Caenidae	*Caenis*	--	--	--	--	4	9	22	13	19	2	2	3
	Ephemerellidae		--	--	--	--	--	--	--	--	--	2	--	--
	Heptageniidae	*Stenonema*	--	--	--	--	65	31	7	44	24	--	8	20
	Isonythidae	*Isonychia*	--	--	--	--	--	1	--	--	4	--	1	2
	Leptophlebiidae		--	--	--	--	70	12	--	7	9	--	1	6
	Tricorythidae	*Tricorythodes*	--	--	--	--	18	24	15	9	11	4	5	5
Hemiptera	Belostomatida	*Belostoma*	--	--	--	--	--	--	--	--	--	--	2	--
	Gerridae	*Metrobates*	--	--	--	--	--	1	--	1	--	4	7	--
	Veliidae	*Rhagovelia*	--	--	--	--	--	--	--	--	--	2	--	--
Megaloptera	Corydalidae	*Corydalus*	--	--	--	--	1	--	--	--	1	2	4	2
Odonata	Calopterygidae	*Hetaerina*	--	--	--	--	--	3	5	1	4	--	2	1
	Coenogrionidae	*Argia*	--	--	--	--	6	2	11	2	1	1	3	2
	Gomphidae	*Dromogomphus*	--	--	--	--	--	1	1	1	--	--	--	1
		Erpetogomphus	--	--	--	--	2	1	--	2	5	16	--	5
		Gomphus	--	--	--	--	--	--	--	1	1	--	2	--
		Progomphus	--	--	--	--	--	3	--	1	--	4	--	--
Oligochaeta	Oligochaeta		--	--	--	--	--	--	--	1	3	--	--	--
Trichoptera	Hydropsychidae	Ceratopsyche	--	--	--	--	21	20	8	20	--	9	23	80
		Hydropsyche	--	--	--	--	8	15	2	17	100	14	24	21
	Hydroptilidae	Ithytrichia	--	--	--	--	--	--	--	--	--	1	--	--
			--	--	--	--	1	--	--	--	--	--	--	--
	Leptoceridae	Nectopsyche	--	--	--	--	--	5	110	--	17	36	94	1
	Polycentropodidae	Cyrnellus	--	--	--	--	--	2	--	--	1	1	3	1
		Total					251	223	211	276	240	211	223	208

Appendix 1e. Benthic macroinvertebrates collected from four sites in the Wichita River in 2011. WR1 and WR2 are upstream and WR3 and WR4 downstream from a reverse osmosis plant that began discharging in February 2009.

			Spring				Summer				Fall			
Order	Family	Genus	WR1	WR2	WR3	WR4	WR1	WR2	WR3	WR4	WR1	WR2	WR3	WR4
Coleoptera	Chrysomelidae		- -	1	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
	Dytiscidae		- -	8	2	- -	- -	- -	- -	- -	- -	- -	- -	- -
	Elmidae	*Dubiraphia*	- -	2	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
		Stenelmis	25	2	1	43	- -	- -	- -	- -	- -	- -	- -	- -
	Gyrinidae	*Gyretes*	- -	5	2	3	- -	- -	- -	- -	- -	- -	- -	- -
	Halipilidae	*Peltodytes*	- -	2	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
	Hydrochidae	*Hydrochus*	- -	6	2	- -	- -	- -	- -	- -	- -	- -	- -	- -
	Hydrophilidae	*Helophorus*	- -	- -	2	- -	- -	- -	- -	- -	- -	- -	- -	- -
		Tropisternus	- -	2	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
			- -	1	1	- -	- -	- -	- -	- -	- -	- -	- -	- -
Decapoda	Palaemonidae	*Palaemonetes*	- -	3	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Diptera	Ceratopogonidae		- -	3	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
	Chironomidae		93	68	24	83	- -	- -	- -	- -	- -	- -	- -	- -
	Simuliidae		- -	- -	- -	1	- -	- -	- -	- -	- -	- -	- -	- -
	Tipulidae		- -	1	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Ephemeroptera	Baetidae		- -	11	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
	Caenidae	*Caenis*	- -	- -	- -	2	- -	- -	- -	- -	- -	- -	- -	- -
	Heptageniidae	*Stenonema*	3	1	- -	9	- -	- -	- -	- -	- -	- -	- -	- -
	Leptophlebiidae		7	24	1	31	- -	- -	- -	- -	- -	- -	- -	- -
	Tricorythidae	*Tricorythodes*	1	- -	- -	2	- -	- -	- -	- -	- -	- -	- -	- -
Gastropoda	Physidae	*Physa*	- -	25	1	- -	- -	- -	- -	- -	- -	- -	- -	- -
Hemiptera	Belostomatida	*Belostoma*	- -	- -	1	- -	- -	- -	- -	- -	- -	- -	- -	- -
	Corixidae	*Palmacorixa*	- -	4	34	4	- -	- -	- -	- -	- -	- -	- -	- -
	Hebridae	*Lipogomphus*	- -	1	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
	Naucoridae	*Limnocoris*	- -	2	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
	Veliidae	*Rhagovelia*	- -	1	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Hydracarina			- -	- -	1	- -	- -	- -	- -	- -	- -	- -	- -	- -
Megaloptera	Corydalidae	*Corydalus*	- -	- -	- -	1	- -	- -	- -	- -	- -	- -	- -	- -
Odonata	Calopterygidae	*Hetaerina*	2	1	- -	1	- -	- -	- -	- -	- -	- -	- -	- -
	Coenogrionidae	*Argia*	2	2	9	3	- -	- -	- -	- -	- -	- -	- -	- -
	Gomphidae	*Erpetogomphus*	8	2	- -	2	- -	- -	- -	- -	- -	- -	- -	- -
		Gomphus	- -	2	- -	5	- -	- -	- -	- -	- -	- -	- -	- -
		Progomphus	- -	1	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
		Stylurus	- -	3	- -	1	- -	- -	- -	- -	- -	- -	- -	- -
	Macromidae	*Didymops*	- -	1	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Oligochaeta	Oligochaeta		26	8	1	7	- -	- -	- -	- -	- -	- -	- -	- -
Trichoptera	Hydropsychidae	*Ceratopsyche*	16	3	- -	27	- -	- -	- -	- -	- -	- -	- -	- -
		Hydropsyche	39	1	- -	7	- -	- -	- -	- -	- -	- -	- -	- -
	Leptoceridae	*Nectopsyche*	- -	11	125	2	- -	- -	- -	- -	- -	- -	- -	- -
		Total	222	208	207	234								

Appendix 2a. Total fish collected by season at each sample site in 2005. WR1 and WR2 are upstream and WR3 and WR4 downstream from a reverse osmosis plant that began discharging in February 2009.

	Spring				Summer				Fall			
Species	WR1	WR2	WR3	WR4	WR1	WR2	WR3	WR4	WR1	WR2	WR3	WR4
Aplodinotus grunniens	--	--	1	2	1	--	--	1	--	--	2	--
Carpiodes carpio	--	--	1	--	1	--	--	--	1	1	--	--
Cyprinella lutrensis	1,161	1,308	354	1030	1,363	434	920	818	136	698	299	1,180
Cyprinella venusta	--	--	--	--	--	--	--	--	--	--	--	--
Cyprinodon rubrofluviatilis	--	--	--	--	--	--	--	--	--	--	--	--
Cyprinus carpio	--	--	1	--	--	--	--	--	--	--	--	--
Dorosoma cepedianum	--	1	--	--	4	--	20	18	--	--	--	--
Dorosoma petenense	--	--	--	--	1	--	--	--	--	--	--	--
Fundulus grandis	--	--	--	--	--	--	--	1	--	--	--	--
Gambusia affinis	22	18	9	9	272	96	379	107	17	10	60	16
Hybognathus placitus	1	1	1	--	2	15	5	16	--	--	--	--
Ictalurus furcatus	--	--	--	--	--	1	1	1	--	--	--	--
Ictalurus punctatus	--	--	2	--	2	1	5	15	--	2	--	--
Ictiobus bubalus	--	1	--	--	--	4	1	--	--	--	1	--
Lepisosteus oculatus	--	1	--	--	--	--	--	--	1	--	--	--
Lepisosteus osseus	--	3	--	1	4	1	--	--	--	--	--	--
Lepisosteus platostomus	--	--	1	--	--	--	--	--	--	--	--	--
Lepomis cyanellus	--	--	2	--	--	1	--	1	--	--	--	--
Lepomis gulosus	--	--	--	--	1	--	1	--	--	--	--	--
Lepomis humilis	1	--	3	3	2	--	1	6	--	--	--	2
Lepomis macrochirus	--	--	--	--	--	--	1	--	--	--	1	--
Lepomis megalotis	1	1	--	6	--	1	1	4	--	1	--	--
Lepomis sp.(unknown)	--	--	--	--	1	--	1	--	--	--	--	--
Macrhybopsis australis	--	--	--	--	--	--	--	--	--	--	--	--
Macrhybopsis hyostoma	--	--	--	--	--	--	--	3	--	--	--	2
Macrhybopsis storeriana	--	--	--	--	--	--	--	--	--	--	--	--
Menidia beryllina	--	--	--	1	14	11	21	10	2	--	--	1
Notropis atherinoides	5	--	3	--	--	--	1	--	--	--	1	--
Notropis buchanani	--	6	--	1	--	--	2	6	--	--	--	--
Notropis potteri	--	--	--	--	--	--	--	--	--	--	--	--
Notropis stramineus	--	--	--	--	2	2	7	1	--	--	--	1
Phenacobius mirabilis	--	--	--	--	1	3	--	1	--	2	--	--
Pimephales promelas	1	--	--	1	4	25	11	27	--	--	--	--
Pimephales vigilax	17	65	29	38	221	147	639	197	7	1	5	22
Pomoxis annularis	--	--	--	--	--	--	--	--	--	--	--	--
Pylodictis olivaris	--	--	--	--	--	2	--	1	--	--	--	--
Total	1,209	1,405	407	1,092	1,896	744	2,017	1,234	164	715	369	1,224

Appendix 2b. Total fish collected by season at each sample site in 2008. WR1 and WR2 are upstream and WR3 and WR4 downstream from a reverse osmosis plant that began discharging in February 2009.

	Spring				Summer				Fall			
Species	WR1	WR2	WR3	WR4	WR1	WR2	WR3	WR4	WR1	WR2	WR3	WR4
Aplodinotus grunniens	--	1	--	--	--	--	1	--	--	--	--	--
Carpiodes carpio	--	--	--	--	--	2	9	1	3	1	1	--
Cyprinella lutrensis	792	349	648	1,033	221	892	288	395	1,239	1,104	715	495
Cyprinella venusta	--	--	--	--	--	--	--	--	--	--	--	--
Cyprinodon rubrofluviatilis	--	--	--	--	--	--	--	--	1	--	--	--
Cyprinus carpio	--	--	--	--	--	--	--	--	--	1	1	--
Dorosoma cepedianum	--	--	--	--	--	1	--	--	--	--	--	--
Dorosoma petenense	--	--	--	--	--	--	--	--	--	--	--	--
Fundulus grandis	--	--	--	--	--	--	--	--	--	--	--	--
Gambusia affinis	4	6	21	10	16	14	76	15	38	43	52	6
Hybognathus placitus	--	--	--	--	5	85	42	28	9	18	--	2
Ictalurus furcatus	--	--	--	--	6	14	4	--	--	2	--	--
Ictalurus punctatus	3	2	--	2	--	9	10	3	2	9	6	8
Ictiobus bubalus	--	--	--	--	1	--	6	--	1	--	--	--
Lepisosteus oculatus	--	--	--	--	--	--	--	--	--	--	--	--
Lepisosteus osseus	--	--	--	--	--	--	--	--	--	1	--	1
Lepisosteus platostomus	--	--	--	--	--	--	--	--	--	--	1	--
Lepomis cyanellus	1	--	1	2	--	--	--	--	--	--	--	--
Lepomis gulosus	--	--	--	--	--	1	--	--	--	--	--	--
Lepomis humilis	1	1	1	1	--	3	1	1	--	--	--	2
Lepomis macrochirus	--	--	--	--	--	--	--	--	--	--	--	2
Lepomis megalotis	--	--	--	1	1	7	1	5	1	6	1	2
Lepomis sp.(unknown)	--	--	--	--	--	--	--	--	--	--	--	--
Macrhybopsis australis	--	--	--	--	--	--	2	--	--	--	--	--
Macrhybopsis hyostoma	--	--	--	--	--	2	--	--	--	--	--	1
Macrhybopsis storeriana	--	--	--	--	--	--	--	--	--	--	1	--
Menidia beryllina	--	--	1	1	--	4	6	6	--	--	1	1
Notropis atherinoides	1	--	--	--	--	--	--	2	1	3	2	5
Notropis buchanani	--	1	1	--	--	2	--	17	--	2	2	3
Notropis potteri	--	--	--	--	--	--	--	--	--	--	--	--
Notropis stramineus	--	1	--	--	2	--	--	--	9	--	8	4
Phenacobius mirabilis	--	--	--	--	2	1	1	2	--	1	--	--
Pimephales promelas	1	--	--	--	--	1	--	--	--	--	--	--
Pimephales vigilax	133	24	57	52	177	226	383	209	304	655	419	230
Pomoxis annularis	--	1	--	--	--	--	--	--	--	--	--	--
Pylodictis olivaris	--	--	--	--	1	--	--	--	--	1	--	--
Total	937	386	730	1,102	432	1,264	830	684	1,608	1,847	1,210	762

Appendix 2c. Total fish collected by season at each sample site in 2009. WR1 and WR2 are upstream and WR3 and WR4 downstream from a reverse osmosis plant that began discharging in February 2009.

	Spring				Summer				Fall			
Species	WR1	WR2	WR3	WR4	WR1	WR2	WR3	WR4	WR1	WR2	WR3	WR4
Aplodinotus grunniens	--	--	--	--	--	--	--	--	--	--	--	--
Carpiodes carpio	--	--	--	--	--	1	--	1	--	2	1	--
Cyprinella lutrensis	--	--	--	--	114	347	230	310	469	716	578	1,104
Cyprinella venusta	--	--	--	--	--	--	--	--	--	1	--	--
Cyprinodon rubrofluviatilis	--	--	--	--	--	--	--	--	--	2	--	--
Cyprinus carpio	--	--	--	--	--	--	--	--	--	--	--	--
Dorosoma cepedianum	--	--	--	--	23	21	27	8	--	--	--	--
Dorosoma petenense	--	--	--	--	--	--	--	--	--	--	--	--
Fundulus grandis	--	--	--	--	--	--	1	--	--	--	--	--
Gambusia affinis	--	--	--	--	45	54	42	27	31	40	29	7
Hybognathus placitus	--	--	--	--	1	2	10	12	--	--	--	--
Ictalurus furcatus	--	--	--	--	2	1	--	3	--	--	--	--
Ictalurus punctatus	--	--	--	--	4	5	4	3	--	7	2	2
Ictiobus bubalus	--	--	--	--	--	1	--	--	--	--	--	--
Lepisosteus oculatus	--	--	--	--	--	--	--	--	--	--	--	--
Lepisosteus osseus	--	--	--	--	2	--	1	--	1	1	--	--
Lepisosteus platostomus	--	--	--	--	--	--	--	--	1	--	--	--
Lepomis cyanellus	--	--	--	--	--	--	1	--	--	--	--	--
Lepomis gulosus	--	--	--	--	--	1	--	--	--	--	--	--
Lepomis humilis	--	--	--	--	--	--	1	--	--	--	2	1
Lepomis macrochirus	--	--	--	--	--	--	--	--	--	--	--	--
Lepomis megalotis	--	--	--	--	--	4	--	1	--	--	--	1
Lepomis sp.(unknown)	--	--	--	--	--	--	--	--	--	--	--	--
Macrhybopsis australis	--	--	--	--	--	--	--	2	--	2	2	3
Macrhybopsis hyostoma	--	--	--	--	--	--	--	--	--	1	--	--
Macrhybopsis storeriana	--	--	--	--	--	--	--	--	--	--	--	--
Menidia beryllina	--	--	--	--	--	6	3	--	--	--	--	1
Notropis atherinoides	--	--	--	--	1	--	2	--	7	37	30	62
Notropis buchanani	--	--	--	--	--	--	--	1	--	--	--	1
Notropis potteri	--	--	--	--	--	--	--	1	--	--	--	--
Notropis stramineus	--	--	--	--	1	5	5	6	8	63	23	77
Phenacobius mirabilis	--	--	--	--	--	--	--	--	3	2	--	--
Pimephales promelas	--	--	--	--	--	--	--	--	--	--	--	--
Pimephales vigilax	--	--	--	--	101	62	83	100	203	233	276	210
Pomoxis annularis	--	--	--	--	--	--	--	--	--	--	--	--
Pylodictis olivaris	--	--	--	--	--	--	--	--	--	--	--	--
Total					294	510	410	475	723	1,107	943	1,469

Appendix 2d. Total fish collected by season at each sample site in 2010. WR1 and WR2 are upstream and WR3 and WR4 downstream from a reverse osmosis plant that began discharging in February 2009.

	Spring				Summer				Fall			
Species	WR1	WR2	WR3	WR4	WR1	WR2	WR3	WR4	WR1	WR2	WR3	WR4
Aplodinotus grunniens	--	--	--	--	--	--	--	--	--	--	--	--
Carpiodes carpio	--	--	--	--	--	--	--	--	--	--	--	--
Cyprinella lutrensis	--	--	--	--	306	309	88	475	1,009	1,284	831	1,087
Cyprinella venusta	--	--	--	--	--	--	--	--	--	--	--	--
Cyprinodon rubrofluviatilis	--	--	--	--	--	--	--	--	--	--	--	--
Cyprinus carpio	--	--	--	--	--	--	--	1	--	--	--	--
Dorosoma cepedianum	--	--	--	--	--	--	--	--	--	--	--	--
Dorosoma petenense	--	--	--	--	--	--	--	--	--	--	--	--
Fundulus grandis	--	--	--	--	--	--	--	--	--	--	--	--
Gambusia affinis	--	--	--	--	1	--	1	23	25	58	3	8
Hybognathus placitus	--	--	--	--	--	7	2	3	2	2	--	--
Ictalurus furcatus	--	--	--	--	1	--	2	1	--	1	2	--
Ictalurus punctatus	--	--	--	--	2	4	--	2	--	3	2	1
Ictiobus bubalus	--	--	--	--	1	--	--	--	--	4	--	--
Lepisosteus oculatus	--	--	--	--	--	--	--	--	--	--	--	--
Lepisosteus osseus	--	--	--	--	2	1	--	--	--	2	--	--
Lepisosteus platostomus	--	--	--	--	--	--	--	--	--	--	--	--
Lepomis cyanellus	--	--	--	--	--	--	--	--	--	--	--	--
Lepomis gulosus	--	--	--	--	--	--	--	--	--	--	--	--
Lepomis humilis	--	--	--	--	--	--	--	--	--	--	--	--
Lepomis macrochirus	--	--	--	--	--	--	--	--	1	--	--	--
Lepomis megalotis	--	--	--	--	--	--	--	3	--	--	--	--
Lepomis sp.(unknown)	--	--	--	--	--	--	--	--	--	--	--	--
Macrhybopsis australis	--	--	--	--	--	2	--	--	--	1	--	2
Macrhybopsis hyostoma	--	--	--	--	--	--	--	--	--	2	--	--
Macrhybopsis storeriana	--	--	--	--	--	--	--	--	--	--	--	--
Menidia beryllina	--	--	--	--	1	3	4	27	--	11	1	--
Notropis atherinoides	--	--	--	--	3	22	11	28	9	196	174	427
Notropis buchanani	--	--	--	--	--	9	3	6	1	18	7	17
Notropis potteri	--	--	--	--	--	--	--	--	--	--	--	--
Notropis stramineus	--	--	--	--	--	--	2	2	17	50	30	46
Phenacobius mirabilis	--	--	--	--	--	--	--	--	--	--	--	3
Pimephales promelas	--	--	--	--	--	--	--	--	--	--	--	1
Pimephales vigilax	--	--	--	--	15	9	42	109	131	101	118	97
Pomoxis annularis	--	--	--	--	--	--	--	--	--	--	--	--
Pylodictis olivaris	--	--	--	--	--	--	--	--	--	--	--	--
Total					332	366	155	680	1,195	1,733	1,168	1,689

Appendix 2e. Total fish collected by season at each sample site in 2011. WR1 and WR2 are upstream and WR3 and WR4 downstream from a reverse osmosis plant that began discharging in February 2009.

	Spring				Summer				Fall			
Species	WR1	WR2	WR3	WR4	WR1	WR2	WR3	WR4	WR1	WR2	WR3	WR4
Aplodinotus grunniens	--	--	--	--	--	--	--	--	--	--	--	--
Carpiodes carpio	--	--	--	--	--	--	--	--	--	--	--	--
Cyprinella lutrensis	379	904	571	1275	--	--	--	--	--	--	--	--
Cyprinella venusta	1	--	--	--	--	--	--	--	--	--	--	--
Cyprinodon rubrofluviatilis	--	--	--	--	--	--	--	--	--	--	--	--
Cyprinus carpio	--	--	--	--	--	--	--	--	--	--	--	--
Dorosoma cepedianum	--	--	--	--	--	--	--	--	--	--	--	--
Dorosoma petenense	--	--	--	--	--	--	--	--	--	--	--	--
Fundulus grandis	--	--	--	--	--	--	--	--	--	--	--	--
Gambusia affinis	--	4	--	2	--	--	--	--	--	--	--	--
Hybognathus placitus	--	3	--	--	--	--	--	--	--	--	--	--
Ictalurus furcatus	--	--	--	--	--	--	--	--	--	--	--	--
Ictalurus punctatus	2	1	--	--	--	--	--	--	--	--	--	--
Ictiobus bubalus	1	--	1	--	--	--	--	--	--	--	--	--
Lepisosteus oculatus	--	--	--	--	--	--	--	--	--	--	--	--
Lepisosteus osseus	1	--	--	1	--	--	--	--	--	--	--	--
Lepisosteus platostomus	--	--	1	--	--	--	--	--	--	--	--	--
Lepomis cyanellus	--	--	--	--	--	--	--	--	--	--	--	--
Lepomis gulosus	--	--	--	--	--	--	--	--	--	--	--	--
Lepomis humilis	--	--	--	--	--	--	--	--	--	--	--	--
Lepomis macrochirus	1	--	--	--	--	--	--	--	--	--	--	--
Lepomis megalotis	--	--	--	--	--	--	--	--	--	--	--	--
Lepomis sp.(unknown)	--	--	--	--	--	--	--	--	--	--	--	--
Macrhybopsis australis	--	2	--	3	--	--	--	--	--	--	--	--
Macrhybopsis hyostoma	--	--	--	--	--	--	--	--	--	--	--	--
Macrhybopsis storeriana	--	--	--	--	--	--	--	--	--	--	--	--
Menidia beryllina	--	2	--	--	--	--	--	--	--	--	--	--
Notropis atherinoides	45	205	56	91	--	--	--	--	--	--	--	--
Notropis buchanani	6	82	13	76	--	--	--	--	--	--	--	--
Notropis potteri	--	--	--	--	--	--	--	--	--	--	--	--
Notropis stramineus	4	50	16	11	--	--	--	--	--	--	--	--
Phenacobius mirabilis	--	--	--	1	--	--	--	--	--	--	--	--
Pimephales promelas	--	--	--	--	--	--	--	--	--	--	--	--
Pimephales vigilax	88	141	55	180	--	--	--	--	--	--	--	--
Pomoxis annularis	--	--	--	1	--	--	--	--	--	--	--	--
Pylodictis olivaris	--	1	1	1	--	--	--	--	--	--	--	--
Total	528	1395	714	1,642								

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