An Investigation into the Potential Impacts of Coal Tar Contamination on the Invertebrate Community of the Congaree River near the City of Columbia, Richland County, SC

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07/07/2017

2600 Bull Street
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Technical Report Number 0804-17

dhec
S.C. Department of Health and Environmental Control

Suggested Citation

Glover, J.B. 2017. An investigation into the potential impacts of coal tar contamination on the invertebrate community of the Congaree River near the City of Columbia, Richland County, SC. The South Carolina Department of Health and Environmental Control Technical Report No. ***-17. Bureau of Water, Columbia, SC.

Summary

On 15 June 2017, staff of the Aquatic Biology Section within the Bureau of Water of DHEC conducted an aquatic macroinvertebrate bioassessment of the Congaree River near Columbia, SC. The goal of the study was to determine if sediment contaminated with coal tar in the Congaree River was having an adverse impact to the indigenous invertebrate fauna near the sediment plume. The contamination was a waste by-product of a former manufactured gas plant, which was in operation during the first half of the 20th century.

The extent of contaminated sediment had been well characterized previously by South Carolina Electric and Gas (SCE&G) through a voluntary cleanup agreement with DHEC. Much of the contaminated sediment had been covered with tons of sediment in 2015, after severe flooding resulted in a breach of a canal. This sediment also covered much of the natural invertebrate habitat in this section of river. Two stations were established to evaluate the potential effects of the contamination of the biotic health of the river. A control site was located immediately upstream of the Gervais Street Bridge and a test site was established at the Blossom Street Bridge, directly downriver from the region with the highest levels of coal tar contamination.

The results of the June 2017 study indicated that the aquatic macroinvertebrate community at the Blossom Street Bridge was comparable to the upriver control, both receiving a bioclassification score of 4.5 (Excellent) on the Carolina Biocondition Scale. The community structure at both sites showed that there was a diverse and balanced community of invertebrates, with the presence of numerous pollution sensitive species. The EPT index, which quantifies the number of pollution sensitive mayflies, stoneflies, and caddisflies, respectively, was 22 at both the control and test site. These values were similar to those recorded in the recent past by DHEC on the lower Broad River and other locations on the Congaree River. The biotic condition on the Broad and Congaree Rivers, as measured by macroinvertebrate bioassessments, were much better than on the lower Saluda River, where bioclassifications ranged from Poor to Fair in the recent past. These lower ratings on the Saluda River are likely a result of numerous factors common to rivers located directly below large dams. These conditions are well studied and include flashy flows, altered water chemistry, and the disruption of the continuum of energy transfer in lotic waters.

At the time of this investigation, any current or potential harm to the aquatic invertebrate community near the contaminated site was not suggested. Rather the results indicated a balanced and indigenous community of aquatic invertebrate species that are indicative of a healthy river. The study does not address the potential of the tar contamination to effect other environmental end points such bioaccumulation, the potential of toxicity in the region of the higher tar contamination, or chronic impacts that may occur in other assemblages such as in fish. The study addresses, in part, environmental risk and thus is not intended to address the risk to human health from direct exposure to the contaminated sediment, which has been evaluated in other reports.

Introduction

Brief History of Manufactured Gas

Beginning in the early 1800's and continuing to date, fossil fuels became an ever increasing requirement of domestic and industrial growth throughout the world (Tarr 2014). Natural gas is one such fuel source that is familiar to most and that is used extensively today in homes and industry. However, up until 1950 the gas used for equivalent purposes was not natural gas, which is mostly methane, but a mixture of flammable gases produced from coal through a series of refinery processes. In addition to gas, there were also several refinery byproducts produced, such as tar, which was at times either repurposed and used or discarded. This flammable gas was known by various names but today the phrase "manufactured gas" or "town-gas" is often used in reference to coal-gas, with a former facility often being called a manufactured gas plant (MGP).

As industrialization expanded, pollution caused by the disposal of the byproducts became a global issue of concern and this continues to date (Hatheway 2012). Noxious odors, the contamination of soils near facilities, the contamination of wells, and the pollution of surface waters were common complaints during the period when plants were in operation. This spurred lawsuits and led to some state and federal environmental regulations being adopted to mitigate harm (Tarr 2014). By the 1970's, the manufactured gas industry was all but gone in the US. However, many of the environmental regulations that were enacted during this decade aimed at remediating legacy contaminants of this kind. One of the first comprehensive efforts to document the number of "town gas" operations and provide an estimate of the amount of tar produced by these facilities was conducted by the U.S. Environmental Protection Agency (EPA) and published in 1985 (EPA 1985). In this report, an estimated 1500 MGP existed in the US between 1889 and 1950, which produced an estimated 11 billion gallons of tar as a byproduct. These tar byproducts may have been sold or reused at the facility, but much of the excess was disposed of in some fashion. To compile these statistics EPA utilized a variety of literature including Browns Directory of American Gas Companies, which was an annual report produced since the late 1800s. For SC, a total of 11 sites were reported with 2 being considered "large sites"(>200 mm scf/year). South Carolina as a whole produced an estimated 33 million gallons (125 million liters) of tar, which ranks 29th Nationally. This compares to 2.8 billion gallons (10.5 billion liters) for the state of New York (ranked 1) and 1 million gallons (3.79 million liters) of tar for Oklahoma (ranked 51st).

The subject of this current investigation and report is the Columbia facility owned at the time by the SC Gas and Light Company (now SCE&G), which was the largest tar producer in the state. The average rate of production by this facility was 289,000 gallons (1.1 million liters) of tar produced each year, with peak production at 369,000 gallons (1.4 million liters) of tar per year (EPA 1985).

Congaree River and its Watershed

The Congaree River is a relatively short segment of waterway that is contained within the Santee Watershed, the headwaters of which are in the Blue Ridge Mountains (Figure 1). The Congaree begins near Columbia, SC after the Saluda River and the Broad River merge. After the Wateree River merges with the Congaree River, a name change occurs, with the union creating the Santee River. The headwaters of both the Broad River and the Saluda River are in the Blue Ridge Mountains, with some tributaries separated only by a mountain ridge. Their paths diverge as they carve their way through the piedmont. The waters of the Saluda are fully contained within SC, while some to the Broad Rivers headwaters are located in NC. The Broad River Watershed is about twice the size of the Saluda, at over 13,700 Km^2 versus 6500 Km^2, respectively. The landuse is very similar for both the Saluda and the Broad River Watersheds (Figure 2), being mostly forested and rural. Both watersheds have similar proportions of developed area (15.7% Saluda, 12.5% Broad) with pasture/hay also being rather dominant (14.8% Saluda, 15.2% Broad). The waterways in both watersheds have numerous impoundments with Lake Murray near Columbia likely exerting the greatest influence on the chemical and biological differences seen between the lower portions of the two rivers. Once the two rivers merge, the entire watershed upstream of points on the Congaree River should, in theory, be an aggregate of the Broad River and Saluda River watersheds. In reality however the two rivers appear to remain unmixed for some distance, with samples collected from the Richland County side of the Congaree best thought of as the Broad River Watershed and those of the Lexington County side best considered the Saluda River watershed.

Tar in the Congaree River

It was in March, 1951 that the nascent SC Water Pollution Control Authority, established a year earlier and residing as a unit within the State Board of Health, received its first complaint about tar contamination in the Congaree River (SC Board of Health 1950/51). Three anglers wrote a letter to the board demanding an investigation and a hearing concerning the "condition of the Congaree River below Columbia bridge in reference to gas tar and other impure substances" entering the river. They wrote "We fish on this stream and unless something is done to prohibit polluting of same, there will be very little or no fishing in the near future." After a hearing in April the authority notified the SC Electric and Gas Company of the complaint and representatives appeared before the authority at a May 1951 board meeting, at which time it was acknowledged by SCE&G staff that "there was a possibility of the discharge into the Congaree River of a small quantity of tarry substances from the gas manufacture plant." In a June, 1951 board meeting, it was agreed that monitoring of the tarry substance should be initiated at the facility and if detected, that a request would be made for SCE&G to appear before the authority for explanation.

No further mention of the tarry substance or the facility could be found in the literature or annual reports of the State Board of Health, the Water Pollution Control Authority, or the Pollution Control Authority. It was in the 1950's that natural gas began to replace manufactured gas throughout the Nation (Tarr 2014) and the refinery process at the Columbia facility was discontinued. The small staff of the Water Pollution Control Authority (13 total in 1957) appeared to have focused much of their energies on sewage within the highly polluted waterways of the state, using what environmental laws they had at their disposal during this era to attempt improvements. For example, in 1965 the SC Water Pollution Control Authority ordered Columbia, Cayce, and West Columbia to implement sewage treatment because of the polluted condition in the Congaree River (Florence Morning News, 1965). By the time more robust federal and state environmental laws were enacted in the 1970's, it appears the knowledge of this tarry substance, until now, had been lost to history.

An awareness of the tarry substance was revived in June, 2010 when DHEC received reports of a tar like material (TLM) in the sediments of the Congaree River. An investigation traced the likely source to the old SCE&G manufacture gas plant. Subsequent studies carried out shortly after this by SCE&G delineated the extent of the contaminated sediment within the river, the majority of which is found beginning downriver of the confluence of an unnamed tributary that drained the MGP site, extending downriver approximately 9000 feet (2743.2 meters) and medially into the river approximately 200 feet (60.96 meters). This tributary converged with the Congaree immediately downriver of the Gervais Street Bridge. Additional information, to include site history, can be found in SCANA (2012) and SCANA (2013).

Bioassessments of Waters of the Nation

Broadly defined, bioassessment of surface water is the use of living organisms or the chemicals they produce to determine the conditions of natural waters, particularly as it relates to degradation of our waterways (Cairns and Dickenson 1973). For example, an indicator species or group of species, such as Fecal coliform bacteria, may suggest a sewage spill or septic tank leak, which may indicate high levels of pathogens that are harmful to human health. Elevated levels of chlorophyll a or microcystin (a toxin produced by cyanobacteria) may suggest nutrients, such as from fertilizers, could be polluting the waterway. The response of certain species of organisms exposed to potentially contaminated water or sediment may indicate toxicity, the end point being the organisms ability to survive and reproduce. Since aquatic animals are continuously exposed to their surrounding waters they may bioaccumulate and/or biomagnify certain chemicals, which may cause acute or chronic toxicity to the organism or to humans and other animals that might consume them.

The investigation conducted in 2017 and presented here is of the variety thought of as a community bioassessment. Of the thousands of species of plants and animals living in natural waters, some are intolerant of certain contaminants or physical alterations while others can survive in highly polluted waters. By knowing the tolerance thresholds for these organisms, their physical presence or absence can tell environmental mangers a great deal about both current and past conditions of the water. This was first recognized well over 100 years ago by Cohn (1853), with much literature being produced since that time. Freshwater macroinvertabrates, which are species of animals which do not have backbones and are large enough to be seen without the aid of a microscope, are a highly diverse group of creatures present in waterways around the world. This assemblage includes aquatic insects, crustaceans, aquatic snails, and clams. These creatures provide the end points to assess the condition of the Congaree River both upriver and downriver of the contaminated site.

Methods

The macroinvertebrate bioassessment program as it exists today at DHEC, began in the early 1970's, and has been used to meet various needs and requirements of the Clean Water Act, the SC Pollution Control Act, and other state and federal laws developed to preserve and protect the environment and public health. Methods for the collection and interpretation of macroinvertebrate bioassessments can be found in DHEC (1998). These methods were originally developed for wadeable streams but have been utilized also in large rivers. After samples are collected and preserved in ethanol, returned to the laboratory, identified, and entered into a computer database, it is possible to calculate a numeric value that represents the biocondition of the stream or river. The final score is referred to as the bioclassification score and the narrative description of the condition of the waterway is as follows: Poor (1), Fair (2), Good-Fair (3), Good (4), and Excellent (5). There are two component parts to the bioclassification score; the EPT Index and the Biotic Index. The EPT Index is the sum of the different species at a location that belong to the orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). As a group the species in these three orders are intolerant of pollution and will be reduced or completely absent in polluted streams and rivers. The Biotic Index (BI) is calculated by incorporating tolerance values (TV) for each species of organisms collected at a site into an equation. Numerous methods of calculating tolerance values have been proposed including those by Pantel and Buck (1953), Chutter (1972), Hillsenhoph (1977) and Lenat (1993), the latter of which is specific for the southeastern U.S. The tolerance values of Lenat (1993) range from 1 to 10 for a given species, with 1 being the least tolerant species (better) and 10 being the most tolerant species to pollution. The biotic index thus also ranges from 1 to 10 with a lower score indicating a less polluted stream or river. The final bioclassification is computed by first standardizing the EPT Index and Biotic Index to a common scale of 1 to 5 and then taking the arithmetic mean. The ecoregion in which a stream is located greatly influences the composition of aquatic macroinvertebrate communities and different scales are used to compute bioclassification scores based on the geographic location of the sample site (Lenat 1993). The bioclassification score describes the overall health of a stream but is not meant to diagnose cause. However, if a potential stressor is known to exist, such as a point source discharge, an upstream site may be established as a control for the downstream location, with the difference between the scores of the two sites used for evaluation. Select examples of similar bioassessment investigations into sediment contamination from MGPs are shown in Table 1, and include sites in Michigan, Vermont, Colorado, and New York.

On 15 June 2017, Scott Castleberry, David Eargle , and Justin Lewandoski with DHEC's Aquatic Biology Section collected aquatic macroinvertebrates from two sites located on the eastern (Broad River) side of the Congaree River near downtown Columbia. These sites are near the confluence of the Broad and Saluda Rivers and are just upstream and just downstream of the section of riverbed where the major plume of contaminated sediment is located. No samples were collected directly in the area containing the highest levels of contaminated sediment because the 2015 floods and resulting blow out of the Columbia Canal, which buried most available habitat in that area under a thick layer of sediment. At both sampling locations, the waters of the Saluda and Broad Rivers remain relatively unmixed. As the Broad contributes about two thirds of the volume of the Congaree, these sampling sites would naturally be influenced almost entirely by the waters of the Broad River with little or no effect from conditions in the Saluda. Urban development was very dense near both sites as would be expected in a city. That said, the watershed of the Congaree River is sufficiently large that these sites likely experience significant influence from the more forested areas upriver. At the time of sampling, water levels were relatively low with the USGS gauging station, “Congaree River at Columbia” registering about 3.05 feet.

The upstream control site, station S-1007, was established on the eastern side of the Congaree River just upstream of the Gervais Street Bridge (Figure 3). Sampling took place over a 180 meter reach with the bridge forming the downstream border. Habitat here consisted primarily of boulders, cobbles and exposed bedrock often covered with riverweed *(Podostemum ceratophyllum).* Logs and other woody habitat were also plentiful. Good riparian root habitats were difficult to find and processed leaf detritus was absent, which is not unusual in large rivers. Very little sedimentation was observed. Flow was strong but low water levels allowed easy access by wading. Three biologists sampled this site for a total of 4.5 person-hours.

The downstream test site, station CSB-001R, was sampled from a point adjacent to the pump station at the end of Wheat Street and extended upstream from there for 150 m with the reach ending slightly downstream of the Blossom Street Bridge (Figure 4). Like the upstream site, boulders, cobbles and bedrock covered in riverweed, along with submerged logs and sticks, made up the most abundant habitats. Riparian subaquatic root habitat again was scarce. No detrital leaf packs were observed, which is consistent with predictions of the river continuum concept for large rivers (Vannote et al. 1980). There was a moderate amount of sedimentation here but in this regard, this site was much more similar to the upstream site, S-1007, than it was to the area between the two, which based on observations from several days prior, appeared buried in sediment. Flow was strong as it was upstream and the low water levels allowed easy access to the available habitats by wading. Three biologists sampled this site for a total of 4.5 person- hours.

Evaluation of Data

The bioclassification scores were compared to evaluate the results from these two sample sites. Component parts of the bioclassification scores along with other observations of individual species collected at each site were also compared.

Over the past several years DHEC has conducted increased numbers of bioassessments on large rivers in an attempt to gain a better understanding of the biological conditions of these waterways. Bioassessments of large rivers have also been part of various permitting requirements including FERC relicensing of large impoundments. While the similarity of the two sites located upriver and downriver of the contaminated river reach formed the basis of the evaluation, to add context and insight the results of other nearby stations are included in this report. These include stations collected from the Saluda River below Lake Murray Dam, two sites on the lower Broad River and two additional sites further downriver on the Congaree River. Sites on the Saluda River were collected in 2006 as part of a FERC relicensing project (Carnagey Biological Services 2006) while sampling sites on the Saluda, Broad and Congaree were collected by DHEC in 2014.

Results and Discussion

The aquatic macroinvertrate bioassessment conducted on the Congaree River in 2017 indicated the presence of a balanced and indigenous community of aquatic invertebrates at each sample location (Table 2, Table 3). The taxa richness at the upstream control site was 54 while 55 different taxa were indentified at the Blossom Street Bridge site. The EPT index of 22 at both the control and downriver location indicated there were abundant species of pollution intolerant organisms, and this suggests a healthy ecosystem. The Biotic Index values of 4.56 at the control and 4.64 at the Blossom Street station were remarkably similar and points to a waterway that is unimpaired by severe pollution or physical alteration. Because the bioclassification protocols were designed for smaller, wadeable streams, we report here the bioclassification scores using both the piedmont and coastal plain criteria. While the watersheds of most small streams are contained within a single ecoregion, the sites on the Congaree River, while physically located in the coastal plain, are of mostly piedmont origin. Regardless, both the upstream and downstream sites were identical with a bioclassification of Excellent (4.5) at both sites using the coastal plain criteria and Good (4.2) using the piedmont criteria. While the indices were nearly identical, there were slight faunal differences between the two sites, which is to be expected for most waterways. The upstream control had more stoneflies, while more unionid mussels were encountered at the Blossom

Street Bridge location (Figure 5). The unionid mussels that documented at the Blossom Street site included *Elliptio roanokensis* (Roanoke Slabshell), *Elliptio congarea* (Carolina Slabshell), *Lampsilis cariosa* (Yellow Lamp mussel), and *Elliptio complanata* (Eastern Eliptio). Differences in species composition is likely due to natural variability rather than significant differences in water quality. The presence of the relatively immobile unionid mussels, some of which are up to 5 years of age, further suggests that the contaminated sediment has not impacted the native invertebrate fauna of the Congaree River at the Blossom Street Bridge. The presence of a very young Yellow Lamp mussel also demonstrates ongoing recruitment to this area.

Bioassessment results for the Saluda, Broad, and Congaree Rivers conducted in previous years are reported here to add context and insight into the results of this investigation (Figure 6). Results from the Saluda River were gathered in 2006 by Carnagey Biological Services (2006), which was conducted during a FERC Relicensing process of the Lake Murray Dam. There were 6 sites collected by DHEC in 2014 as part of the ambient monitoring program: 2 on the lower Saluda River, 2 on the Lower Broad River, and 2 on the Congaree River. As shown in Figure 6, stations on the Lower Broad River and the Congaree River are comparable and indicate a Good to Excellent biocondition. By contrast, the invertebrate fauna on the Saluda River near the Lake Murray Dam resulted in a score of Poor (1.0 - 1.5) in 2006. Conditions progressively improved moving away from the dam with a biocondition of Fair (2.0 - 2.2) being measured in the Saluda River near the Zoo. The values shown in Figure 6 for the Saluda are all from the year 2006. Not shown are two additional sampling sites from 2014, evaluated by DHEC, that indicated a bioclassification of 2.5 (Fair to Good-Fair) at S-1002, which is fairly close to the dam and also a score of 2.5 at S-298, a station slightly upriver of the zoo location. This suggests that conditions may have improved somewhat since 2006, although season, natural variability, or difference in local conditions at the sampling site could account for the differences. Regardless, the biotic condition of the Saluda River is not as good as those in the Broad and Congaree, likely because of numerous variables associated with the reservoir. The effects of large dams on rivers have been studied and reviewed extensively (see Poff 1997) and changes in aquatic biota are thought related to numerous conditions such as flashy flows, water chemistry alterations, and alterations of energy flows within lotic waterways.

Conclusion

The results of this study show that the Congaree River in the vicinity of a large section of river contaminated with coal tar contained a diverse community of aquatic macroinvertebrates, and this is indicative of a healthy river system. While the area immediately adjacent to both sampling locations is highly urbanized, the watershed itself remains relatively well forested. Both sites are below the confluence of the Saluda River, but on the east side of the river it appears the water remains highly stratified, with the Broad River likely dominating conditions in the river at that point. There are no indications that the contaminated sediment has contributed measureable acute or chronic toxicity to the benthic invertebrate fauna in the Congaree River near Blossom Street. It is unclear if results may have been different before the 2015 floods, in which the majority of the contaminated sediment was covered in heavy fresh sediment from upriver. It is unknown if future exposure or mobilization of tar might result in harm in aquatic invertebrates or prevent recolonization of the region where the sediment is most highly contaminated. However in June of 2017, the benthic community appeared healthy and comparable to other nearby sites that have been sampled in the recent past.

The familiar three-legged stool analogy as it relates to surface water quality was articulated first by EPA, with the legs representing: 1. Water Chemistry, 2. Whole effluent toxicity, and 3. Instream biological condition. Chapman (1990) extended this concept to sediment contamination, which was referred to as the Sediment Quality Triad (SQT) representing: 1. Sediment Chemistry, 2. Sediment Toxicity Tests (Bioassays) and 3. Field effects on benthic organism. Chapman and Anderson (2005) suggested these three lines of evidence could be used to help guide decisions related to environmental risk from contaminated sediment within waterways. It should be noted that regardless of how one might conceptualize these investigations, the results should not necessarily be thought of as diagnostic or prescriptive. Rather, the primary goal of these sorts of investigations are quite simple, and that is to characterize the chemical, physical, and biological conditions near the contaminated site, the results of which may be useful as a tool to inform decisions. This report should also not necessarily be thought of as comprehensive. While results can provide insight into the potential toxic effects of the contaminated sediment on native invertebrate fauna, there are other assemblages, such as diadromous fish, which may be more or less vulnerable to this form of pollution. Lastly this study addresses ecological risk, with the risk to human health evaluated by different methods and means, the results of which are presented in other documents.

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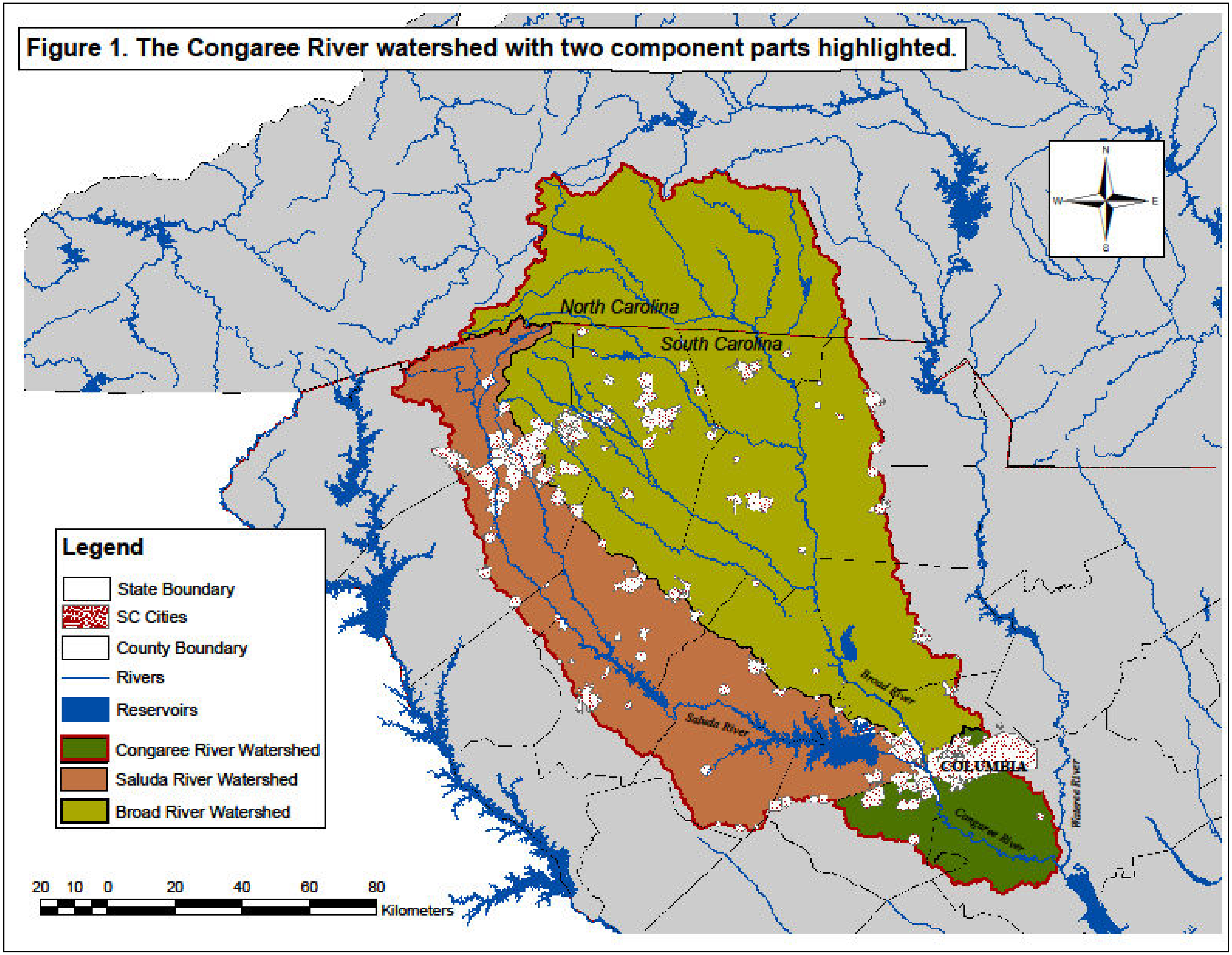


Figure 1. The Congaree River watershed with two component parts highlighted.

Figure 2. Percent landuse within the Broad River and Saluda River Watersheds.

Data compiled from the 2011 National Land Cover Database; some categories combined, see Glover et al.(2010)

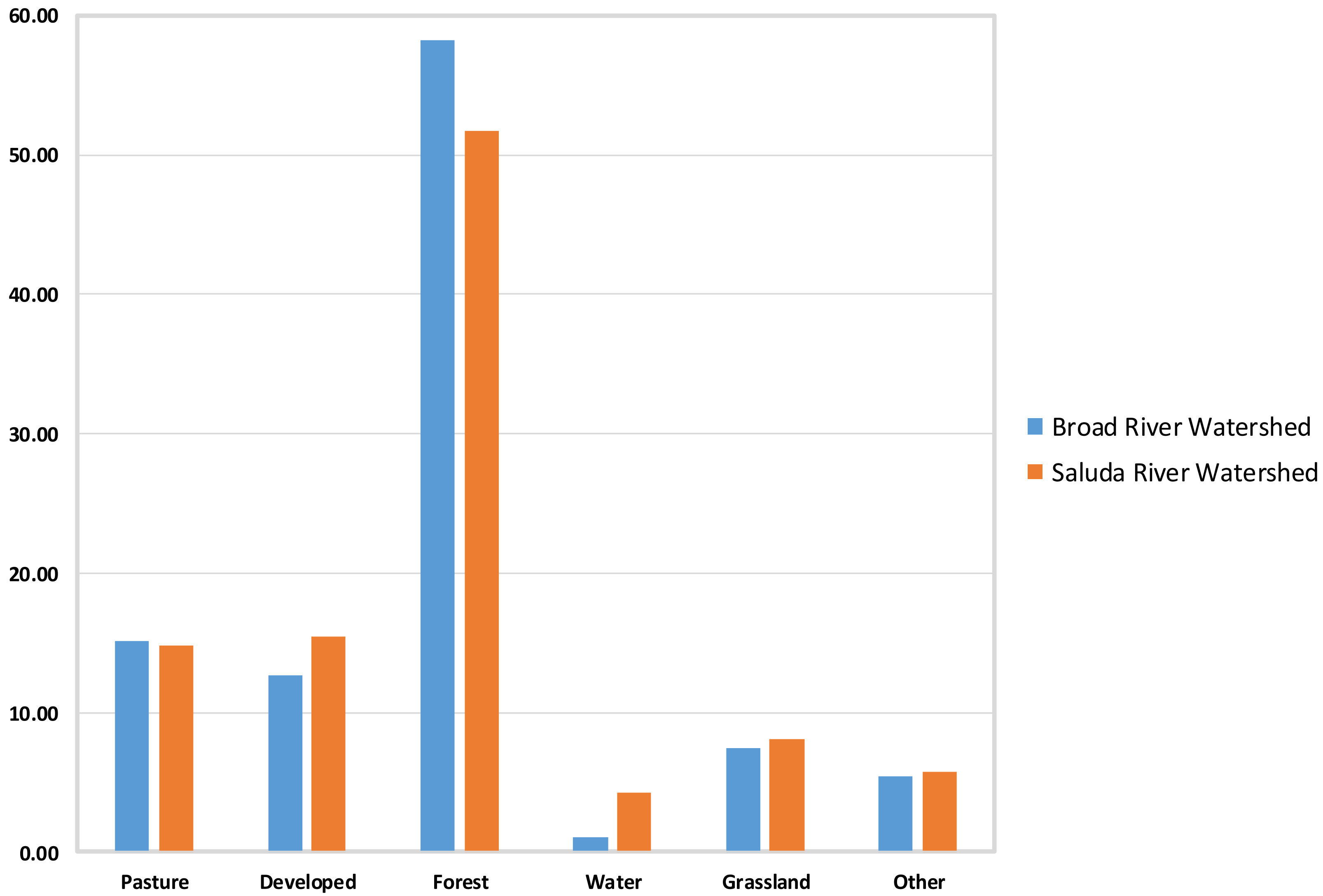
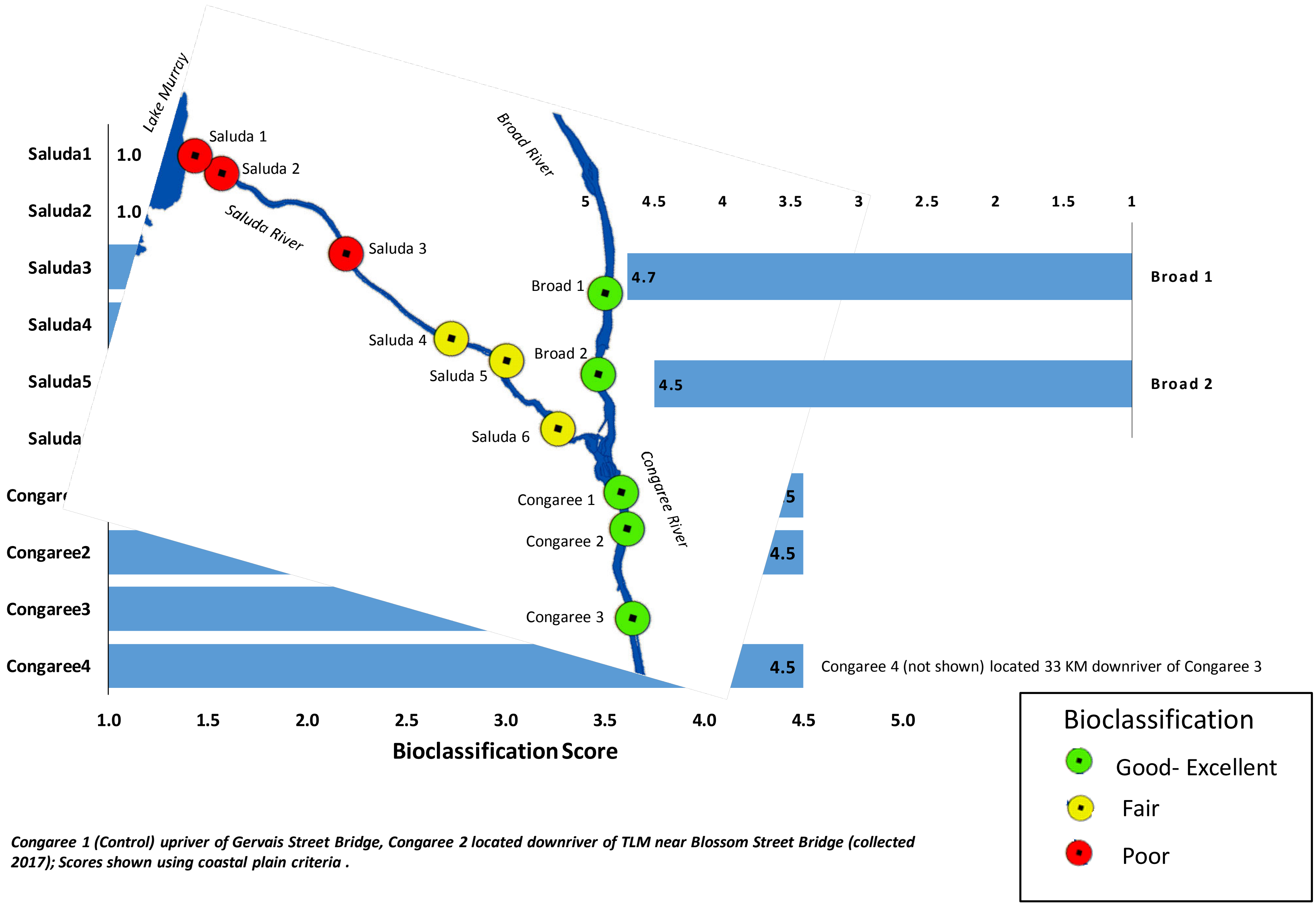


Figure 3. Congaree River looking downriver toward the Gervais Street Bridge.

Figure 4. Congaree River looking upriver toward Blossom Street Bridge.

Figure 5. Freshwater mussels found in the Congaree River near Blossom Street Bridge; A. *Elliptio roanokensis* (Roanoke Slabshell), B. *Elliptio congarea* (Carolina Slabshell), C. *Lampsilis cariosa* (Yellow Lamp mussel), and D. *Elliptio complanata* (Eastern Eilliptio).

Figure 6. Bioclassification Scores of the Saluda, Broad, and Congaree Rivers Near Columbia, SC



Congaree 1 (Control) upriver of Gervais Street Bridge, Congaree 2 located downriver of TLM near Blossom Street Bridge (collected 2017); Scores shown using coastal plain criteria .

Table 1. Select examples of macroinvertebrate community bioassessments related to manufactured gas plants and coal tar contamination.

MGP	Location	Waterbody	Citation
Michigan Consolidated Energy	Muskegon Lake, MI	Muskegon Lake	Tuckeman (2002)
Listed only as Barre Coal Site	Barre, VT	Stevens Branch	Fiske and Langdon (1996)
Poudre Valley Gas Comp.	Fort Collins, CO	Cache la Poudre River	Oberholster et al. (2006)
Hudson Gas Company	NY	Hudson River	Azzolina et al. (2015)

Table 2. Results of an aquatic macroinvertebrate bioassessment conduct on the Congaree River near Columbia, SC. S-1007 located upriver of sediment contamination; CSB-001R located immediately downriver of section of river contaminated by coal tar.

Station	Taxa Richness	EPT Index	Biotic Index	Bioclassification Score (Coastal Plains Criteria)	Bioclassification Score (Piedmont Criteria)
S-1007 (Control)	54	22	4.56	4.5	4.2
CSB-001R	55	22	4.64	4.5	4.2

Table 3. Aquatic macroinvertebrates collected on 15 June 2007, from the Congaree River near Columbia, SC.

PHYLUM	CLASS	ORDER	FAMILY	Taxa	S-1007	CSB-001R
Annelida	Hirudinea	Rhynchobdellida	Glossiphoniidae	Glossiphoniidae	1	2
Annelida	Oligochaeta	NA	NA	Oligochaeta	6	15
Arthropoda	Crustacea	Amphipoda	Gammaridae	Crangonyx sp.	1	3
Arthropoda	Crustacea	Amphipoda	Gammaridae	Gammaridae	2	0
Arthropoda	Crustacea	Decapoda	Cambaridae	Cambaridae	1	1
Arthropoda	Crustacea	Isopoda	Asellidae	Caecidotea sp.	1	1
Arthropoda	Hexapoda	Coleoptera	Elmidae	Ancyronyx variegatus	0	1
Arthropoda	Hexapoda	Coleoptera	Elmidae	Macronychus glabratus	11	10
Arthropoda	Hexapoda	Coleoptera	Elmidae	Microcylloepus pusillus	2	0
Arthropoda	Hexapoda	Coleoptera	Elmidae	Stenelmis sp.	6	5
Arthropoda	Hexapoda	Coleoptera	Hydrophilidae	Sperchopsis tessellatus	0	1
Arthropoda	Hexapoda	Diptera	Chironomidae	Ablabesmyia rhamphe GR	1	0
Arthropoda	Hexapoda	Diptera	Chironomidae	Chironomidae	0	1
Arthropoda	Hexapoda	Diptera	Chironomidae	Chironomus sp.	4	0
Arthropoda	Hexapoda	Diptera	Chironomidae	Orthocladiinae	2	0
Arthropoda	Hexapoda	Diptera	Chironomidae	Paratanytarsus sp.	1	0
Arthropoda	Hexapoda	Diptera	Chironomidae	Polypedilum flavum	2	0
Arthropoda	Hexapoda	Diptera	Chironomidae	Polypedilum illinoense	0	1
Arthropoda	Hexapoda	Diptera	Chironomidae	Polypedilum scalaenum gp.	1	0
Arthropoda	Hexapoda	Diptera	Chironomidae	Polypedilum sp.	1	0
Arthropoda	Hexapoda	Diptera	Chironomidae	Rheotanytarsus exiguus gr	1	0
Arthropoda	Hexapoda	Diptera	Chironomidae	Rheotanytarsus sp.	0	2
Arthropoda	Hexapoda	Diptera	Chironomidae	Stenochironomus sp.	0	5
Arthropoda	Hexapoda	Diptera	Chironomidae	Tanytarsus sp.	1	0
Arthropoda	Hexapoda	Diptera	Chironomidae	Thienemanniella sp.	2	1
Arthropoda	Hexapoda	Diptera	Chironomidae	Tribelos fusicorne	2	0
Arthropoda	Hexapoda	Diptera	Chironomidae	Tribelos jucundum	1	0
Arthropoda	Hexapoda	Diptera	Chironomidae	Tribelos sp.	1	0
Arthropoda	Hexapoda	Diptera	Simuliidae	Simuliidae	6	0
Arthropoda	Hexapoda	Diptera	Simuliidae	Simulium sp.	23	13
Arthropoda	Hexapoda	Diptera	Tipulidae	Tipula sp.	0	1
Arthropoda	Hexapoda	Ephemeroptera	Baetidae	Acerpenna pygmaea	2	4
Arthropoda	Hexapoda	Ephemeroptera	Baetidae	Baetidae	1	0
Arthropoda	Hexapoda	Ephemeroptera	Baetidae	Baetis intercalaris	21	4
Arthropoda	Hexapoda	Ephemeroptera	Baetidae	Baetis pluto	4	0
Arthropoda	Hexapoda	Ephemeroptera	Baetidae	Baetis sp.	2	0
Arthropoda	Hexapoda	Ephemeroptera	Baetidae	Heterocloeon curiosum	57	14
Arthropoda	Hexapoda	Ephemeroptera	Baetidae	Heterocloeon petersi	24	1
Arthropoda	Hexapoda	Ephemeroptera	Caenidae	Caenis diminuta	1	0
Arthropoda	Hexapoda	Ephemeroptera	Heptageniidae	Heptagenia marginalis gr	4	2
Arthropoda	Hexapoda	Ephemeroptera	Heptageniidae	Heptageniidae	0	2
Arthropoda	Hexapoda	Ephemeroptera	Heptageniidae	Maccaffertium (patterned) sp.	29	42
Arthropoda	Hexapoda	Ephemeroptera	Heptageniidae	Maccaffertium exiguum	3	2
Arthropoda	Hexapoda	Ephemeroptera	Heptageniidae	Maccaffertium sp.	19	7
Arthropoda	Hexapoda	Ephemeroptera	Heptageniidae	Maccaffertium terminatum	0	3
Arthropoda	Hexapoda	Ephemeroptera	Heptageniidae	Stenacron interpunctatum	11	0
Arthropoda	Hexapoda	Ephemeroptera	Heptageniidae	Stenacron pallidum	0	3
Arthropoda	Hexapoda	Ephemeroptera	Heptageniidae	Stenacron sp.	0	2

Table 3. continued.

PHYLUM	CLASS	ORDER	FAMILY	Taxa	S-1007	CSB-001R
Arthropoda	Hexapoda	Ephemeroptera	Isonychiadea	Isonychia sp.	34	23
Arthropoda	Hexapoda	Ephemeroptera	Tricorythidae	Tricorythodes sp.	11	10
Arthropoda	Hexapoda	Lepidoptera	Pyralidae	Petrophila sp.	1	0
Arthropoda	Hexapoda	Megaloptera	Corydalidae	Corydalus cornutus	2	3
Arthropoda	Hexapoda	Odonata	Aeshnidae	Boyeria vinosa	5	3
Arthropoda	Hexapoda	Odonata	Calopterygidae	Hetaerina sp.	18	3
Arthropoda	Hexapoda	Odonata	Coenagrionidae	Argia sp.	12	15
Arthropoda	Hexapoda	Odonata	Coenagrionidae	Coenagrionidae	1	0
Arthropoda	Hexapoda	Odonata	Coenagrionidae	Enallagma sp.	1	0
Arthropoda	Hexapoda	Odonata	Corduliidae	Neurocordulia sp.	0	1
Arthropoda	Hexapoda	Odonata	Gomphidae	Erpetogomphus designatus	1	1
Arthropoda	Hexapoda	Odonata	Gomphidae	Gomphus sp.	0	1
Arthropoda	Hexapoda	Odonata	Gomphidae	Stylurus sp.	0	1
Arthropoda	Hexapoda	Odonata	Macromiidae	Macromia sp.	1	2
Arthropoda	Hexapoda	Plecoptera	Perlidae	Neoperla sp.	0	1
Arthropoda	Hexapoda	Plecoptera	Perlidae	Paragnetina kansensis	12	0
Arthropoda	Hexapoda	Trichoptera	Brachycentridae	Brachycentrus numerosus	0	1
Arthropoda	Hexapoda	Trichoptera	Glossosomatidae	Protoptila sp.	1	0
Arthropoda	Hexapoda	Trichoptera	Hydropsychidae	Cheumatopsyche sp.	21	20
Arthropoda	Hexapoda	Trichoptera	Hydropsychidae	Hydropsyche (H.) sp.	3	0
Arthropoda	Hexapoda	Trichoptera	Hydropsychidae	Hydropsyche phalerata	0	1
Arthropoda	Hexapoda	Trichoptera	Hydropsychidae	Hydropsyche venularis	87	28
Arthropoda	Hexapoda	Trichoptera	Hydropsychidae	Hydropsyche venularis/rossi/simulans	46	28
Arthropoda	Hexapoda	Trichoptera	Hydropsychidae	Hydropsychidae	2	1
Arthropoda	Hexapoda	Trichoptera	Hydropsychidae	Macrostemum carolina	11	6
Arthropoda	Hexapoda	Trichoptera	Lepidostomatidae	Lepidostoma sp.	0	4
Arthropoda	Hexapoda	Trichoptera	Leptoceridae	Ceraclea sp.	0	1
Arthropoda	Hexapoda	Trichoptera	Leptoceridae	Nectopsyche exquisita	2	0
Arthropoda	Hexapoda	Trichoptera	Leptoceridae	Triaenodes ignitus	1	4
Arthropoda	Hexapoda	Trichoptera	Leptoceridae	Triaenodes injusta	12	26
Arthropoda	Hexapoda	Trichoptera	Leptoceridae	Triaenodes sp.	1	2
Arthropoda	Hexapoda	Trichoptera	Philopotamidae	Chimarra aterrima group	38	0
Arthropoda	Hexapoda	Trichoptera	Philopotamidae	Chimarra obscura	1	0
Arthropoda	Hexapoda	Trichoptera	Philopotamidae	Chimarra socia	24	25
Arthropoda	Hexapoda	Trichoptera	Philopotamidae	Chimarra sp.	0	21
Mollusca	Gastropoda	Mesogastropoda	Pleuroceridae	Pleurocera catenaria	10	22
Mollusca	Gastropoda	Mesogastropoda	Viviparidae	Campeloma sp.	3	3
Mollusca	Gastropoda	NA	NA	Gastropoda	0	1
Mollusca	Gastropoda	Neotaenioglossa	Hydrobiidae	Somatogyrus virginicus	4	19
Mollusca	Pelecypoda	Heterodonta	Corbiculidae	Corbicula fluminea	0	25
Mollusca	Pelecypoda	Unionoida	Unionidae	Elliptio complanata	0	5
Mollusca	Pelecypoda	Unionoida	Unionidae	Elliptio congaraea	0	3
Mollusca	Pelecypoda	Unionoida	Unionidae	Elliptio roanokensis	0	18
Mollusca	Pelecypoda	Unionoida	Unionidae	Elliptio sp.	1	0
Mollusca	Pelecypoda	Unionoida	Unionidae	Lampsilis cariosa	0	2
Platyhelminthes	Turbellaria	NA	NA	Turbellaria	8	6