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WATERSHED ASSESSMENT OF THE NORTH RIVER SYSTEM FOR RECOVERY AND RESTORATION OF RARE MUSSEL SPECIES

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By

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WATERSHED ASSESSMENT OF THE NORTH RIVER SYSTEM FOR RECOVERY AND RESTORATION OF RARE MUSSEL SPECIES

ABSTRACT

The North River watershed in west-central Alabama is an important resource for water supply and for the conservation of rare mussels in Alabama. The main channel of North River is listed as an impaired stream by the Alabama Department of Environmental Management due to over nutrification, sedimentation, and habitat degradation. The mussel population inhabiting North River has declined over the past 20 years with only remnant populations now existing in the upper reaches of North River. Water quality conditions in the watershed have changed in parallel fashion over the past 30 years with water becoming more mineralized and more fertile. Sediment bedload continues to be a significant issue in the North River and may be a major factor limiting the distribution of mussels in the watershed. Current biological conditions have remained similar to baseline biological conditions measured 30 years ago in parts of the watershed, whereas in some North River subwatersheds, stream biology has deteriorated substantially.

INTRODUCTION

Protection and conservation of water resources is becoming a local, regional, and national priority in the face of water supply shortages due to over consumption, drought, the uncertainties of climate change, and the need to provide adequate water to meet habitat and life history requirements for fish and wildlife. Alabama's future water needs for public supplies, economic activity, and energy production will be great. Sustainable water use and water production, as well as a process for protecting and conserving fish and wildlife and the natural systems that produce water, will be the keys to satisfying these needs. Events of the past decade, including the droughts of 2000 and 2007, and still unresolved water sharing issues between Alabama, Georgia, and Florida are examples of water resource problems that have became front-page natural resource management issues for Alabama as well as the nation. With the expanding economy and population in the Southeast, and with climate change increasing the probability of severe drought a systematic, science-based approach to water planning and management will be needed if this region is to remain prosperous and productive.

The Southeast has a high number of rare aquatic species, many of which are protected under the Federal Endangered Species Act and state conservation regulations. Several of these species are restricted in distribution, occur in small disjunct populations, and are threatened by pollution and habitat degradation (Mirarchi, 2004). The mussel and fish faunas of the Mobile River Basin have high degrees of endemism and diversity, which can be attributed to the large size of the basin, numerous aquatic habitat types due to the varied landscapes found in the basin, geographic barriers such as the Fall Line, and the proximity of the basin to adjacent drainages with diverse faunas (Williams, 1982).

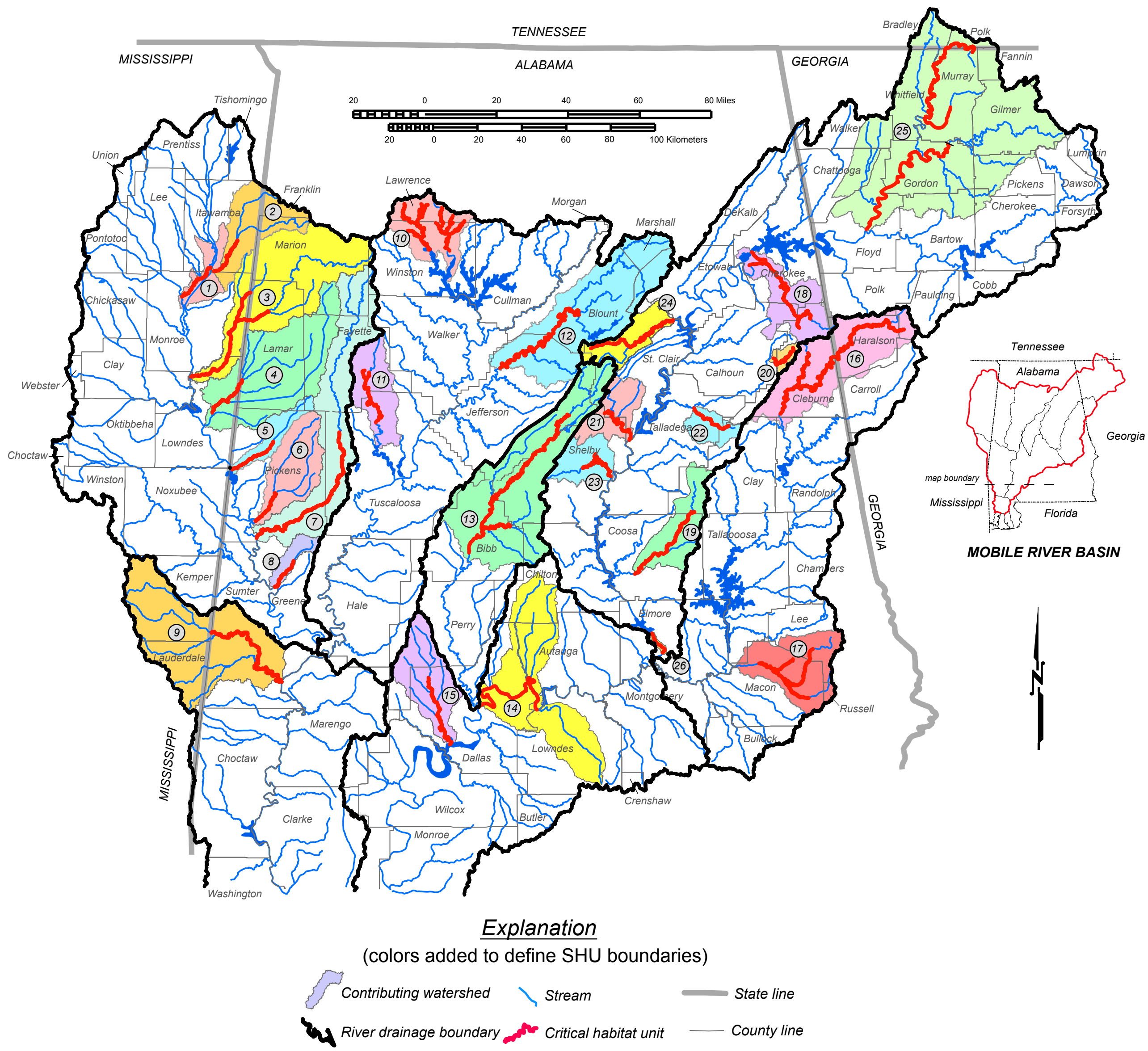
The mussel fauna of the Southeast has been substantially diminished over the past 100 years directly because of physical changes and loss of habitat and indirectly because these changes interfere with the unique life history requirements of mussels. Many habitats in the Southeast, particularly large rivers, have changed due to impoundment, channel modification, eutrophication, and increased erosion and sedimentation (Hartfield, 1994; Mott and Hartfield, 1994). The mussel's sedentary mode of life and unique reproduction strategies, when combined with habitat disruption and fragmentation, have resulted in a decline in mussel populations to the point that many species are now on the federal threatened and endangered species list.

Hinkley (1906) reported 40 mussel species from the Tombigbee River system, while Williams and others (1992) reported that 50 species were known to have occurred in the upper Tombigbee (upstream of the confluence of the Tombigbee and Black Warrior Rivers) and 48 in the Black Warrior system, based on taxonomic revisions in recent decades. Williams and others (2008), in a comprehensive review of the mussels of Alabama, tallied 51 species known from the Black Warrior drainage.

Currently, 17 species of mussels in the Mobile River Basin are recognized as endangered or threatened by the U.S. Fish and Wildlife Service (USFWS), and 14 species in the genus *Pleurobema,* endemic to the Mobile River Basin, are considered extinct by the USFWS (Hartfield, 1994). The type locality for one of these extinct species, *Pleurobema hagleri* (= *P. furvum*), is the North River where it was reported to exist prior to 1920 (van der Schalie, 1981).

The goal of the Endangered Species Act is to recover and restore threatened or endangered species. For recovery and restoration to be considered successful, species populations must increase, they must be restored in areas where they formerly occurred, the population must be stable and reproducing, habitat must be restored so that species are supported, and the threats causing the decline must be reduced or eliminated.

The USFWS has designated 26 river and stream segments (units) in the Mobile River Basin (fig. 1) as critical habitat for three threatened and eight endangered freshwater mussel species under the Endangered Species Act of 1973, as amended (see 69 Federal Register 40084). The habitat units encompass approximately 1,093 miles of stream and river channels in four states. Although this is a small portion of each species' historic range, the habitat units include a significant part of the Mobile River Basin's remaining high-quality, free-flowing rivers and streams and reflect the variety of small stream to large river habitats once occupied by these species. The 26 critical habitat units were selected by USFWS based on the best available information about the essential habitat components required by these 11 species including geomorphically stable stream and river banks and channels; a stream flow regime sufficient for normal behavior, growth, and survival of all life stages of mussels and their fish hosts; acceptable water-quality conditions necessary for normal behavior, growth, and viability of all life stages; sand, gravel, and (or) cobble substrates with low amounts of fine sediment and attached filamentous algae; the presence of fish



1. East Fork Tombigbee River
2. Bull Mountain Creek
3. Buttahatchee River and Sipsey Creek
4. Luxapalila and Yellow Creeks
5. Coalfire Creek
6. Lubbub Creek
7. Sipsey River
8. Trussels Creek
9. Sucarnoochee River
10. Sipsey Fork and tributaries
11. North River and Clear Creek
12. Locust Fork and Little Warrior River
13. Cahaba and Little Cahaba Rivers
14. Alabama River
15. Bogue Chitto Creek
16. Tallapoosa River and Cane Creek
17. Uphapee, Choctafaula, and Chewacla Creeks
18. Coosa River and Terrapin Creek
19. Hatchet Creek
20. Shoal Creek
21. Kelly and Shoal Creek
22. Cheaha Creek
23. Yellowleaf Creek and Muddy Prong
24. Big Canoe Creek
25. Oostanaula, Coosawattee, and Conasaufa Rivers and Floyd Creek
26. Lower Coosa River

Figure 1. Strategic habitat units for threatened and endangered mussel species in the Mobile River Basin (from O'Neil and others, 2008).

hosts with adequate living, foraging, and spawning areas; and few or no competitive or predaceous nonnative species.

The USFWS, in cooperation with the Alabama Aquatic Biodiversity Center (AABC) of the Wildlife and Freshwater Fisheries Division (WFFD) of the Alabama Department of Conservation and Natural Resources (ADCNR), the Geological Survey of Alabama (GSA), and the Alabama Clean Water Partnership (ACWP) has initiated the following activities designed to enhance species recovery opportunities in the 26 Mobile River Basin critical habitat reaches:

1. Establishment of strategic habitat units. Strategic habitat units (SHU) were established (fig. 1) for the 26 critical habitat units designated by USFWS by determining the encompassing watershed boundary at the downstream point of each critical habitat reach and then mapping this watershed unit in a Geographic Information System (GIS) (O'Neil and others, 2008). This initial step creates the spatial boundary within which recovery activities can be implemented.

2. Development of SHU-specific watershed and threats information. For successful species recovery, watersheds must be understood from a biological, water quality, habitat, and land-use perspective. The type of watershed information developed for each SHU is determined by the type and intensity of threats posed. This information may include, but is not limited to, additional biological surveys to refine species distributions; surveys to determine water-quality threats that may affect listed species; a landscape analysis to determine land cover and land use patterns, SHU watershed characteristics, and land cover changes through time; studies to better understand biological phenomena (reproduction periods, migration routes, breeding habitats, etc.) that are important for managing and recovering species; hydrogeologic studies to determine groundwater characteristics and recharge areas for spring- and cave-dwelling species; biomonitoring studies using multi-metric procedures to identify impaired stream reaches; and comprehensive habitat studies to evaluate habitat impairment and examine hydrologic processes shaping and degrading habitat.

3. Identification of areas needing protection. Using the threats and watershed assessment data, stream reaches that need protection, management, and(or) restoration will be identified. Linking the location of imperiled species with specific threats is a critical part of this process. Such linking can only be accomplished in the required detail by conducting SHU-specific studies.

4. Development of an action plan for species recovery and restoration. Once threats are linked with species, an action plan for recovery can be developed so that species restoration can begin. The action plan is implemented through a cooperative partnership of local landowners, organizations, and agencies including watershed partnerships, local and county governments, local businesses and farmers, state and federal agencies, and other interested parties using a variety of means including protecting stream habitat through land purchase or landowner conservation agreements; management of habitat and water quality by eliminating polluted runoff sources and by reducing pollutant loads through more restrictive water-quality permitting and more aggressive best management practices (BMP) implementation; conducting riparian improvement or physically repairing a substantially degraded stream reach; restoration of biodiversity with culture-raised species; and implementing a broad spectrum of educational initiatives aimed at school children, government officials and regulators, land owners and business professionals, and the general public with the general intent to provide science-based information about the watershed and its importance to the economic health of the region.

The agencies and organizations involved in this project have begun this process by delineating SHUs for most of the 26 critical habitat units in the Mobile River Basin, by establishing the AABC for the purpose of species culture, restoration, and enhancement, and by initiating detailed studies of selected SHUs in the Mobile River Basin. This report presents watershed assessment information for the North River SHU and offers suggestions and a proposed action plan for restoration activities.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the assistance of Jeff Powell and Paul Hartfield of the U.S. Fish and Wildlife Service for providing guidance and support for the SHU concept and encouraging use of the watershed approach for species recovery and restoration. Tom Shepard, Brett Smith, and Cal Johnson of GSA provided field support and assistance with collecting fish IBI samples and conducting habitat assessments in the watershed. Jerry Moss, Jay Haffner, Andrew Henderson, and Jim Piper of ADCNR assisted with field collections. Kellie Johnston and Abner Patton of the Black Warrior River Clean Water Partnership provided a forum for discussion of watershed issues in the North River and are actively working to develop a North River watershed management plan.

STUDY AREA

The North River watershed (fig. 2) is approximately 418 mi^2 (square miles) in area upstream of the Lake Tuscaloosa dam and 425 mi^2 at its junction with the Black Warrior River. The watershed is about 40 miles long from the dam to the headwaters and 14 miles wide at its greatest width. North River flows through two physiographic sections, the Cumberland Plateau and the East Gulf Coastal Plain (fig. 3). The northern and eastern parts of the watershed drain land in the Warrior Basin District (underlain by the Pottsville Formation of Pennsylvanian age) of the Cumberland Plateau while the western lake region drains land in the Fall Line Hills District (underlain by the Coker Formation of Cretaceous age) of the East Gulf Coastal Plain (figs. 2, 3). The Warrior Basin is a broad, dissected plateau about 80 miles wide in Alabama underlain primarily by sandstone, shale, and mineable coal and lying mainly in Winston, Cullman, Walker, Jefferson, and Tuscaloosa Counties. The upper Black Warrior River and its tributaries–the Locust Fork, Mulberry Fork, Sipsey Fork, and North River–are dominant drainage features in the district with streams occurring in steep-sided valleys, many of which are gorge-like in their lower reaches.

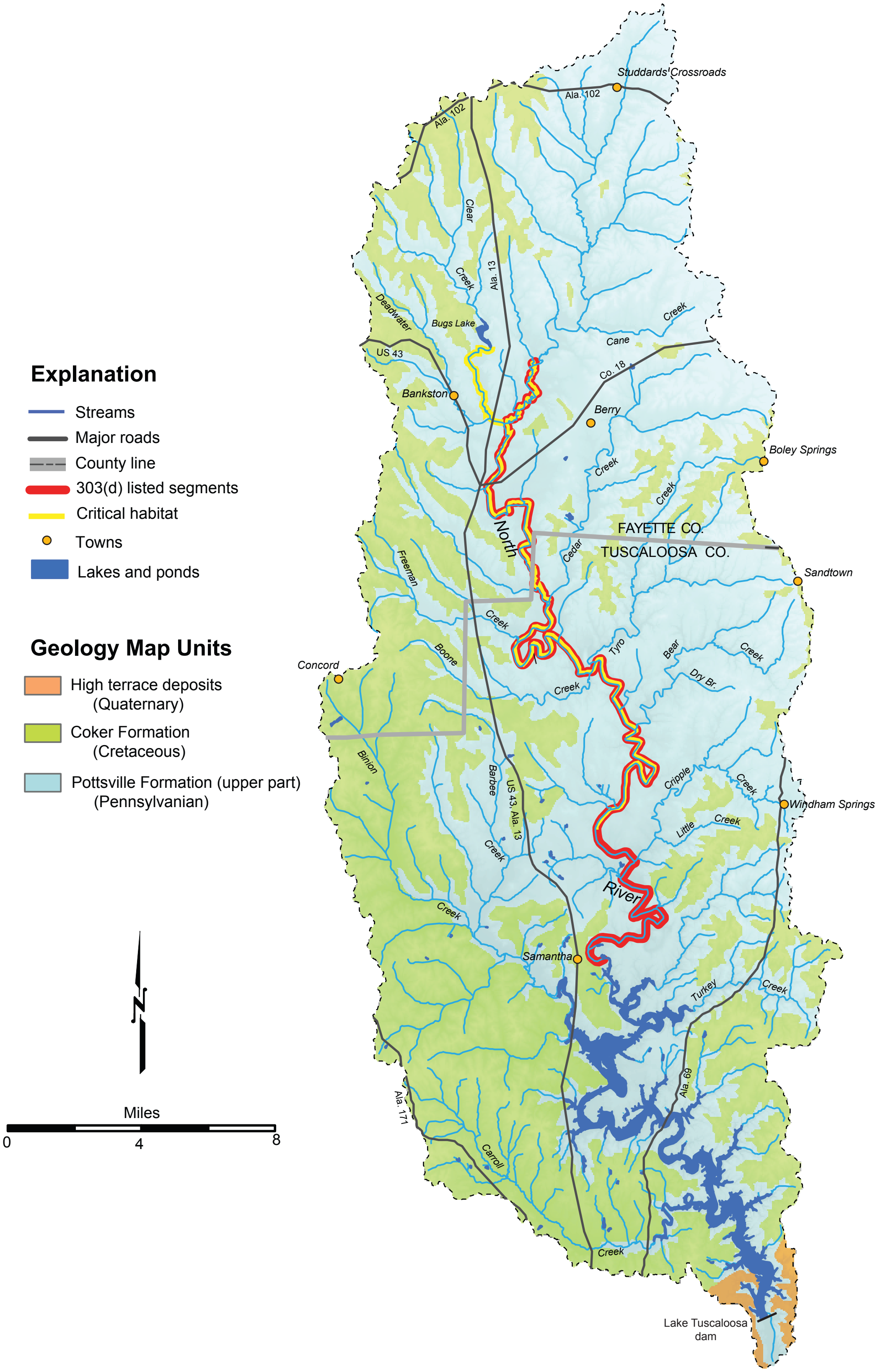


Figure 2. The North River watershed.

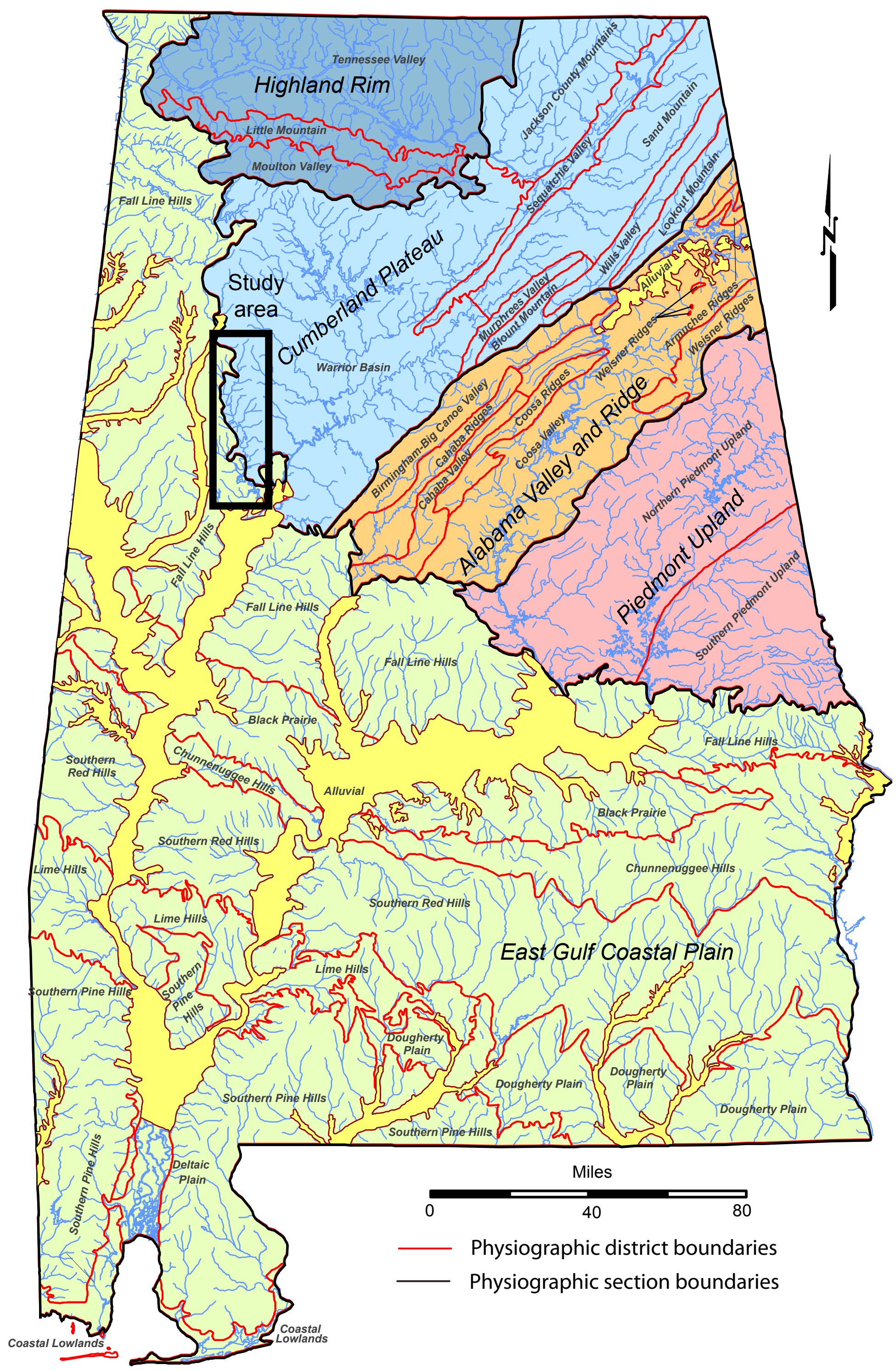


Figure 3. Alabama physiography (modified from Sapp and Emplaincourt, 1975)

The Fall Line Hills District is a wide crescent-shaped band extending from the Tennessee River in northwest Alabama through the middle portion of the Mobile River Basin to the Chattahoochee River drainage in east Alabama. The Fall Line Hills district forms the southwestern and southern boundary to the Highland Rim, Cumberland Plateau, Alabama Valley and Ridge, and the Piedmont Upland sections. Topography can be fairly rugged with steep slopes occurring near streams. In the western portion of the district, around Lake Tuscaloosa, the Fall Line is an irregularly shaped transition belt about 15 miles wide where rocks of the Pottsville Formation dip below the land surface and are overlain by the sands and gravels of the Coker Formation in the Fall Line Hills (fig. 3).

The drainage pattern in North River is dendritic with frequent stream adjustments attributable to the joint and fracture system. Flow in larger streams of the Warrior Basin upstream of the Fall Line is usually sustained during summer months but many headwater tributaries go dry in late summer and fall because of low to no groundwater recharge from the Pottsville shales. Streams draining the Fall Line Hills are well sustained, even in the driest years, because of extensive sand and gravel aquifers. Average annual discharge for the North River at Samantha (USGS site 02464000, 223 mi^2) is 373 ft^3/s or 1.67 $ft^3/s/mi^2$. Average daily discharge extremes for the period of record (1939-54 and 1969-2008) were 22,600 ft^3/s on March 20, 1970 (25,500 ft^3/s peak instantaneous discharge) and several days of near zero flow–0.1 ft^3/s–on September 5-15, 1954. The distribution of average daily flows per month for the period of record (fig. 4) reveals that September has on average the lowest flows and February the highest.

Slack (1987) reported that about 59 percent of the total flow entering Lake Tuscaloosa during wet years is from the North River (based on the Samantha gage), 13 percent from Binion Creek, six percent from Cripple Creek, 4 percent from Carroll Creek, 3 percent from Turkey Creek, 2 percent from Dry Creek, and about 13 percent from smaller ungaged tributaries. During dry years about 59

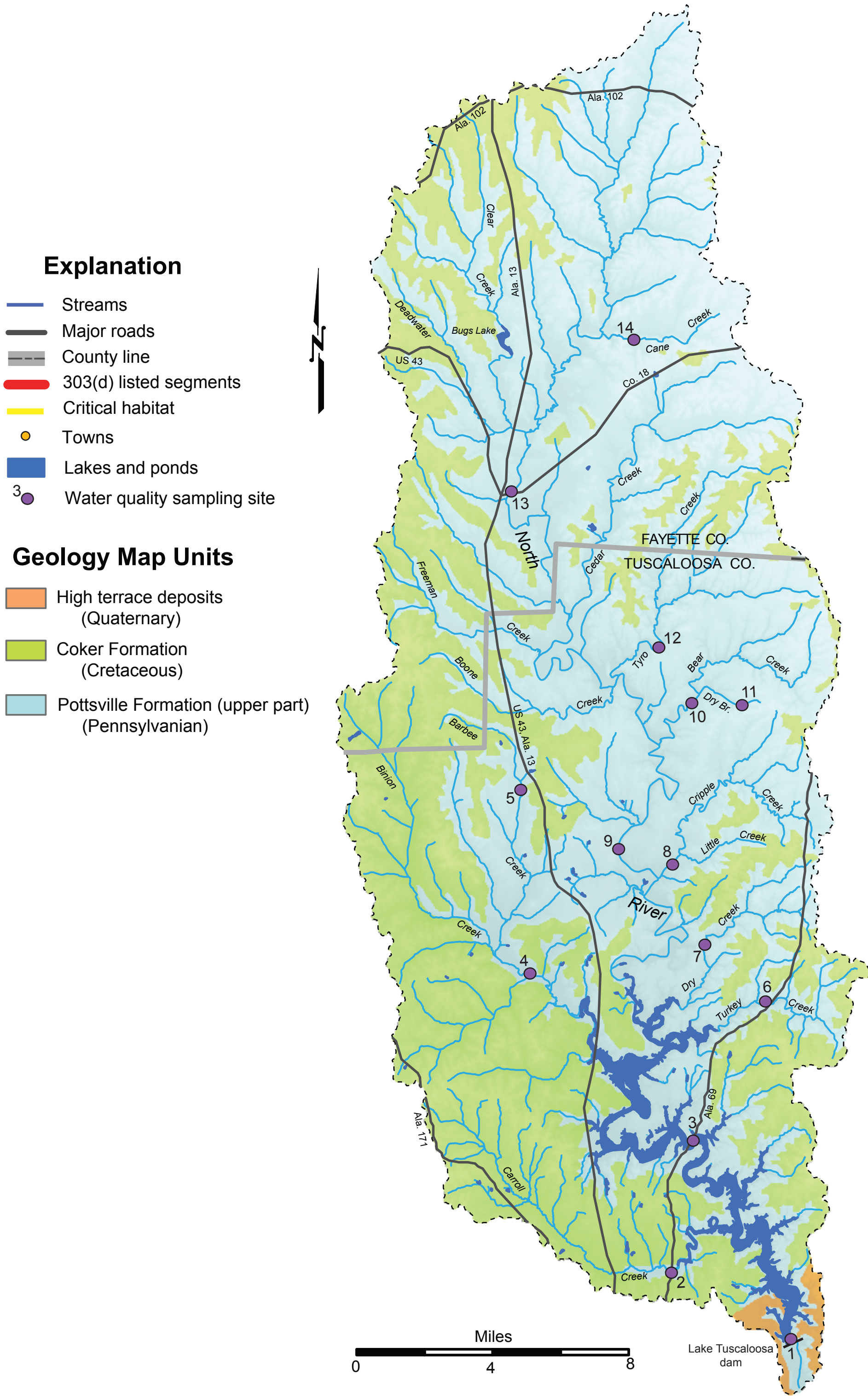


Figure 5. Water quality sampling sites in the North River watershed (see table 1).

percent from Binion Creek, 3 percent from Cripple Creek, 3 percent from Carroll Creek, 2 percent from Turkey Creek, 2 percent from Dry Creek, and about 14 percent from smaller ungaged tributaries.

Created in 1970 (gates closed June 1969 with spillover in March 1970), Lake Tuscaloosa is one of the largest water supply reservoirs in Alabama with a surface area of 5,885 acres and a shoreline of 177 miles (Parker, 1962). Impounded waters extend upstream for about 28 miles from the dam. Maximum depth of the reservoir is 110 feet at the dam and the useable storage volume in the reservoir is 40 billion gallons yielding a safe maximum withdrawal rate of 200 million gallons per day (mgd). Unlike many other areas of the state that have suffered from insufficient water supplies during the recent droughts of 2000 and 2007, or are likely to do so in the near future, Tuscaloosa and the surrounding areas should enjoy a reliable, excellent water supply source in Lake Tuscaloosa. Sustained economic growth requires adequate infrastructure, and water supply is one of the critical infrastructure components. Lake Tuscaloosa fills this infrastructure role in the region and is a major component of the economy in west Alabama. Another small impoundment in the North River watershed is located on Clear Creek (fig. 2). Bays Lake is a 63.5 acre water supply impoundment on Clear Creek about 4.5 miles northwest of Berry.

RESULTS

WATER QUALITY

Chemical-Physical Constituents

Water-quality data have been collected in the North River system for several decades. Early water-quality studies in North River evaluated its sanitary condition (Water Improvement Advisory Commission, 1949) or were of a more limited reconnaissance nature (Pierce, 1959; Cherry, 1963). The Water Improvement Advisory Commission (1949) reported data collected in October and November 1948 at a location on the North River 5 miles upstream of its mouth. Discharge varied from 45 to 1,200 ft^3/s, dissolved oxygen from 8.4 to 9.8 mg/L, 5-day biochemical oxygen demand (BOD_5) from 0.6 to 4.0 mg/L, pH from 5.9 to 6.7, and hardness (Ca, Mg) from 10 to 42 mg/L. Pierce (1959) reported the results of samples collected in the North River at Ala. Hwy. 69 (fig. 5) on three separate dates in 1956 (table 1). Discharge varied from 26 to 2,060 ft^3/s, pH from 6.2 to 6.8, hardness (Ca, Mg) from 8.0 to 10 mg/L, and specific conductance from 27 to 34 μS/cm. Pierce also reported the concentrations of several major ionic constituents, including calcium, magnesium, sodium, potassium, bicarbonate, sulfate, and chloride, all of which ranged between 0 and 2.8 mg/L. Parker (1962) used the data presented in Pierce (1959) as background water quality information for a project to dam the North River and create Lake Tuscaloosa. Cherry (1963) reported data for four sites in the North River watershed (fig. 5, table 1). For the sample collected in North River near Tuscaloosa in August 1960 (site 3) discharge was 100 ft^3/s, specific conductance was 31 μS/cm, hardness was 10 mg/L, and pH was 6.8. The major ions all ranged between 0.6 and 2.8 mg/L except bicarbonate which was 11 mg/L. Water quality at the other sites in the North River system was similar with a low dissolved solids content. It is apparent in the results of these early samples that water in the North River system was fairly low in ionic content at both high and low discharge rates.

Table 1. Water-quality values for selected sites in the North River watershed.

Sampling site no. (fig. 5)	Stream	Period of record	USGS station no.	Specific conductance (*u* S/cm)	pH (s.u.)	Hardness	Sulfate	Manganese	Iron
						(mg/L--dissolved)			
1	Lake Tuscaloosa near dam	1982-86[a]	02464800	29 - 75	5.2 - 7.0	11 - 22	5.2 - 18	.01 - .61	.01 - .25
2	Carroll Creek at Ala. Hwy. 69	1982-86[a]	02464660	20 - 33	4.6 - 6.8	4 - 9	.1 - 7.7	.023 - .26	.01 - .78
3	North River at Ala. Hwy. 69	1956[b]	02464500	27 - 34	6.2 - 6.8	8 - 10	0 - 2.0	--	.05 - .34
3	North River at Ala. Hwy. 69	1960[c]	02464500	31	6.8	10	2.8	--	.06
3	Lake Tuscaloosa at Ala. Hwy. 69	1982-86[a]	02464500	27 - 79	6.2 - 7.8	8 - 30	<.1 - 15	--	--
4	Binion Creek below Gin Creek	1960[c]	02464360	25	6.9	9	--	--	--
4	Binion Creek below Gin Creek	1982-86[a]	02464360	22 - 69	5.2 - 6.8	10 - 20	3.0 - 15	.01 - .38	.01 - .57
5	Barbee Creek near Samantha	1976-84[d]	02464317	25 - 425	5.4 - 8.0	17 - 200	7.6 - 130	.07 - .70	.01 - .18
6	Turkey Creek below Ala. Hwy. 69	1960[c]	02464146	17	6.7	7	--	--	--
6	Turkey Creek below Ala. Hwy. 69	1977-79[e]	02464146	12 - 31	5.0 - 7.3	2 - 8	1.2 - 4.9	.01 - .04	.02 - .16
6	Turkey Creek below Ala. Hwy. 69	1982-86[a]	02464146	13 - 81	4.9 - 6.9	7 - 29	3.8 - 21	.02 - .30	<.01 - .24
7	Dry Creek near Samantha	1982-86[a]	02464100	22 - 54	4.8 - 7.1	4 - 23	<.1 - 10	.017 - .47	.003 - .72
8	Cripple Creek east of Samantha	1982-86[a]	02464035	24 - 1,840	4.5 - 8.2	0 - 1,100	4.7 - 960	.03 - 3.3	<.01 - .81
9	North River near Samantha	1982-86[a]	02464000	24 - 725	4.8 - 7.4	9 - 45	3.0 - 180	.009 - .82	<.01 - .71
10	Bear Creek near Samantha	1976-84[d]	02463900	16 - 102	4.6 - 7.5	0 - 18	1.4 - 14	--	.01 - .76
10	Bear Creek near Samantha	1977-79[e]	02463900	16 - 94	5.4 - 7.5		1.4 - 14	0 - .06	.01 - .25
11	Dry Branch near Samantha	1976-84[d]	02463890	15 - 43	4.8 - 7.2	2 - 10	2.1 - 4.7	.001 - .08	.01 - .09
12	Tyro Creek near New Lexington	1976-84[d]	02463850	24 - 300	4.7 - 7.4	6 - 140	8.5 - 120	.16 -6.5	.01 - .25
13	Tyro Creek near New Lexington	1981-84[f]	02463850	46 - 268	4.7 - 6.8	--	0 - 94	.15 - 4.6	.03 - .25
14	Tyro Creek at Ford	1981-84[f]	--	25 - 67	5.1 - 7.3	--	0 - 15	0 - .48	.03 - .39
15	Wallace Branch near mouth	1981-84[f]	--	55 - 330	4.8 - 6.8	--	16 - 180	.45 - 7.4	.01 - .32
16	Little Tyro Creek	1981-84[f]	--	93 - 370	4.4 - 6.7	--	33 - 220	.98 - 5.4	.05 - .19
17	North River near Berry	1960[c]	--	30	7.3	9.0	2.8	--	.10
18	Cane Creek near Berry	1976-84[d]	02463585	140 - 870	6.0 - 7.6	53 - 380	51 - 400	.046 - 1.5	.01 - .078

-- not reported

[a] Slack (1987)

[b] Pierce (1959)

[c] Cherry (1963)

[d] Mooty (1985)

[e] Harris and others (1985)

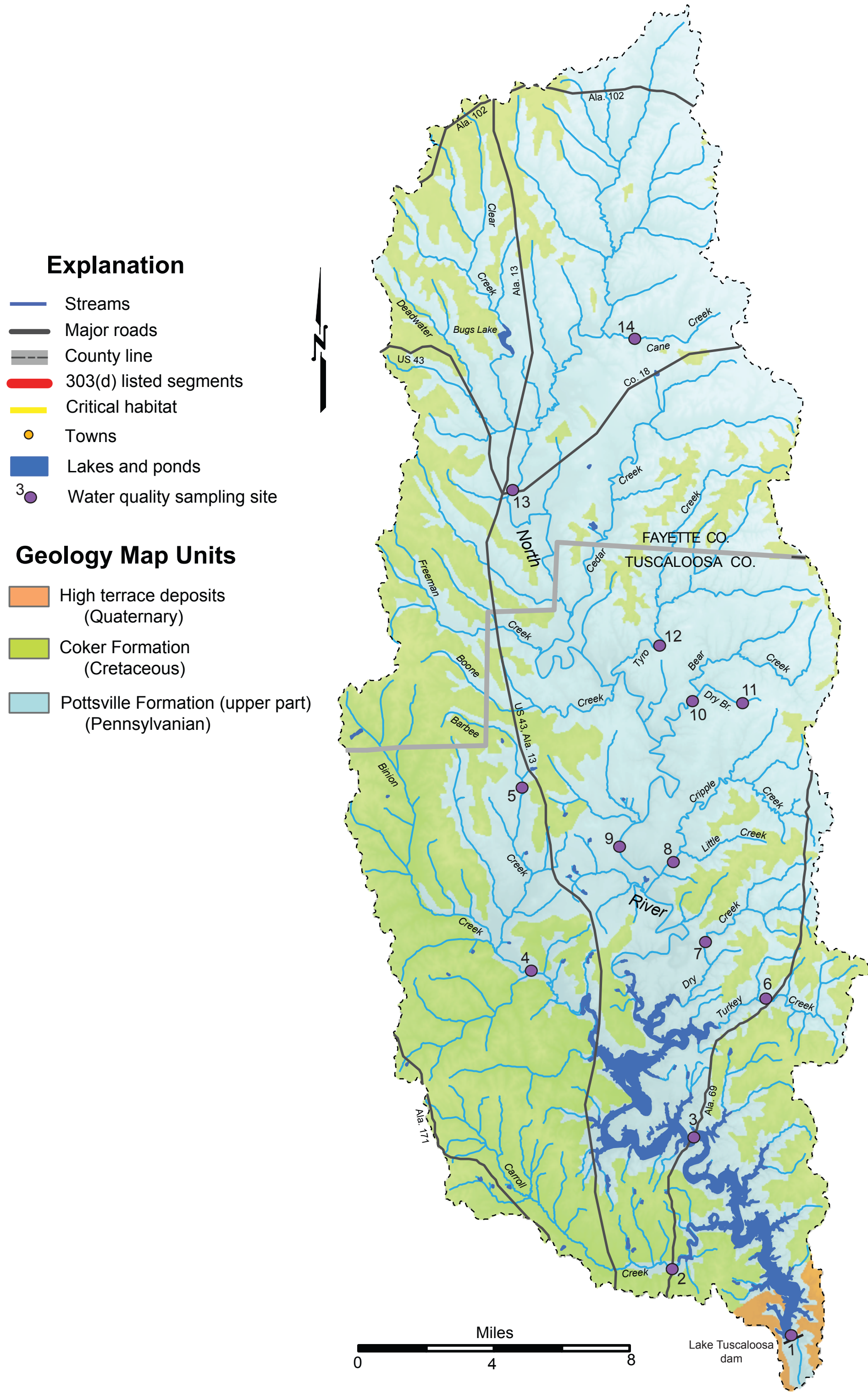


Figure 5. Water quality sampling sites in the North River watershed (see table 1).

More recent investigations quantified relationships between water quality and geology (Puente and others, 1980), water quality related to mine disturbance (Harris and others, 1985), assembled summary compilations of water quality data (Mooty, 1985), and evaluated water quality in Lake Tuscaloosa and its contributing tributaries (Slack, 1987). Puente and others (1980) reported that surface water of selected North River tributaries in 1977-79 was generally acidic, soft, and low in dissolved solids, with streams draining the Pottsville Formation more mineralized than streams draining basins underlain primarily by the Coker Formation.

Mooty (1985) compiled water quality data for several tributaries in the North River system including Turkey Creek, Cripple Creek, Dry Branch, Little Creek, Bear Creek, Tyro Creek, Barbee Creek, Freeman Creek, Cane Creek, and Boone Creek (fig. 5). Building on the information compiled by Mooty, Slack (1987) compared water quality at 16 tributary and lake sampling sites (data collected October 1982 to September 1986) with particular emphasis on water quality parameters affected by the increased coal surface mining activity in the watershed from 1977 to 1986. Slack reported that the water quality of some streams–North River, Little Creek, Cripple Creek, and Turkey Creek–was deteriorating as observed in lower pH, higher concentrations of dissolved minerals including sulfate, and higher concentrations of iron and manganese (table 1). Slack went on to conclude the increasing mineralization in Lake Tuscaloosa was directly linked to the degraded quality of the North River proper caused by mining activity in the watershed. The median sulfate concentration of Lake Tuscaloosa at the dam increased from 6.2 mg/L in 1979 to 14 mg/L in 1985 (Slack, 1987), which represented a 125 percent increase in six years. Using USGS data for the period 1995-99, the median concentration at the dam was calculated to be 16 mg/L. Although concentrations of dissolved minerals have increased in Lake Tuscaloosa since the period of active mining, the concentrations are still very low.

Harris and others (1985) documented the water quality impacts of historic surface mining in the Tyro Creek watershed, an eastern tributary of the North River (fig. 5). Analysis of water samples collected from September 1981 to July 1984 at four sites (table 1) indicated that previous surface mining for coal in the watershed resulted in increased mineral content, lower pH, higher iron and manganese concentrations, and increased sediment load in the affected subwatersheds. Additionally, the authors demonstrated the relationship between discharge and water quality, with ionic constituents decreasing and sediment load increasing with increasing discharge. Ionic parameter concentrations generally increased over the range of low to high discharge in direct proportion to the amount of upstream mining in the watershed.

Mine drainage has historically affected water quality in the North River system. The accelerated weathering of pyritic minerals in the exposed overburden results in the production of sulfuric acid and excessive quantities of soluble mineral salts. These materials enter the groundwater and streams during storm events resulting in increased dissolved solids loads up to several hundred times normal concentrations. Acidic mine drainage also increases stream acidity which can result in significant disruption of the biological community. Mining also increases the sediment load of streams. Suspended sediment yields from streams draining unmined and relatively undisturbed areas generally ranges from 20 to 800 tons/mi^2/yr, while suspended sediment loads of highly disturbed areas can range from 1,000 to 300,000 tons/mi^2/yr (Harkins and others, 1980).

Water quality impacts of historic coal surface mining are still evident in the North River watershed. Specific conductance measurements made in Cane, Cripple, and Turkey Creeks during low stream flows in 2009 (fig. 6) were extremely elevated above historic levels, while conductance measurements in other tributaries were within historic levels. Specific conductance of the North

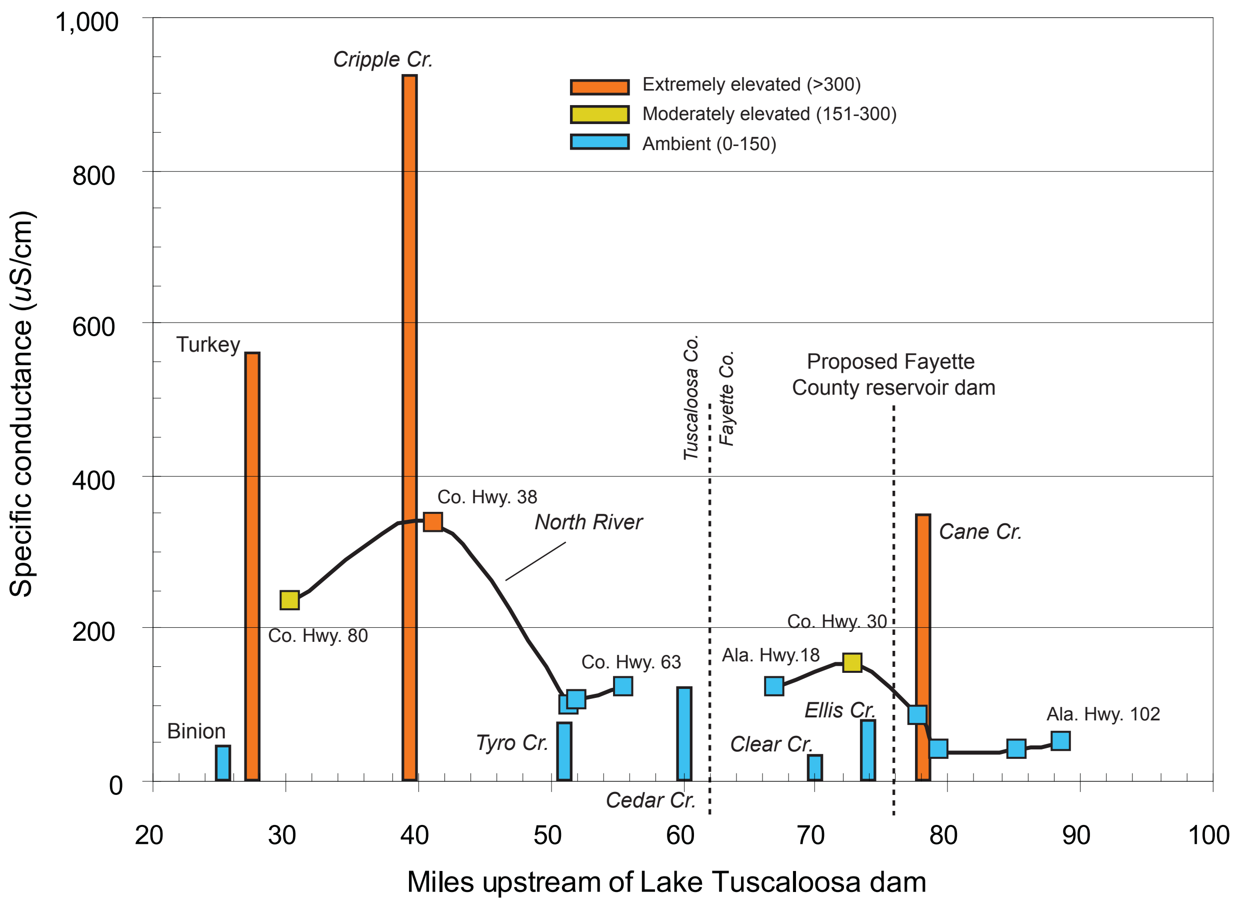


Figure 6. Specific conductance of the North River and tributaries, August - September 2009.

River at Tuscaloosa Co. Hwy. 38 was extremely elevated above ambient while measurements at Fayette Co. Hwys. 30 and 80 were moderately elevated.

Bed Sediment

Bed sediment contaminated with toxic metals or other contaminants can have a substantial impact on the resident mussel and fish communities. Cadmium, chromium, copper, mercury, nickel, and zinc are the metals most toxic to freshwater mussels with mercury, copper, and cadmium having the most toxicity (Naimo, 1995). Furthermore, metals in shallow bed sediments are generally more toxic to juvenile stage mussels since they tend to receive more of their nourishment from interstitial waters and therefore have a higher likelihood of exposure to sediment-borne toxins than adults, which generally receive their nourishment from the water column.

Harris and others (1985) collected bed sediment samples twice in the Tyro Creek watershed as part of their investigation of the effects of coal surface mining on water quality and aquatic communities. In January 2008, a composite bed sediment sample was collected from four stations in the North River system (McGregor and Wynn, 2008), including three in the North River main channel (Fayette Co. Hwy. 30 bridge near Berry, Tuscaloosa Co. Hwy. 55 bridge [Whittson Bridge], and Tuscaloosa Co. Hwy. 38 bridge near Samantha) and one in Clear Creek at Ala. Hwy. 13 bridge near Bankston.

Values of major elements and trace elements for the samples collected during that study are presented in table 2, along with values determined for sediment samples collected in the Black Warrior River (23 samples from eight stations in the Oliver Pool near Tuscaloosa) (Alabama Geological Survey, unpublished data) and the upper Cahaba River system (18 samples from six stations) (Shepard and others, 1994).

Maximum chromium was highest in the Cahaba samples (49.1 mg/kg) and least in North River samples (12 mg/kg). Keller and Zam (1991) reported that the 48-hour (48h) LC_{50} (lethal concentration to 50 percent of test organisms) of chromium, nickel, and mercury exposures to juvenile *Anodonta imbecillis* in soft

Table 2. Quality analyses of bed sediment in the North River, Black Warrior River, and Cahaba River.

	North River[1]		Black Warrior River [2]		Cahaba River[3]	
	min	max	min	max	min	max
Major Elements (mg/kg):						
Bromide	<.6	<.6	<.5	<.5	--	--
Calcium	192	1,060	110	2,110	465	42,600
Chloride	<.4	41.5	10.7	38.5	<.4	<.4
Cyanide	<.08	<.08	<.1	0.55	--	--
Fluoride	<.06	0.11	<.2	8.75	<.2	34.4
Magnesium	313	1,060	106	1970	231	12,600
Ammonia (as N)	11.8	34.1	0.98	27.8	1	48.6
Total Kjeldahl Nitrogen	468	757	112	4,300	337	7,300
Total Nitrate-Nitrite (as N)	0.19	0.49	0.65	11.2	0.8	3.5
Total Phosphorus (as P)	<9	<9	41.7	641	118	477
Orthophosphate	<1	<1	<.5	1.61	<.5	11
Potassium	147	668	<60	1,200	119	1,260
Sodium	8	90	<6	182	<6	107
Sulfate	<.8	195	7.08	356	<.4	28.6
Trace Elements (mg/kg):						
Aluminum	3,140	6,510	597	16,600	1,680	9,340
Antimony	<.2	0.34	<.2	0.965	--	--
Arsenic	<.3	3.92	0.318	22.7	2.58	12.3
Barium	30.1	73	7.64	156	21.7	119
Beryllium	0.2	0.5	<.05	1.1	0.16	2.55
Cadmium	<.3	0.55	<.4	2.11	<.4	2.07
Chromium	5.9	12	<2	25	5	49.1
Cobalt	2.9	7.4	1.34	30.3	1.9	17.7
Copper	3.3	8.4	0.975	26.4	2.28	9.29
Iron	6,000	13,700	473	29,900	6,620	27,800
Lead	3.74	16.2	0.347	21	<.1	4.06
Lithium	2.2	8.4	<1	23.9	<1	8.6
Manganese	176	410	61.8	2130	240	2,580
Mercury	<.08	<.08	0.0066	0.195	0.0103	0.0619
Molybdenum	<2	2	<7	11.5	<7	14.4
Nickel	4	10.4	<1	39.5	5	68.7
Selenium	<.3	0.45	<.3	0.922	<.3	0.49
Silver	<.02	<.02	<2	<2	<2	<2
Strontium	2.85	9.45	1.02	17.3	1.85	21.6
Thallium	<.2	12.2	<.3	0.44	--	--
Vanadium	5.7	16.5	<.6	32.9	5.27	31.6
Zinc	19.2	35.1	8.19	155	14.9	192

[1] North River - 1 sample from each of 4 stations (McGregor and Wynn, 2008).

[2] Black Warrior River - 23 samples from 8 stations in the Oliver Pool (unpublished GSA data, 1992-93).

[3] Cahaba River - 18 samples from 6 stations in the upper Cahaba River system (Shepard and others, 1994).

water (hardness 40-80 mg/L $CaCO_3$) ranged from 216 to 295 µg/L, and that the LC_{50} increased 8 to 200 percent with exposure to moderately hard water (80-100 mg/L $CaCO_3$). Keller and Zam (1991) reported that the LC_{50} of *A. imbecillis* in an effluent containing 6.4 mg/L chromium decreased between 48h and 96h tests.

The highest maximum value of copper was reported from the Black Warrior River (26.4 mg/kg) while the maximum value for the North River was 8.4 mg/kg. Keller and Zam (1991) reported the 48h LC_{50} of copper to juvenile *Anodonta imbecillis* to be 171 µg/L with the 96h LC_{50} reduced to 86 µg/L. Foster and Bates (1978) reported *Quadrula quadrula* in the Muskingum River, Michigan, that were exposed to copper-containing industrial outfall accumulated copper to a lethal level at an exposure of 20.64 µg per gram wet weight, or 10 times the background level, after only 14 days. Imlay (1971) similarly reported copper at a concentration of 25 µg/L was lethal to mussels (species not given).

Mercury was not detected in North River samples, but was detected in the Black Warrior River (0.0066 - 0.195 mg/kg) and Cahaba River (0.0103 - 0.0619 mg/kg) in earlier studies. Reservoir construction is often cited as a cause of elevated mercury concentrations in fish, as naturally occurring mercury in flooded soils is released by bacterial methylation (Bodaly and others, 1984).

Nickel ranged from 4.0-10.4 mg/kg in North River samples but higher maximum values were reported from the Black Warrior and Cahaba Rivers. Keller and Zam (1991) reported the 48h LC_{50} of nickel to juvenile *Anodonta imbecillis* at a water hardness of 39 mg/L $CaCO_3$ to be 240 µg/L and in moderately hard water (60 to 120 mg/L $CaCO_3$) to be 471 µg/L.

North River zinc values ranged from 19.2 to 35.1 mg/kg while the maximum vales in the other rivers systems were several times higher. Zinc was found to be the least toxic metal tested on *A. imbecillis* juveniles by Keller and Zam (1991). Their results indicated water hardness of 39 mg/L $CaCO_3$ yielded a 48h LC_{50} of 355 µg/L and a 48h LC_{50} of 588 µg/L in moderately hard water (60 to 120 mg/L $CaCO_3$).

Bacteria

The Water Improvement Advisory Commission (1949) found fecal coliform bacteria to range from 0.36 to 210 MPN (most probable number per 100 milliliters of sample) in eight samples collected in the North River about 5 miles upstream of its confluence with the Black Warrior River during October and November 1948. The GSA completed an evaluation of *E. coli* bacteria in the North River watershed, including Lake Tuscaloosa, in 2005 (O'Neil, Cook, and others, 2006). Earlier sampling by the city of Tuscaloosa had determined a persistent presence of elevated *E. coli* concentrations in Lake Tuscaloosa (>200 cfu/100 mL [colony forming units per 100 milliliters]). Sources of this contamination were unknown and a study was designed to evaluate both a nonpoint watershed source potential and a groundwater source potential. Sampling sites were established in four areas of the North River watershed: (1) sites near the mouths of most tributaries draining into the North River upstream of Lake Tuscaloosa; (2) sites in the main channel of North River upstream of Lake Tuscaloosa; (3) sites in Lake Tuscaloosa proper; and (4) sites in tributaries draining directly into Lake Tuscaloosa. Multiple sites were established in the larger tributaries and in tributaries with suspected polluted runoff. The sampling regime was designed to collect water samples during the two extremes of the hydrologic cycle, low flows and high flows. Samples collected during low flow periods represent source water originating from shallow groundwater aquifers. If bacteria from poorly maintained septic tanks, damaged sanitary sewer systems, or infiltration of animal wastes were in contact with shallow ground water, then sampling during low flow periods should detect these problems. Samples collected during high flow periods represent source water from overland runoff of rainfall. Bacteria contamination originating from livestock or poultry operations, or from poorly managed treatment facilities, would be detected during high flow periods.

Water samples were collected at 232 stations in the North River watershed. Nine of the 232 stations were added after the high flow samples were collected in late spring and early summer, and 33 stations were not sampled during the low flow period in the fall because of dry stream channels. Bacteria samples were collected at each site during high flow periods in April and June and during low flow periods in September and October. For analytical purposes, Lake Tuscaloosa proper was divided into three sections (lower, middle, and upper) (fig. 7). The lower section extended from the Lake Tuscaloosa dam upstream to the mouth of Carroll Creek; the middle section extended from Carroll Creek mouth upstream to near Tierce-Patton Road; and the upper section extended from near Tierce-Patton Road upstream to Binion Creek.

The concentration of *E. coli* bacteria ranged from 1 to 14,670 cfu (median 100) for the low flow period, and from 22 to 17,980 (median 488) for the high flow period (table 3, fig. 7). During high stream flows within the lake proper, including small direct tributaries, the upper section had higher median and average *E. coli* bacteria concentrations compared to the middle and lower sections (table 3). Direct tributaries to Lake Tuscaloosa had high *E. coli* bacteria concentrations (613 - 17,250 cfu) during high flows with the highest measurements in Carroll Creek. During low flows, the median *E. coli* bacteria concentrations were similar throughout the lake, with median *E. coli* counts less than 200 cfu in the three sections (table 3). Additional evidence that storm water flows are related to high bacteria counts is that during high stream flows approximately 30.5 percent of the samples collected and analyzed for *E. coli* were less than 200 cfu and 69.5 percent were greater than or equal to 200 cfu. During low flows approximately 71 percent of the samples were less than 200 cfu and 29 percent were greater than or equal to 200 cfu.

For *E. coli* concentrations during low flows, excluding the lake proper, a large part of the eastern watershed was less than 200 cfu, while about one third to one half of the western watershed was greater than 200 cfu (fig. 7). Many stations around the lake proper had *E. coli* less than 200 cfu during low flow periods, whereas a few stations had *E. coli* counts between 200 and 1,000 cfu. Both Carroll and Binion Creeks, major tributaries to Lake Tuscaloosa proper, had

Table 3. Summary total coliform and *E. coli* bacteria concentrations for samples collected in the North River/Lake Tuscaloosa watershed, 2005.

	Total coliforms				*E. coli*			
	Min [1]	Max	Med	Avg	Min	Max	Med	Avg
Low stream flows (September-October)								
Lake Tuscaloosa								
Upper lake	1,986	11,120	6,200	6,632	6	1,414	120	262
Middle lake	273	23,820	3,320	5,513	1	1,120	61	161
Lower lake	435	173,290	4,140	9,290	2	14,670	133	519
Tributaries	4,960	18,500	8,230	9,320	2	613	228	257
North River								
Main channel	1,300	7,480	2,425	3,329	8	145	83	82
Tributaries	1,414	241,960	7,195	13,476	3	921	91	185
ALL STATIONS	273	241,960	4,870	8,242	1	14,670	100	263
High stream flows (April-June)								
Lake Tuscaloosa								
Upper lake	2,420	242,000	135,665	128,983	32	6,450	980	1,542
Middle lake	1,553	242,000	11,180	31,178	33	17,980	203	998
Lower lake	3,010	242,000	26,130	47,139	22	4,260	579	844
Tributaries	6,700	242,000	34,480	62,907	613	17,250	3,050	4,028
North River								
Main channel	1,046	26,030	11,980	10,927	41	2,040	1,378	1,088
Tributaries	1,986	129,970	7,650	23,181	47	12,360	435	1,407
ALL STATIONS	1,046	242,000	15,000	44,446	22	17,980	488	1,324

[1] min-minimum; max-maximum; med-median; avg-average.

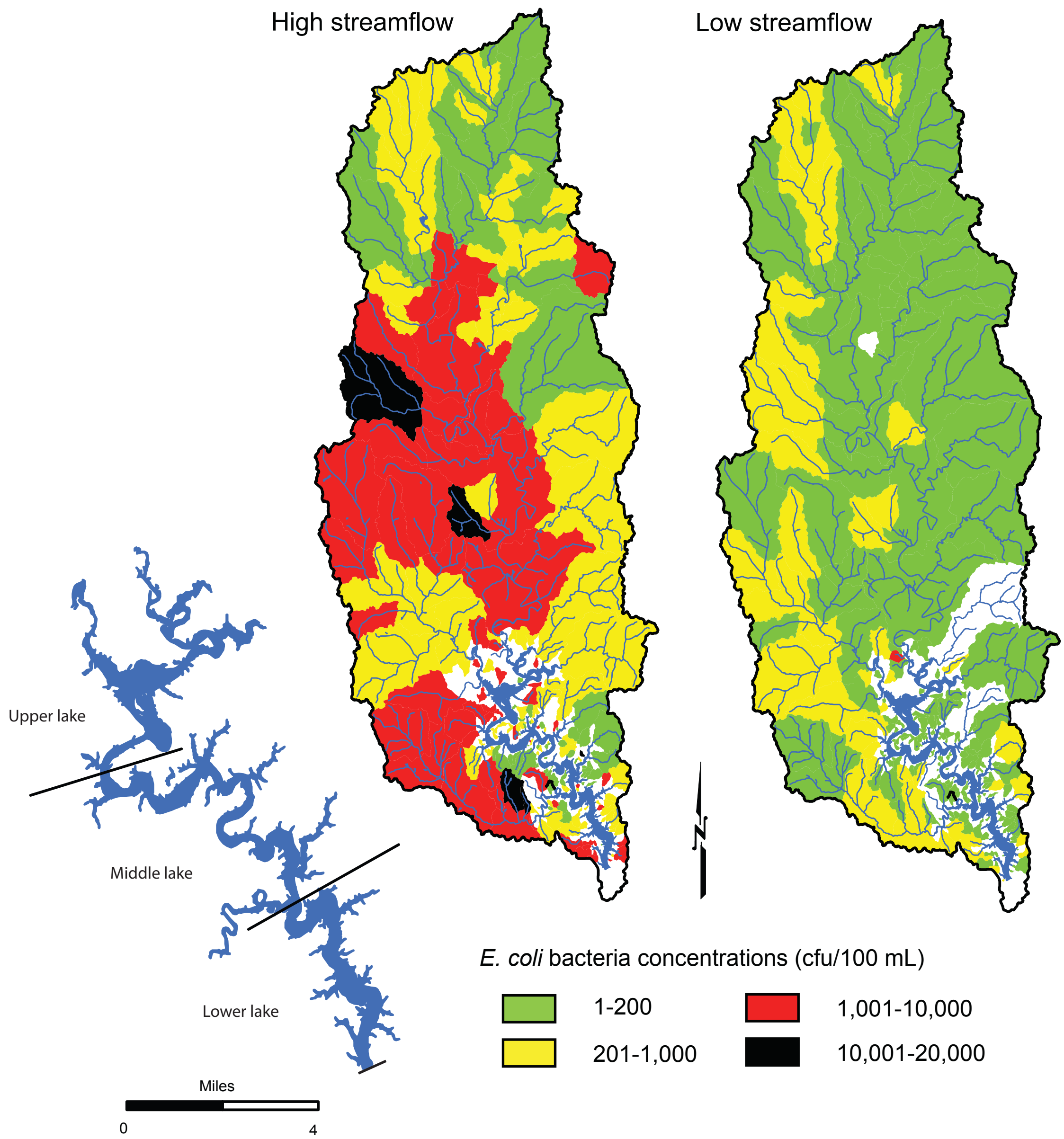


Figure 7. Occurrence of *E. coli* bacteria in the North River watershed during high and low streamflows (O'Neil and others, 2006).

several stations with *E. coli* bacteria ranging between 200 and 1,000 cfu during low flow periods.

Elevated *E. coli* concentrations were more widespread during high stream flows (fig. 7). A few headwater streams and a few small streams draining directly into Lake Tuscaloosa were less than 200 cfu. Several stations in main channel North River, and tributaries to North River in this area (Sandy Point Creek, Boones Creek, and lower Tyro Creek), had *E. coli* concentrations in the 1,000 to 10,000 cfu range. Headwater tributaries to Binion Creek and stations in the embayment of Binion Creek were also in this range. All samples taken in the Carroll Creek watershed were between 1,000 and 10,000 cfu for *E. coli*, and many small direct tributaries to Lake Tuscaloosa were in the 1,000 to 10,000 cfu range. A few stations sampled during high stream flows had *E. coli* concentrations greater than 10,000 cfu including two sites in the North River proper, two sites in the Carroll Creek watershed, and one site in Lake Tuscaloosa.

The bacteria sampling strategy of this study was designed to incorporate both surface-water (high stream flows) and groundwater (low stream flows) sources to the North River/Lake Tuscaloosa watershed. This approach was desirable because the North River/Lake Tuscaloosa area is hydrogeologically diverse with source water originating from geologic units of the Pottsville and Coker Formations and modified by runoff from multiple land use activities, discharged effluents, and any groundwater contamination that may be in the watershed. Elevated bacteria concentrations can be caused by many factors including storm water runoff over agricultural and urban areas, leaking and(or) improperly functioning septic tanks, and(or) discharge from poorly operated waste treatment facilities. Shallow groundwater overlying the Pottsville Formation in the eastern part of the watershed travels relatively quickly and directly to the nearest stream outlet, while shallow groundwater in soils overlying the more sandy and gravelly Coker Formation in the western part of the watershed tends to percolate deeper, thus providing more time for natural treatment before it enters a stream channel.

Alfaqih (2008) used this recent *E. coli* dataset to further explore the potential sources of contamination in the watershed. Detailed hydrologic and bacteria models were developed for the watershed. Unrestricted access of large animals to stream channels and poor handling of poultry waste were identified as significant contributors of *E. coli* bacteria to the North River. The *E. coli* concentrations increased substantially in subwatersheds as the number of chicken houses increased. Modeling results demonstrated that if 50 percent of waste from unrestricted pasture inputs and chicken houses was controlled then about 38 percent of the rain events would produce *E. coli* concentrations in Lake Tuscaloosa exceeding 200 cfu. If all sources of manure from pastures and chicken houses were controlled, then only 10 percent of the rain events would produce *E. coli* concentrations exceeding 200 cfu. Controls for large animal access are fencing of pasture and(or) creation of a dense riparian buffer to control animal access. Controls for concentrated manure are incineration, burial, waste storage structures, composting, and filter strips. Composting was determined to be the most viable option after applying a decision analysis model (Alfaqih, 2008).

MUSSELS

Collections in the upper North River system upstream of Lake Tuscaloosa from 1991 to 1996 (table 4, fig. 8, appendix A) documented 14 species of unionid mussels (Freda, 1992; Pierson, 1992; McGregor and Pierson, 1999). Thirteen species were represented by live and fresh dead material and one species by a single weathered dead shell only. A total of 201 mussels, either live or fresh dead, were found at 33 stations (table 5). Another mussel survey was conducted during the spring and summer of 2008 in the North River watershed (McGregor and Wynn, 2008). Fifteen species were collected, with 13 represented by live animals or fresh dead shells and two represented by weathered dead shells only (table 5). A total of 145 mussels, either live or fresh dead, were found at 29

Table 4. Biological and habitat sampling sites in the North River watershed.

Site No.	Sampling site	County	Latitude	Longitude	section, township, range	Type of data: Mussel	Fish	Habitat
1	Carrolls Creek at Ala. Hwy. 69	Tuscaloosa	33.29450	87.56839	sec. 22, T. 20 S., R. 10 W.		X	X
2	Binion Creek at Old Fayette Road	Tuscaloosa	33.42470	87.64267	sec. 2, T. 19 S., R. 11 W.			X
3	Binion Creek at Kemp Road	Tuscaloosa	33.47908	87.70377	sec. 17, T. 18 S., R. 11 W.		X	X
4	Turkey Creek at Ala. Hwy. 69	Tuscaloosa	33.40974	87.51101	sec. 7, T. 19 S., R. 9 W.		X	X
5	North River at Cripple Creek mouth	Tuscaloosa	33.46583	87.57655	sec. 22, T. 18 S., R. 10 W.	X		
6	Cripple Creek near mouth	Tuscaloosa	33.46660	87.57532	sec. 22, T. 18 S., R. 10 W.		X	X
7	Cripple Creek at Co. Hwy. 38	Tuscaloosa	33.49287	87.56232	sec. 10, T. 18 S., R. 10 W.	X		
8	Cripple Creek at Johnson Branch mouth	Tuscaloosa	33.50860	87.54010	sec. 1, T. 18 S., R. 10 W.	X		
9	North River at Co. Hwy. 38	Tuscaloosa	33.47959	87.59682	sec. 17, T. 18 S., R. 10 W.	X	X	X
10	North River US[1] of Co. Hwy. 38	Tuscaloosa	33.50683	87.58037	sec. 4, T. 18 S., R. 10 W.	X		
11	North River near Bear Creek mouth	Tuscaloosa	33.52106	87.58009	sec. 34, T. 17 S., R. 10 W.	X		
12	North River at Bear Creek	Tuscaloosa	33.52434	87.57652	sec. 34, T. 17 S., R. 10 W.	X		
13	Bear Creek at USGS site	Tuscaloosa	33.54228	87.56160	sec. 26, T. 17 S., R. 10 W.		X	X
14	North River DS[1] of Tyro Creek	Tuscaloosa	33.54430	87.58547	sec. 28, T. 17 S., R. 10 W.	X		X
15	Tyro Creek nr Whitson Bridge	Tuscaloosa	33.55329	87.60063	sec. 20, T. 17 S., R. 10 W.			X
16	Tyro Creek at Tyro Creek Road	Tuscaloosa	33.56605	87.57632	sec. 15, T. 17 S., R. 10 W.		X	X
17	Boone Creek at Co. Hwy. 55	Tuscaloosa	33.54292	87.60442	sec. 29, T. 17 S., R. 10 W.	X		X
18	Boone Creek at Co. Hwy 63	Tuscaloosa	33.53607	87.62292	sec. 31, T. 17 S., R. 10 W.	X		
19	North River at Wittson Bridge	Tuscaloosa	33.54987	87.59717	sec. 29, T. 17 S., R. 10 W.	X		X
20	North River DS of Tusc. Co. Hwy. 63	Tuscaloosa	33.76353	87.60797	sec. 19, T. 17 S., R. 10 W.	X		
21	North River at Tusc. Co. Hwy. 63	Tuscaloosa	33.56177	87.63010	sec. 19, T. 17 S., R. 10 W.	X	X	X
22	North River US of Tusc. Co, Hwy. 63	Tuscaloosa	33.55438	87.63864	sec. 19, T. 17 S., R. 10 W.	X		
23	North River at Cedar Creek mouth	Tuscaloosa	33.57955	87.62258	sec. 18, T. 17 S., R. 10 W.	X	X	
24	Cedar Creek near mouth	Tuscaloosa	33.58055	87.62142	sec. 18, T. 17 S., R. 10 W.	X	X	X
25	Cedar Creek at Co. Hwy. 63	Fayette	33.61263	87.60509	sec. 32, T. 16 S., R. 10 W.			X
26	Cedar Creek at Berry	Fayette	33.65047	87.58901	sec. 16, T. 16 S., R. 10 W.			X
27	North River US of Cedar Creek	Tuscaloosa	33.58047	87.62245	sec. 18, T. 17 S., R. 10 W.	X		X
28	North River at Ala. Hwy. 18	Fayette	33.63093	87.65468	sec. 26, T. 16 S., R. 11 W.	X		X
29	North River DS of Clear Creek	Fayette	33.65098	87.64525	sec. 24, T. 16 S., R. 11 W.	X		
30	Clear Creek at Ala. Hwy. 13	Fayette	33.65070	87.65177	sec. 14, T. 16 S., R. 11 W.	X		

Table 4. Biological and habitat sampling sites in the North River watershed -- continued.

Site No.	Sampling site	County	Latitude	Longitude	section, township, range	Type of data		
						Mussel	Fish	Habitat
31	Deadwater Creek at Clear Creek	Fayette	33.66163	87.65304	sec. 14, T. 16 S., R. 11 W.		X	X
32	Deadwater Creek at RR tracks	Fayette	33.65961	87.65718	sec. 14, T. 16 S., R. 11 W.	X	X	X
33	Deadwater at Bankston	Fayette	33.67104	87.67310	sec. 10, T. 16 S., R. 11 W.			X
34	Clear Creek at Deadwater Creek mouth	Fayette	33.66228	87.65247	sec. 14, T. 16 S., R. 11 W.		X	X
35	Clear Creek at Co. Hwy. 93	Fayette	33.67835	87.65993	sec. 11, T. 16 S., R. 11 W.	X	X	X
36	Clear Creek at Lowery Road	Fayette	33.68933	87.66294	sec. 2, T. 16 S., R. 10 W.	X		X
37	Clear Creek DS of Bugs Lake	Fayette	33.69333	87.65257	sec. 2, T. 16 S., R. 11 W.	X	X	X
38	Boles Creek at CR 67	Fayette	33.73529	87.69601	sec. 21, T. 15 S., R. 11 W.			X
39	Clear Creek at Clear Creek Road	Fayette	33.73395	87.67212	sec. 22, T. 15 S., R. 11 W.	X	X	X
40	Clear at Co. Hwy. 93 (upper)	Fayette	33.75908	87.66723	sec. 22, T. 15 S., R. 11 W.			X
41	North River at Co. Hwy. 30	Fayette	33.68056	87.63143	sec. 7, T. 16 S., R. 10 W.	X	X	X
42	Ellis Creek	Fayette	33.71108	87.64043	sec. 25, T. 15 S., R. 11 W.			X
43	North River DS Fayette Co. dam site	Fayette	33.70342	87.62359	sec. 31, T. 15 S., R. 10 W.	X		
44	North River at Fayette Co. dam site	Fayette	33.70522	87.62137	sec. 31, T. 15 S., R. 10 W.	X		
45	Star Branch at dam site	Fayette	33.70745	87.61831	sec. 31, T. 15 S., R. 10 W.	X		
46	North River DS of Cane Creek	Fayette	33.70163	87.60676	sec. 32, T. 15 S., R. 10 W.	X		X
47	Cane Creek near mouth	Fayette	33.70154	87.60180	sec. 32, T. 15 S., R. 10 W.	X		
48	Cane Creek at Co. Hwy. 63	Fayette	33.69981	87.58854	sec. 33, T. 15 S., R. 10 W.	X	X	X
49	North River near Laney Branch	Fayette	33.71098	87.60252	sec. 29, T. 15 S. R. 10 W.	X		
50	North River DS of Jenkins Cemetery	Fayette	33.71492	87.60375	sec. 29, T. 15 S. R. 10 W.	X		
51	North River US of Jenkins Cemetery	Fayette	33.71665	87.60508	sec. 29, T. 15 S. R. 10 W.	X	X	X
52	Beaver Creek	Fayette	33.75340	87.63160	sec. 18, T. 15 S., R. 10 W.	X		
53	George Creek near mouth	Fayette	33.73892	87.59871	sec. 20, T. 15 S., R. 10 W.	X		
54	George Creek at Co. Hwy. 63	Fayette	33.74725	87.59077	sec. 15, T. 15 S., R. 10 W.	X		X
55	North River US George Creek (1)	Fayette	33.74021	87.60276	sec. 17, T. 15 S., R.10 W.	X		
56	North River US George Creek (2)	Fayette	33.74683	87.60420	sec. 17, T. 15 S., R.10 W.	X		
57	North River US George Creek (3)	Fayette	33.75315	87.60630	sec. 17, T. 15 S., R.10 W.	X		
58	North River at Lowery Branch	Fayette	33.76020	87.61040	sec. 8, T. 15 S., R. 10 W.	X	X	X
59	North River at Co. Hwy. 63	Fayette	33.76863	87.60110	sec. 5/8, T. 15 S., R. 10 W.	X		
60	Hendon Creek near Co. Hwy. 63	Fayette	33.77512	87.60365	sec. 5, T. 15 S., R. 10 W.	X		
61	North River at Ala. Hwy. 102	Fayette	33.80535	87.58376	sec. 28, T. 14 S., R. 10 W.	X	X	X

[1] DS - downstream, US - upstream

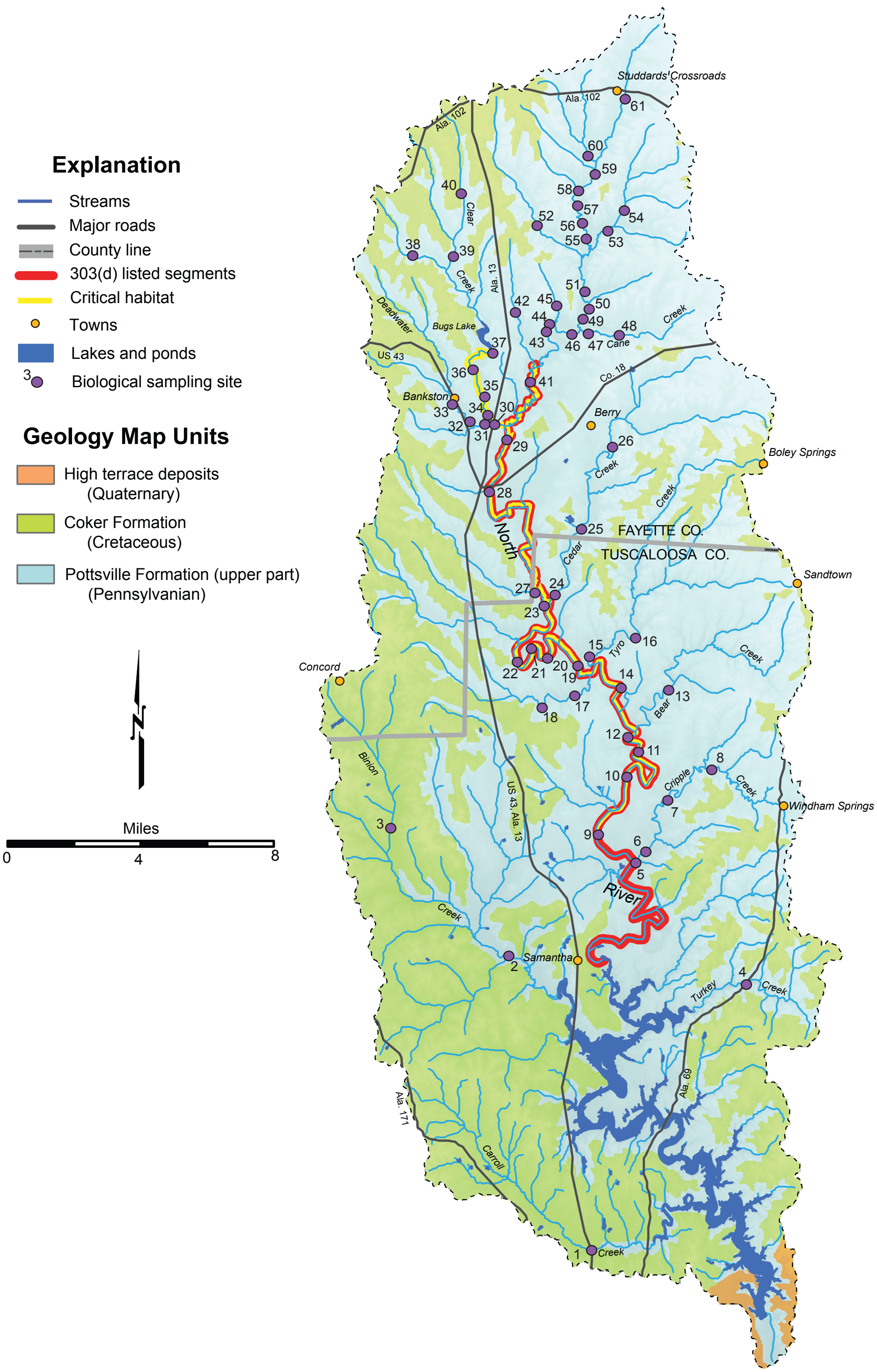


Figure 8. Biological sampling sites in the North River watershed.

Table 5. Comparison of mussel population status between two sampling periods in the North River watershed.

Species - common name	Conservation Status[1]	Total live and fresh dead individuals			
		All sites		Standardized sites[2]	
		1991-93, 96[3]	2005-08[4]	1991-93	2008
Amblema plicata - Threeridge	P4	1	wd[5]	1	wd
Anodontoides radiatus - Rayed Creekshell	P2	--	4	--	2
Elliptio arca - Alabama Spike	P1	1	--	1	--
Elliptio arctata - Delicate Spike	P1	1	34	wd	--
Hamiota perovalis - Orangenacre Mucket	T, P2	13	3	10	2
Lampsilis ornata - Southern Pocketbook	P4	10	2	2	1
Lampsilis straminea - Southern Fatmucket	P3	35	22	12	3
Lampsilis teres - Yellow Sandshell	P5	wd	1	wd	--
Pleurobema furvum - Dark Pigtoe	E, P1	25	2	6	1
Pyganodon grandis - Giant Floater	P5	1	wd	--	--
Quadrula asperata - Alabama Orb	P5	31	12	13	10
Quadrula verrucosa - Pistolgrip	P4	3	11	2	9
Strophitus subvexus - Southern Creekmussel	P3	59	28	28	11
Uniomerus tetralasmus - Pondhorn	P4	--	1	--	1
Villosa lienosa - Little Spectaclecase	P5	7	15	4	8
Villosa vibex - Southern Rainbow	P5	14	10	7	3
Total individuals		201	145	86	51
Number sampling sites		33	29	13	13

[1] E-endangered, T-threatened; State ranks: P1=Highest Conservation Concern, P2=High Conservation Concern, P3=Moderate Conservation Concern, P4=Low Conservation Concern, P5=Lowest Conservation Concern.

[2] Standardized sites were represented by 13 stations in the watershed that were sampled during both the earlier and recent surveys. These included sites 9, 19, 23, 24, 28, 30, 35, 41, 54, 58, 59, 60, 61 (see table 4).

[3] From McGregor and Pierson (1999).

[4] From McGregor and Wynn (2008).

[5] wd (weathered dead) shells, not included in total counts.

stations. Sampling time totaled 62 hours in 2008, with 34 hours in main channel North River stations and 28 hours in tributary stations. A catch per unit area (CPUE) of 2.2 mussels per hour was determined for species collected either live or fresh dead in 2008.

Pleurobema furvum and *Hamiota perovalis* were collected live during sampling in the North River system from 1991 to 1996, and *P. furvum* was the fourth most abundant species among 14 species reported. However, only one live and one fresh dead specimen of *P. furvum* were found in 2008 (at station 30 in Clear Creek), suggesting a sharp decline in abundance. Similarly, *H. perovalis* was found at five stations in the earlier study (13 live or fresh dead) but at only three stations (two in Clear Creek and one in main channel North River) during 2008 (3 live or fresh dead). *Ptychobranchus greenii*, another federally listed endangered species, which was reported by van der Schalie (1981) to occur in the drainage prior to 1920, was not collected in either study, nor was *Pleurobema hagleri*, another species known from the drainage prior to 1920, which has not been reported in the scientific literature, technical reports, or museum collections in over 30 years and is considered extinct by the USFWS (Hartfield, 1994).

During the earlier survey (McGregor and Pierson, 1999) dominant mussels collected (table 5) were *Strophitus subvexus* (59 individuals), *Quadrula asperata* (31 individuals), *Lampsilis straminea* (35 individuals), *Pleurobema furvum* (25 individuals), and *Villosa vibex* (14 individuals). The most widespread were *S. subvexus* (23 stations), *V. vibex* (14 stations) and *L. straminea* (13 stations) (appendix A). The most abundant species collected during the 2008 survey, either live or fresh dead (table 5), were *Elliptio arctata* (34 individuals), *S. subvexus* (28 individuals), *L. straminea* (22 individuals), and *Villosa lienosa* (15 individuals). The most widespread were *S. subvexus* (9 stations), *V. lienosa* (7 stations), and *L. straminea* and *Quadrula asperata* (5 stations each). During each of these studies the exotic Asian clam, *Corbicula fluminea*, was commonly encountered at all stations, with the exception of a few headwater and tributary sites.

Reasons for the change in dominance and frequency between the studies are not clear from available data, but several explanations are possible including changes in habitat quality, habitat availability, and sample bias. During the previous study the most diverse and abundant mussel fauna was located at site 23, North River at the mouth of Cedar Creek, where 20 live or fresh dead individuals among 8 species were collected on August 22, 1993 (appendix A, table 6). Only one weathered dead shell was found there on June 5, 2008. Another sampling site near the mouth of Cedar Creek near its mouth, site 24, was the next most diverse location with 7 species found on November 29, 1991. No species were found at this site on June 5, 2008. Sample bias could also partially account for the discrepancy in abundance and distribution. During the 2008 survey numerous *Elliptio arctata* were found in a unique niche preferred by that species, under large slab rocks (19 were found under one rock at site 36 in Clear Creek). This species was poorly represented in early collections, and since no discussion of sampling methodology was offered by McGregor and Pierson (1999), it is unknown if this habitat was examined. If not, it is possible that *E. arctata* may have been underrepresented in the samples.

Two species collected in 2008 were not reported in earlier collections by McGregor and Pierson (1999)—*Anodontoides radiatus* and *Uniomerus tetralasmus*—and one species reported during the previous study, *Elliptio arca*, was not collected in the 2008 surveys. *Anodontoides radiatus* strongly resembles *Strophitus subvexus*, and distinguishing the two can be problematic. In the Mobile River Basin, *A. radiatus* is widespread downstream of the Fall Line with some populations residing at the Fall Line, while *S. subvexus* is now generally considered to be restricted to the Black Warrior and Tombigbee River drainages, usually downstream of the Fall Line but with some populations upstream (Williams and others, 2008). It is possible that some individuals reported as *S. subvexus* in the previous study were misidentified. In the Mobile River Basin *Uniomerus tetralasmus* is generally restricted to downstream of the Fall Line, with some records from the upper Coosa River system. It is found in headwater

Table 6. Number of mussel species and fish community biological condition for sampling sites in the North River watershed (colors represent mussel diversity and biological condition for each site).

Excellent Good Fair Poor

Number of mussel species		Biological condition		Tributary sites
1991-96	2008	1974-88	2008-09	
				1. Carroll Creek at Ala. Hwy. 69
				3. Binion Creek at Kemp Road
				4. Turkey Creek at Ala. Hwy. 69
				6. Cripple Creek near mouth
	0			7. Cripple Creek at Co. Hwy. 38
	1			8. Cripple Creek at Johnson Branch
				13. Bear Creek at USGS site
				16. Tyro Creek at Tyro Creek Road
	2			17. Boone Creek at Co. Hwy. 55
	1			18. Boone Creek at Co. Hwy. 63
7	0			24. Cedar Creek near mouth
8	6			30. Clear Creek at Ala. Hwy. 13
				31. Deadwater Creek at Clear Creek
	4			32. Deadwater Creek at RR tracks
				34. Clear Creek at Deadwater Creek mouth
4	3			35. Clear Creek at Co. Hwy. 93
	7			36. Clear Creek at Lowery Road
	8			37. Clear Creek DS of Bugs Lake
	0			39. Clear Creek at Clear Creek Road
0				45. Star Branch at dam site
0				47. Cane Creek near mouth
	0			48. Cane Creek at Co. Hwy. 63
	0			52. Beaver Creek
4				53. George Creek near mouth
1	0			54. George Creek at Co. Hwy. 63
0	0			60. Hendon Creek near Co. Hwy. 63

DS - downstream, US - upstream

Number of mussel species		Biological condition		Main channel sites
1991-96	2008	1974-88	2008-09	
	3			5. North River at Cripple Creek mouth
7	6			9. North River at Co. Hwy 38
	2			10. North River US of CR 38
	0			11. North River near Bear Creek mouth
	3			12. North River at Bear Creek
	1			14. North River DS of Tyro Creek
3	1			19. North River at Wittson Bridge
3				20. North River DS of Tusc. Co. Hwy. 63
3				21. North River at Tusc. Co. Hwy. 63
2				22. North River US of Tusc. Co. Hwy. 63
8	1			23. North River at Cedar Creek mouth
7				27. North River US of Cedar Creek
5	2			28. North River at Ala. Hwy. 18
	0			29. North River DS of Clear Creek
4	3			41. North River at Co. Hwy. 30
1				43. North River DS of Fayette Co. dam site
2				44. North River at Fayette Co. dam site
3				46. North River DS of Cane Creek
2				49. North River near Laney Branch
4				50. North River DS of Jenkins Cemetery
3				51. North River US of Jenkins Cemetery
1				55. North River US of George Creek (1)
2				56. North River US of George Creek (2)
2				57. North River US of George Creek (3)
2	3			58. North River at Lowery Branch
3	2			59. North River at Fayette Co. Hwy. 63
0	0			61. North River at Ala. Hwy. 102

streams, ponds, and floodplain lakes, may be locally abundant, and can withstand extended periods of dewatering (Williams and others, 2008). It may have been merely overlooked during the previous studies. This collection represents a new tributary record for the species. Only one fresh dead and two weathered dead shells of *Elliptio arca* were reported by McGregor and Pierson (1999) and may have been misidentified, since *E. arca* strongly resembles *E. arctata*. However, *E. arca* has been documented from the North River system (Williams and others, 2008) and its limited presence in the earlier survey and absence during the 2008 survey may document a decline within the system.

A variety of human activities in the North River drainage have contributed to siltation of the main channel and tributaries. As observed in the 2008 survey (McGregor and Wynn, 2008), the substrate in pools and in some riffle areas was often dominated by a dense layer of coarse sand covered with a fine layer of silt. Live mussels were usually found in areas of slow to moderate current in relatively silt-free sand or gravel substrate. Freshwater mussels are benthic filter-feeding organisms and as such are exposed to pollutants that are dissolved in water, associated with suspended sediments, or deposited in bottom sediments (Naimo, 1995). Because mussels are relatively long-lived, generally sedentary in nature, easily collected, large enough to provide sufficient tissue mass for analysis, tolerant of a wide assortment of pollutants, and known to bioaccumulate contaminants, their collective value as indicator organisms for evaluation of long-term ecosystem function and health is well known.

While relatively little information is available on the lethal limits of various pollutants to freshwater mussels, ongoing research documents tolerances of various species and life history stages of mussels (Newton and Bartsch, 2007; Newton and Cope, 2007; Cope and others, 2008). The acute toxic effects of pollutants on mussels have been examined in some tests, but the sublethal effects of long-term exposure to low environmental concentrations are poorly understood (see Naimo, 1995, for a review of toxic metal effects). Also, it is widely understood that, despite improvements in modern effluent treatment facilities, freshwater mollusks continue to be negatively affected by ammonia, chlorine, copper, zinc, elevated temperature, organic waste, suspended solids, and nutrients.

Generally, the metals most toxic to freshwater mussels include cadmium, chromium, copper, mercury, nickel, and zinc (Keller and Zam, 1991; Naimo, 1995), with mercury, copper, and cadmium the most toxic (Khangarot and Ray, 1987). It should be noted that freshwater mussels become stressed at metal concentrations much lower than those reported in acute toxicity tests and that most tests are conducted under laboratory conditions and might not reflect conditions in nature (Naimo, 1995). Exposures to metals and other contaminants may not be immediately lethal, but over time may interrupt metabolic activities, enzyme function, respiration, and other important biological activities, leading to death. Organic contents of the sediment and water column are also very important in the ability of mussels to uptake toxins. Graney and others (1984) observed that Asian clams decreased the uptake of cadmium as the organic content of test substrates increased, and that clams in tanks with no substrate or with sand only had much higher tissue burdens than those in tanks with organic or clay-enriched substrates. They also found that clams accumulated more cadmium at 21˚C than at 9˚C and at pH 7.8 than at pH 5.0. Jacobson and others (1997) reported that juvenile mussels are at greater risk to contamination than adults due to their shallow residency in benthic sediments, where toxicants such as metals may be sequestered at high levels. Metal toxicity to mussels may very well be a factor in mussel population declines in the North River system due to the continued impact of coal mine drainage on water quality in the upper part of the watershed.

BIOLOGICAL CONDITION

The science and practice of stream monitoring, assessment, and evaluation has grown substantially since passage of the Clean Water Act in 1972. Biological and habitat assessment methods have been added to the traditional chemical and physical measurements of stream water quality, and water resource and fisheries management professionals now have expanded and enhanced methods for evaluating water resource conditions. Biological assessment methods incorporate a variety of taxonomic groups including algae, benthic macroinvertebrates, and fishes, all of which reflect stream water quality through the composition, structure, and functional relationships of their biological communities (Barbour and others, 1999). In particular, the Index of Biotic Integrity (IBI) method, based on the fish community (Karr, 1981), has proven to be an effective tool for evaluating stream health and in some states to provide a scientifically credible basis for numerically regulating and managing stream water quality.

In Alabama, the IBI has been used by the Tennessee Valley Authority (TVA) throughout the Tennessee River basin since 1986 (Saylor and Ahlstedt, 1990) to evaluate stream biological conditions. The IBI has also been used by GSA to assess biological conditions in the following river systems:

- upper Cahaba River system (Shepard and others, 1997)
- lower Cahaba River system (O'Neil and Shepard, 2000a)
- the upper Black Warrior River system (O'Neil and Shepard, 2000b; Shepard and others, 2002; Shepard and others 2004)
- Hatchet Creek (O'Neil and Shepard, 2004)
- Choccolocco Creek (O'Neil and Chandler, 2005)
- Choctawhatchee-Pea River system (Cook and O'Neil, 2000).

The Alabama Department of Environmental Management (ADEM) uses the IBI for stream screening assessments in their water-quality monitoring activities (ADEM, 1999).

A recent study (O'Neil, Shepard, and Cook, 2006) outlined a fish community sampling protocol that proved acceptable for collecting a representative fish community sample for the purpose of calculating an IBI score. This research demonstrated that sampling should be stratified over four basic stream habitat types (riffles, runs, pools, and shorelines). A minimum of 10 sampling efforts each should be completed in riffle, run, and pool habitats and two sampling efforts should be completed along stream shorelines. This level of sampling effort and intensity, termed the “30+2" method, was determined sufficient to yield a fish community sample acceptable for calculating IBIs. Within the 30+2 IBI sampling method, small-mesh minnow seines serve as a complement to the backpack electroshocker and are used to catch, scoop, or dip stunned fishes and to trap fishes in sloughs and backwaters. At other times, seines are used as the primary device for capturing fishes in pools and runs and along shoals.

Biological condition at 21 sites in the North River system was evaluated by calculating the IBI using the metrics and scoring criteria presented in O’Neil and Shepard (2000b) (tables 7, 8). Four sites rated poor (1-Carroll Creek, 4-Turkey Creek, 35-Clear Creek at Fayette Co. Hwy. 93, and 61-North River at Ala. Hwy. 102), 11 sites rated fair, and 5 sites rated good (16-Tyro Creek, 21-North River at Tuscaloosa. Co. Hwy. 63, 23-North River at Cedar Creek, 24-Cedar Creek near its mouth, and 58-North River at Lowery Branch). One site, 51-North River upstream of Jenkins Cemetery, rated excellent for biological condition. Historical data existed for nine of the 21 sites where collecting methods were such that an IBI could be calculated (table 6). Biological condition degraded from fair to poor at Carroll Creek and from good to poor at Turkey Creek, was unchanged at six sites, and improved from fair to excellent at site 51, North River at Jenkins Cemetery. The IBI varies seasonally reflecting natural fish community changes due to reproduction cycles, population recruitment and growth, and climate-related flood and drought cycles. As such, several samples should be collected from different seasons at any one site to adequately characterize the statistical distribution (baseline) of IBIs. Sufficient seasonal collections existed for nine sites to calculate a historical IBI baseline (fig. 9). Comparison of the single sample taken in 2008-09 with this IBI baseline revealed that six of the nine recent samples fell within baseline variation observed in historical samples. For site 4-Turkey Creek the recent sample fell well below baseline indicating substantial degradation of biological condition, while at two sites, North River upstream of

Table 7. Actual IBI metric values for sites in the North River watershed, 2008-09.

Stream site	IBI metrics											
	1	2	3	4	5	6	7	8	9	10	11	12
	TOTSP	DAR	MIN	SUN	SUCK	INTSP	PSUN	OMNI	INSCYP	TC	CATCH	DELHY
1	21	4	6	5	0	0	21.9	0.2	9.7	0.4	311	0
3	13	3	4	2	0	0	2.7	0	59.0	2.7	52	0
4	11	3	4	2	0	0	26.9	54.6	8.5	0	111	0
6	23	4	6	4	4	0	32.2	26.8	15.7	1.5	209	0
9	23	4	7	4	2	1	24.9	28.7	26.0	0.8	247	0
13	23	4	11	3	2	1	16.2	9.3	42.6	0	206	0
16	17	4	6	2	2	1	13.8	8.8	52.0	2.5	113	0
21	22	4	7	4	2	1	10.8	18.6	51.8	2.1	347	0
23	27	6	7	3	3	1	11.3	1.7	34.0	3.8	168	0
24	27	4	10	4	2	0	25.6	17.0	32.8	1.9	373	0
31	29	4	9	3	3	0	31.3	0.9	42.9	2.3	148	0
32	26	5	10	3	2	0	14.2	0.3	43.6	0.6	248	0.6
34	22	4	3	3	3	1	25.2	3.1	35.0	3.1	143	0
35	22	5	5	3	1	1	35.8	14.0	21.4	0.4	194	1.2
37	23	5	5	4	1	1	23.5	47.2	7.6	5.0	292	0.3
39	22	5	6	3	1	0	3.4	3.6	65.7	0.6	429	0
41	29	5	9	6	4	0	38.8	10.8	23.2	0.5	265	0
48	20	2	6	5	2	0	48.0	27.0	3.2	8.0	251	0.6
51	32	6	12	4	3	2	5.4	1.4	76.8	1.0	493	0.7
58	23	4	8	3	3	2	9.7	10.0	47.0	0	395	3.3
61	16	3	5	3	2	1	13.8	34.3	12.5	0	428	1.9

TOTSP-no. native species; DAR-no. darter species; MIN-no. minnow species; SUN-no. sunfish species;
SUCK-no. sucker species; INTSP-no. intolerant species; PSUN-proportion of sunfish; OMNI-proportion of omnivores and herbivores;
INSCYP - proportion of insectivorous cyprinids; TC-proportion of top carnivores; CATCH-catch per hour;
DELHY-proportion with DELT+hybrids.

Table 8. IBI scores for sites in the North River watershed, 2008-09.

Sample site	IBI metrics 1 TOTSP	2 DAR	3 MIN	4 SUN	5 SUCK	6 INTSP	7 PSUN	8 OMNI	9 INSCYP	10 TC	11 CATCH	12 DELHY	Final IBI	Biological condition
1	5	5	3	5	1	1	3	5	1	1	3	5	38	poor
3	3	3	3	3	1	1	5	5	5	5	1	5	40	fair
4	3	3	3	3	1	1	3	1	1	1	3	5	28	poor
6	5	5	5	5	5	1	1	3	1	3	3	5	42	fair
9	5	3	3	5	3	3	3	3	3	3	3	5	42	fair
13	5	5	5	3	3	3	3	5	3	1	3	5	44	fair
16	5	5	5	3	3	3	3	5	5	5	3	5	50	good
21	5	3	3	5	3	3	3	5	5	5	5	5	50	good
23	5	5	3	3	5	3	5	5	3	5	3	5	50	good
24	5	5	5	5	3	1	3	5	3	3	5	5	48	good
31	5	5	5	3	5	1	1	5	3	5	1	5	44	fair
32	5	5	5	3	3	1	3	5	3	1	3	5	42	fair
34	5	3	1	3	5	3	3	5	3	5	1	5	42	fair
35	5	5	3	3	3	3	1	5	1	1	3	5	38	poor
37	5	5	3	5	3	3	3	1	1	5	3	5	42	fair
39	5	5	3	3	3	1	5	5	5	1	3	5	44	fair
41	5	5	5	5	5	1	1	5	3	3	3	5	46	fair
48	5	3	5	5	3	1	1	3	1	5	3	5	40	fair
51	5	5	5	5	5	3	5	5	5	3	5	5	56	excellent
58	5	5	5	3	5	5	5	5	3	1	5	3	50	good
61	5	5	5	3	3	3	3	3	1	1	5	1	38	poor

TOTSP-no. native species; DAR-no. darter species; MIN-no. minnow species; SUN-no. sunfish species;
SUCK-no. sucker species; INTSP-no. intolerant species; PSUN-proportion of sunfish; OMNI-proportion of omnivores and herbivores;
INSCYP - proportion of insectivorous cyprinids; TC-proportion of top carnivores; CATCH-catch per hour;
DELHY-proportion with DELT+hybrids.

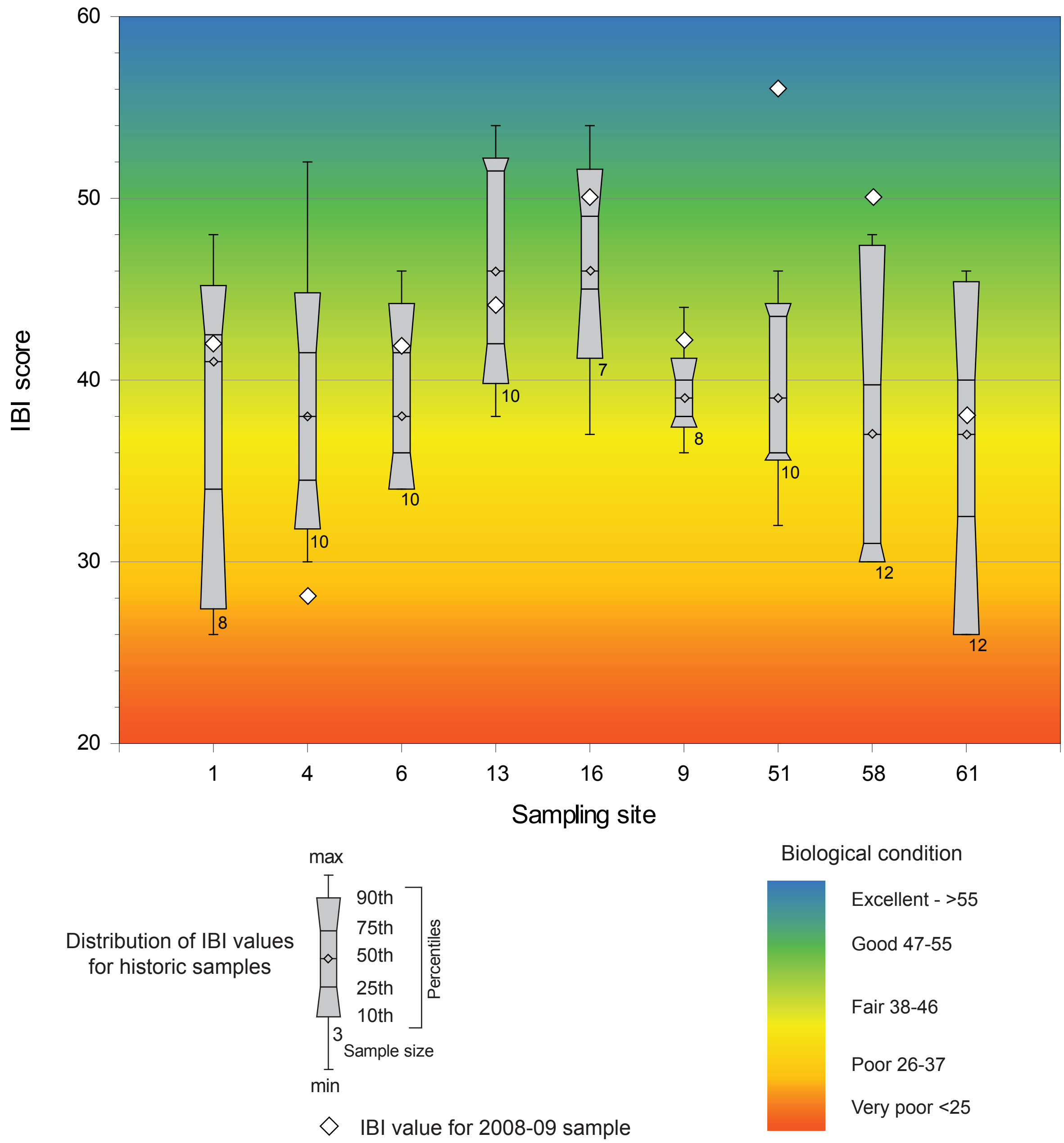


Figure 9. Comparison of historic and recent biological condition for selected sites in the North River watershed.

Jenkins Cemetery (site 51) and North River at Lowery Branch (site 58), the recent samples were above baseline.

Fish samples collected at 21 sites in the North River watershed in 2008-09 (appendix B) yielded 7,465 individuals in 52 species. Cyprinids (carps and minnows) comprised about 53.7 percent of the total catch in 16 species with the largescale stoneroller, *Campostoma oligolepis*, the most common cyprinid collected at 14.5 percent of the total catch. Other abundant cyprinid species found in the North River were the striped shiner, *Luxilus chrysocephalus*, at 6.9 percent; the silverstripe shiner, *Notropis stilbius*, at 6.1 percent; and an intergrade between the pretty and Warrior shiners, *Lythrurus bellus x L. alegnotus*, at 12.3 percent. Sunfishes of the family Centrarchidae were the second most abundant group at 21.7 percent of the total catch in ten species with longear sunfish, *Lepomis megalotis*, and bluegill, *L. macrochirus,* the most common sunfish species at 11 and 5.4 percent of the total catch, respectively. Darters in the family Percidae were the third most common group collected at 16.9 percent of the total catch in eight species. The speckled darter, *Etheostoma stigmaeum*, was the most common percid species at 5.7 percent followed by the blackbanded darter, *Percina nigrofasciata*, at 5 percent and the redspot darter, *E. artesiae*, at 2.3 percent. Species diversity was high at three sites in the North River main channel (site 51-North River near Jenkins Cemetery - 32 species; site 41-North River at Fayette Co. Hwy. 30 - 29 species; and site 23-North River near Cedar Creek mouth - 27 species) and at three tributary sites (site 31-Deadwater Creek at Clear Creek- 29 species; site 24-Cedar Creek near mouth - 27 species; and site 32-Deadwater Creek near RR tracks - 26 species).

Jandebeur (1975) reported 80 species of fishes in the North River system based on 171 collections taken at 56 sites. This list included large river species from the Black Warrior River found in the mouth of North River as well as species indicative of lake and stream habitats in the watershed. The absence of two species in the 2008-09 samples, that were reported by Jandebeur, is noteworthy. The clear chub, *Hybopsis winchelli*, prefers clear streams of small to moderate size with substrates of sand, gravel, and silt. No individuals of the clear chub were found in 2008-09 samples. It has, however, been found in past collections in the system. For site 9, North River at Tuscaloosa Co. Hwy. 38, seven individuals in 4 out of 12 collections were reported in 1972-74 (Jandebeur, 1975), and one individual occurred in one out of eight collections reported in 1986-88 (Mettee and others, 1988). For site 4, Turkey Creek at Ala. Hwy. 69, no individuals were reported in five collections made in 1979-80 (GSA unpublished data) and 35 individuals were found in four out of ten collections in 1986-88 (Mettee and others, 1988).

Prior to closing of the Lake Tuscaloosa dam, the rock darter (*Etheostoma rupestre*) was known from several locations in the main channel of lower North River (Mettee and others, 1996). At the U.S. Hwy. 69 crossing over North River, 103 individuals were taken from 1964-69, 91 individuals were taken in an unnamed tributary to North River near this site during the same time period, and 22 individuals were taken from 1963-67 where U.S. Hwy. 43 crossed Binion Creek prior to flooding. Jandebeur (1975) reported rock darters from several tributaries to North River including Carroll Creek at U.S. Hwy. 69 (9 individuals from 1963-74), Turkey Creek at U.S. Hwy. 69 (9 individuals from 1963-74), Deadwater Creek near Bankston (8 individuals in 1963), and Rice Mine Creek near Tuscaloosa (9 individuals in 1966). Rice Mine Creek is a small tributary entering the Black Warrior River just downstream of the North River. More recent samples documented the continued presence of the rock darter in Turkey Creek at U.S. Hwy. 69 (17 individuals from 1979-80 and 27 individuals from 1986-88). However, Jandebeur (1975) failed to find rock darters in 12 collections in the North River at Tuscaloosa Co. Hwy. 38 from 1972-74, and Mettee and others (1988) also failed to find rock darters in 10 collections from 1986-88 at the same site. Rock darters were not found at any of the 21 sites sampled during the recent 2008-09 surveys in the North River system which included most of the sites just discussed.

HABITAT

Habitat evaluations are an integral part of efforts to describe biological condition because good biological condition is quite often predicated on the presence of stable and diverse habitat. The term habitat, as applied herein, incorporates several features and processes in streams including the physical components such as rock and rubble, logs, mud, channel and substrate condition; the chemical and physical components of water quality such as pH, dissolved chemical constituents, temperature, and dissolved gases; and flow components such as flood and drought frequencies, velocity regimes, and discharge. For quantitative assessment, the habitat concept is generally narrowed to include the physical components of habitat and substrate structure, the degree of channel alteration, and the condition of banks and the adjacent riparian corridor. All of these components directly affect the structure and function of the aquatic biological community and they can be visually assessed for quality and relative degree of impairment. The visual glide-pool and riffle-run assessment procedures used in this study to quantify habitat conditions were originally reported in Plafkin and others (1989) and modified by Barbour and others (1999).

Stream habitat assessments entail evaluating the structure of the surrounding physical habitat that influences water resource quality and thus the condition of the resident biological community (Barbour and others, 1999). Generally, three characteristics of habitat contribute to the maintenance and persistence of aquatic biological communities: the availability and quality of the habitat-substrate components and instream cover, morphology of the instream channel, and structure of the bank and riparian vegetation zone (Plafkin and others, 1989). Barbour and others (1999) developed two sets of habitat metrics, one for evaluating upland stream habitat dominated by riffle-run microhabitats and hard substrates and the other for evaluating lowland and Coastal Plain streams that are dominated by glide-pool and run-pool habitats with unconsolidated sandy substrates (appendix C). The 11 habitat metrics of the glide-pool index and 12 metrics of the riffle/run index are individually scored on a scale of 0 (poor quality) to 20 (optimal quality) and are then summed to give a final score. The maximum possible habitat score is 220 for the glide-pool method and 240 for the riffle-run method. Final habitat scores are sometimes compared to reference streams that are minimally or least impaired in the area. Habitat quality is also sometimes taken as a percentage of the maximum habitat score possible. The percent maximum habitat score method was adopted for this study.

HABITAT METRICS

Instream cover - This habitat metric refers to the quantity and variety of natural substrate features such as fallen trees, logs, branches, undercut banks, and hard substrate particles that aquatic organisms can use as refugia, feeding sites, or for spawning. A diversity of substrate objects and microhabitat types leads to a diverse and productive aquatic community and, hence, a good biological condition. The presence of clean gravel, rocks, and log snags in flowing streams is generally most desirable. However, other objects such as tree roots, aquatic vegetation, and undercut banks provide good habitat for many species.

Pool substrate characterization – This metric is substituted for embeddedness in the riffle-run index for high-gradient streams and evaluates the type and condition of bottom substrates in pools. Firm substrates, like gravel and sand, and aquatic vegetation generally support a greater variety of aquatic organisms compared to pools with unconsolidated mud, bedrock, and silt with no aquatic vegetation.

Pool variability – This metric evaluates the overall mixture of pool types in the stream relative to size and depth. Pools of variable sizes and depths (large-deep, large-shallow, small-deep, and small-shallow) are preferable to pools of uniform depth (small or large-shallow) because they will generally support a greater variety of organisms. Extreme bedload sedimentation will lead to pools of uniform width and depth which strongly impairs aquatic biodiversity.

Man-made channel alteration – This metric quantifies the degree of channel alteration, usually in the form of stream channelization. Channelization changes the fundamental hydrodynamic and energy-flow relationships of a stream resulting in bank erosion and habitat degradation. Channel alteration can result in deposition on the inside of bends, below channel constrictions, and where stream gradient flattens. Channelization decreases stream sinuosity thereby increasing velocities and the potential for channel and bank scour and possibly accelerated downcutting of the channel.

Sediment deposition - This characteristic quantifies the amount of sediment that has accumulated in pools and changes that have taken place on stream bottoms from the processes of erosion and sedimentation. The character of sediment deposits is an indication of the severity of watershed erosion, bank erosion, and stability of the stream. Sediment bars will appear and increase in coverage with continual upstream erosion in the watershed.

Channel sinuosity – Streams with a higher degree of sinuosity provide greater habitat diversity and more opportunities for the stream to support a varied fauna. Streams with sinuous channels are also better structured geomorphologically to hydraulically attenuate floods and storm flows by dissipating energy and protecting banks from excessive erosion.

Channel flow status – The degree to which a channel is filled with water is important because as flow volume decreases, the amount of suitable substrate for aquatic organisms also decreases and biological condition can degrade. Having a suitable amount of submerged area and volume of flow is also important for maintaining acceptable water quality.

Condition of banks – Bank stability is a measure of whether banks are eroded or have the potential for erosion. Steep banks are more likely to collapse and are more prone to erosion than are gently sloping banks and are, therefore, considered unstable. Crumbling and unvegetated banks, exposed tree roots, and exposed soil are signs of accelerated bank erosion.

Bank vegetative protection – This metric is an evaluation of the vegetative protection on stream banks and the near-stream portion of the riparian zone. Roots hold soil in place and reduce erosion potential thus enhancing the local aquatic biological community.

Grazing or other disruptive pressure – The degree to which streamside cover has been removed by animal grazing, mowing or herbicides, and mechanical tree removal is evaluated for this metric. Streams with natural vegetative cover have been shown to have a higher standing crop and variety of organisms compared to streams that are routinely disrupted or managed through mowing and grazing.

Riparian vegetative zone width – The riparian zone serves to buffer the stream from runoff, controls erosion, and provides organic matter and nutrients to the stream. Undisturbed riparian zones with natural vegetation help maintain highly diverse and functional aquatic communities while narrow and impaired riparian zones yield poor biological conditions and are associated with roads, fields, parking lots, and lawns.

The riffle-run habitat assessment method substitutes three habitat metrics and includes one additional metric in order to capture the character of streams with hard, rocky substrates and their associated flow-stream depth regimes.

Epifaunal surface - This parameter evaluates the relative amount and types of natural structures in the stream like cobble, large rocks, trees, logs and branches, and undercut banks which serve as places for spawning and habitat for aquatic macroinvertebrates and fishes. As variety and abundance of structures decrease, habitat structure becomes simplified and biodiversity will decrease.

Embeddedness - Embeddedness is a measure of the relative degree to which rocks and snags are covered or sunken into the silt, sand, and mud. As substrate features become buried, the available high-quality surfaces for shelter, spawning, and feeding decrease, resulting in reduced biodiversity. This parameter is evaluated in riffle and run habitats and is a substitute for the pool substrate character and variability parameter of the glide-pool method.

Velocity/depth regimes - High-quality riffle-run streams generally have four velocity/depth regimes present: slow-deep, slow-shallow, fast-deep, and fast-shallow. The presence of these regimes relates to the stream's ability to support stable aquatic habitat and reflects the degree of geomorphic stability. This parameter is a substitute for the pool variability parameter of the glide-pool method.

Frequency of riffles - Riffles are high-quality habitat in upland streams and this parameter assesses the heterogeneity and occurrence of riffles in a stream. More riffle habitat generally results in a greater variety and abundance of aquatic organisms. This parameter is a substitute for the channel sinuosity parameter of the glide-pool method for low gradient streams.

A rapid habitat assessment was completed for each IBI fish community sample collected in 2008-09. Additionally, a habitat "blitz" was conducted on August 5, 2009, at 29 sites to expand the database to 36 sites (table 9). Habitat quality in the North River varied from poor to optimal with 11 sites in the optimal range (>75 percent of the maximum habitat score), 13 sites in the suboptimal range (65 to 75 percent of the maximum habitat score), and 12 sites in the marginal to poor range (<65 percent of the maximum habitat score (fig.10). Six of the 12 sites in the poor to marginal range were in the Clear Creek watershed.

Table 9. Habitat scores for sites in the North River watershed, 2008-09.

Site No.	Stream	Date	Habitat metrics [1]															Total score	Percent of maximum habitat score
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
1	Carroll Creek at Ala. Hwy. 69	5-Aug-09	13	15	14	12	14	11	9	18	16	16	9	2	--	--	--	149	67.7
2	Binion Creek at Old Fayette Road	5-Aug-09	12	--	--	--	11	8	--	17	10	14	18	20	8	12	14	144	65.5
3	Binion Creek at Kemp Road	10-Apr-09	12	--	--	--	14	10	--	17	15	18	18	20	11	13	8	156	70.9
4	Turkey Creek at Ala. Hwy. 69	14-Jul-09	17	17	14	11	17	17	14	16	14	16	16	13	--	--	--	182	82.7
6	Cripple Creek near mouth	14-Jul-09	3	5	2	8	17	2	4	15	6	14	16	14	--	--	--	106	48.2
9	North River at Co. Hwy. 38	5-Aug-09	14	11	16	15	18	14	5	19	16	16	20	20	--	--	--	184	83.6
13	Bear Creek at USGS site	9-Apr-09	15	16	17	14	12	13	15	17	9	10	18	15	--	--	--	171	77.7
14	North River DS[2] of Tyro Creek	5-Aug-09	8	15	14	16	17	10	16	16	14	16	16	17	--	--	--	175	79.6
15	Tyro Creek near Whitson Bridge	5-Aug-09	10	15	11	10	16	14	16	13	13	16	16	18	--	--	--	168	76.4
16	Tyro Creek at Tyro Creek Road	14-Jul-09	5	5	1	1	16	3	0	3	6	14	16	15	--	--	--	85	38.6
17	Boone Creek at Co. Hwy. 55	5-Aug-09	10	17	16	10	14	16	16	16	16	16	16	15	--	--	--	178	80.9
19	North River at Wittson Bridge	5-Aug-09	11	9	12	14	16	16	9	16	13	16	16	18	--	--	--	166	75.5
21	North River at Tusc. Co. Hwy. 63	5-Aug-09	13	10	15	15	18	12	11	15	11	10	18	12	--	--	--	160	72.7
24	Cedar Creek near mouth	23-Jul-08	13	8	7	9	18	6	3	9	11	14	18	16	--	--	--	132	60.0
25	Cedar Creek at Co. Hwy. 63	5-Aug-09	10	10	14	12	15	16	16	15	15	16	16	8	--	--	--	163	67.9
26	Cedar Creek at Berry	5-Aug-09	5	0	3	0	14	3	0	16	16	14	14	9	--	--	--	94	42.7
27	North River US[2] of Cedar Creek	3-Sep-09	11	12	8	14	17	7	10	17	7	10	18	17	--	--	--	148	61.7
28	North River at Ala. Hwy. 18	5-Aug-09	7	5	14	3	12	16	4	18	16	18	12	20	--	--	--	145	65.9
31	Deadwater Creek at Clear Creek	22-Jul-08	10	4	10	7	17	9	8	9	10	12	20	18	--	--	--	134	60.9
32	Deadwater Creek at RR tracks	5-Aug-09	4	3	11	7	16	4	3	17	7	12	18	15	--	--	--	117	53.2
33	Deadwater at Bankston	5-Aug-09	10	7	8	9	12	9	7	13	11	16	18	20	--	--	--	140	63.6
34	Clear Cr. at Deadwater Cr. mouth	14-Aug-08	12	10	10	2	16	6	0	15	8	4	17	12	--	--	--	112	50.9
35	Clear Creek at Co. Hwy. 93	5-Aug-09	13	11	11	14	12	11	9	12	12	16	20	14	--	--	--	155	70.5
36	Clear Creek at Lowery Road	5-Aug-09	15	13	17	12	17	18	13	14	15	16	20	20	--	--	--	190	86.4
37	Clear Creek DS of Bugs Lake	5-Aug-09	16	17	17	8	17	16	11	8	17	18	20	8	--	--	--	173	78.6
38	Boles Creek at Co. Hwy. 67	5-Aug-09	7	10	12	8	18	9	7	19	14	16	20	14	--	--	--	154	70.0
39	Clear Creek at Clear Creek Road	5-Aug-09	12	9	12	10	16	14	4	17	8	12	12	12	--	--	--	138	62.7
40	Clear at Co. Hwy. 93 (upper)	5-Aug-09	12	11	12	7	10	8	6	18	17	16	16	4	--	--	--	137	62.3
41	North River at Co. Hwy. 30	5-Aug-09	12	9	12	14	16	12	13	16	12	16	16	16	--	--	--	164	74.6
42	Ellis Creek	5-Aug-09	12	9	14	10	17	14	12	11	9	14	18	20	--	--	--	160	72.7
46	North River DS of Cane Creek	5-Aug-09	13	--	--	--	16	15	--	17	12	16	16	16	12	11	16	160	72.7
48	Cane Creek at Co. Hwy. 63	5-Aug-09	17	16	16	14	12	15	12	14	13	16	15	15	--	--	--	175	79.6
51	North River US Jenkins Cemetery	5-Aug-09	14	8	12	10	16	10	5	17	11	16	16	15	--	--	--	150	68.2
54	George Creek at Co. Hwy. 63	5-Aug-09	16	14	13	10	16	15	15	12	9	14	16	16	--	--	--	166	75.5
58	North River at Lowery Branch	5-Aug-09	8	7	15	12	17	17	2	16	11	16	16	18	--	--	--	155	70.5
61	North River at Ala. Hwy. 102	5-Aug-09	16	8	12	9	16	10	2	11	6	16	13	8	--	--	--	127	57.7

-- not applicable

[1] 1-instream cover; 2-epifaunal surface; 3-embeddedness; 4-velocity/depth regimes; 5-channel alteration; 6-sediment deposition; 7-riffle frequency; 8-channel flow status. 9-bank condition; 10-bank vegetative condition; 11-disruptive pressure; 12-riparian zone width; 13-pool substrate characterization; 14-pool variability; 15-channel sinuosity.

[2] DS - downstream, US - upstream

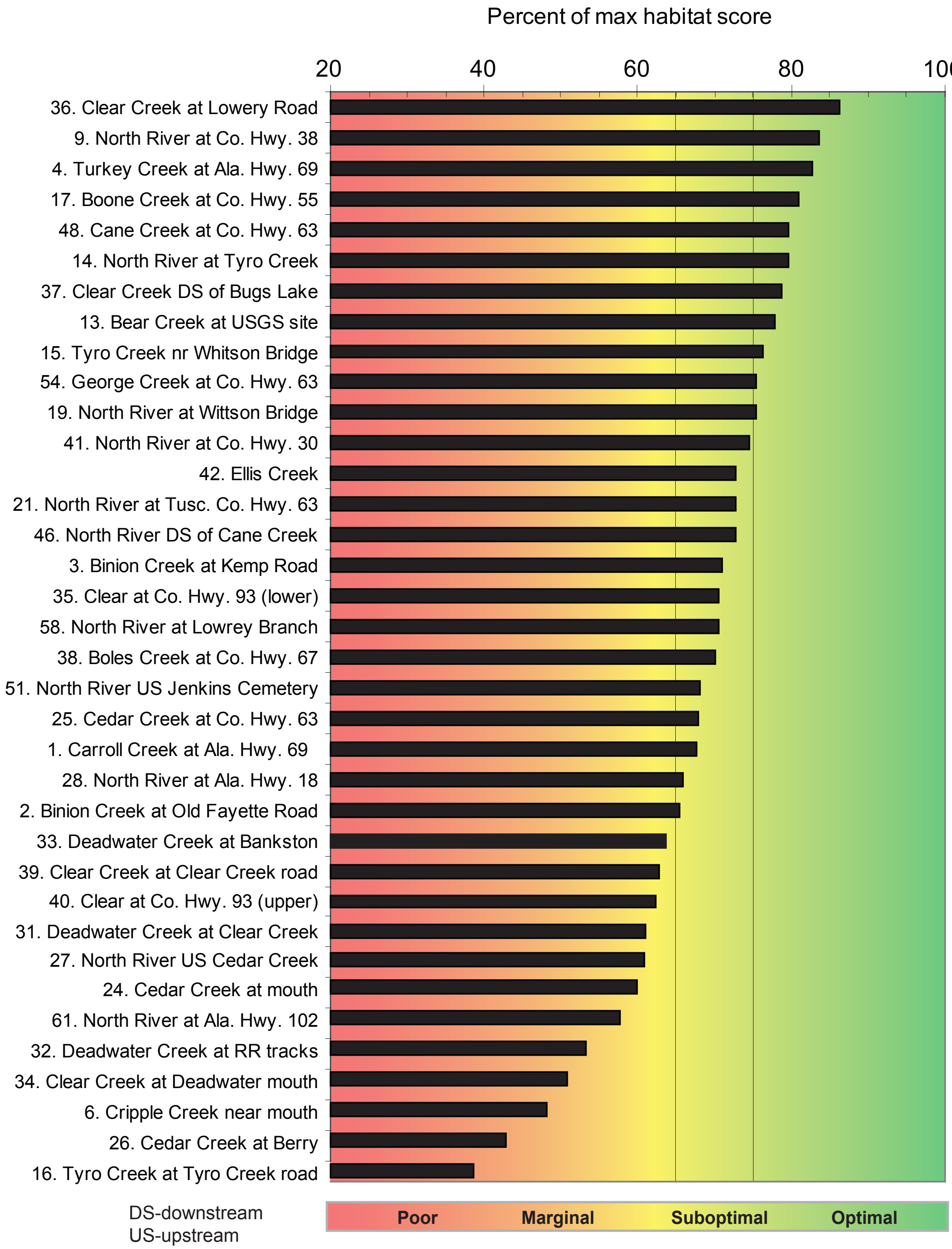


Figure 10. Habitat condition for streams in the North River watershed, 2008-09.

Two of the 12 sites were in the Cedar Creek watershed and the remaining sites were in Cripple Creek, Tyro Creek, and the headwaters of North River.

The habitat parameters embeddedness and degree of sediment deposition were highly correlated with the habitat index (R^2= 0.731 and 0.712, respectively) indicating that sediment bedload, in part, is a significant contributor to poor habitat scores. The fact that several sites in the Clear Creek system are of poor to marginal habitat quality illustrates that sediment is likely a major pollutant impacting this watershed. Field visits to the Clear Creek system in August and September 2009 confirmed that sediment is a significant issue in Clear Creek. Streams had a heavy sand and gravel bedload originating from multiple sources but predominantly from unpaved county roads. Because Clear Creek currently supports the best populations of listed mussel species in the North River system, stream restoration and best management projects to reduce sediment entering streams in the Clear Creek watershed would be beneficial for habitat and lead to improved conditions for mussels.

LAND COVER AND LAND USE

The National Land Cover Database with enhanced cropland data (USDA/NRCS, 2008) was analyzed in a GIS environment to determine the spatial distribution of land cover in the North River watershed (fig. 11). Table 10 shows the percentage of each land cover class in the watershed. Natural resource extraction and development has been a major source of income for the economy of the North River, and this has influenced land cover patterns in the watershed. Eighty-six percent of North River is covered by trees and shrub-like vegetation, and almost half of this area has been converted to evergreen stands and transitional, shrub/scrubby vegetation patches. Agriculture is found on 7 percent of the land in the North River basin, with most of it occurring in close proximity to the main channel of the North River. Crops grown in the basin include corn, cotton, soybeans, peanuts, winter wheat, oats, and sod grass. The North River watershed has experienced steady population growth since the

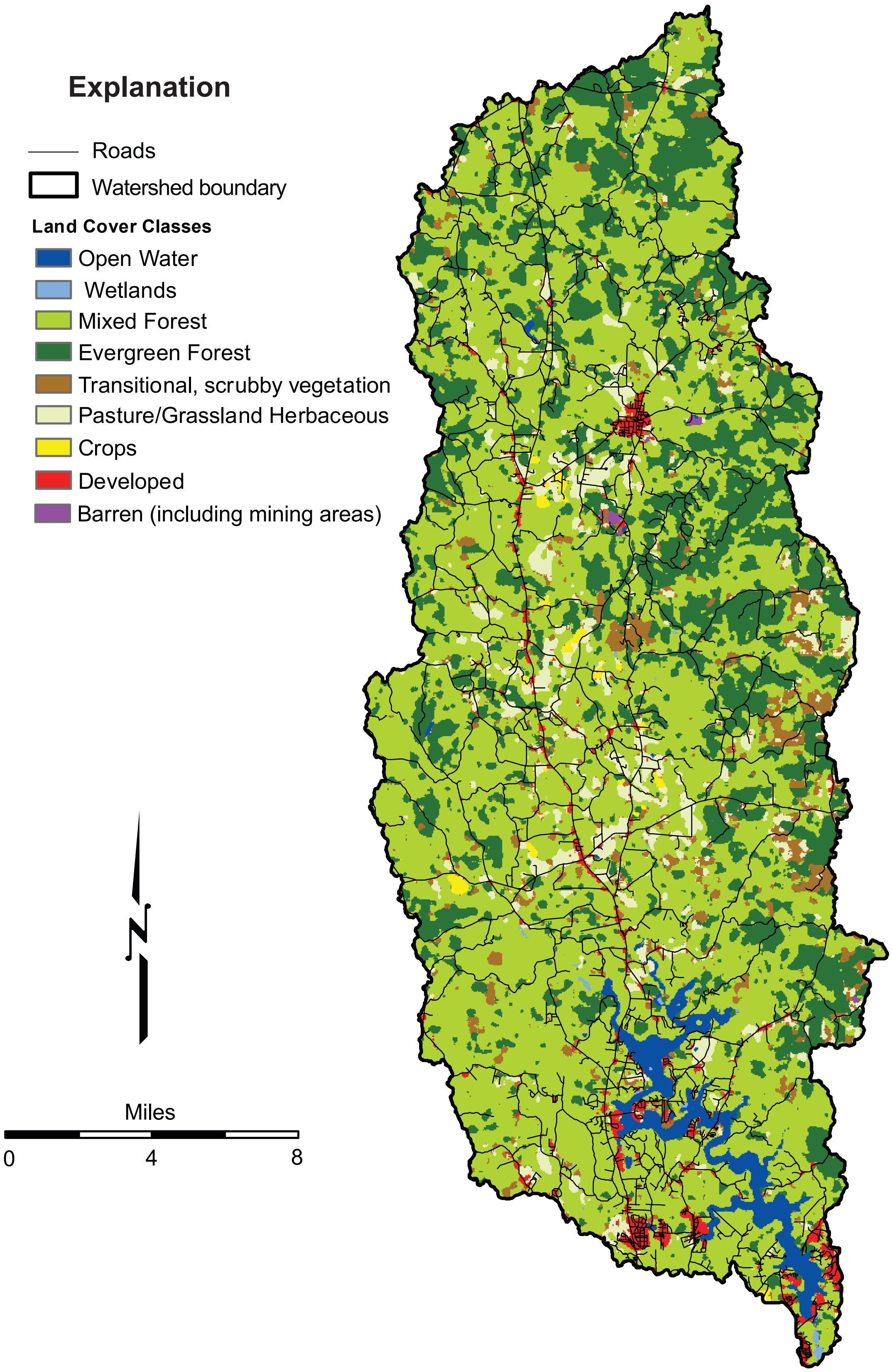


Figure 11. Land cover distribution in the North River watershed (NRCS, 2008)

Table 10. Land cover distribution for the North River watershed, 2008.

Land cover class	Acres	mi^2	Percent
Open Water	6,194	9.67	2.27
Developed	11,575	18.1	4.25
Barren (including active mining operations)	284	0.44	0.10
Mixed Forest	138,498	216	50.95
Transitional, scruby vegetation	23,901	37.3	8.79
Evergreen Forest	69,913	109	25.72
Pasture / Grassland Herbaceous	17,510	27.3	6.44
Crops	1,337	2.08	0.49
Wetlands	2,573	4.01	0.94
Totals	271,785	424	100.00

creation of Lake Tuscaloosa in the 1970s, and currently 4 percent of the watershed is developed.

The extraction of coal resources, tree harvesting, agricultural practices, and urban expansion has led to increased sedimentation and nutrient problems in the North River watershed. As such, the North River was placed on Alabama's list of impaired streams—the 303(d) list—by the Alabama Department of Environmental Management in 1998 (fig. 2). Areas contributing to nonpoint source pollution need to be identified in order to restore water quality in the watershed. The potential non-point source pollution index (PNPI) was used to model sources of nonpoint source pollution throughout the North River watershed (figure 12). The PNPI is a GIS-based, watershed-scale tool created by Munafo and others, 2005, to inform decision makers and the public about the potential environmental impacts of different land management scenarios. Three indicator raster grids were used in ArcMap 9.3 to develop the PNPI: Run-off indicator (ROI), Distance from the river network indicator (DI), and Land Cover indicator (LCI).

The ROI takes into account pollutant mobility and filtering potential in respect of terrain slope, land cover, and geology (Munafo and others, 2005). Land cover (USDA/NRCS, 2008), soils (NRCS, 2006), and a digital elevation model (DEM) (USGS, 1999) were utilized to create soil permeability, land use, and slope raster grids for the ROI. Grid values for the raster datasets were ranked from 1 to 4, with 4 representing highest risk areas. Soils were ranked by their level of impermeability, slopes were ranked by their level of steepness, and land cover types were ranked by their potential to prevent pollution filtering and/or alter the flow velocity of the stream network. Land cover types assigned a higher ROI weight included developed, barren, and cropland classes.

The DI is the hydraulic distance between each grid cell in the basin and the stream network. Distances were calculated with the DEM using the Path Distance tool in the Spatial Analyst extension of ArcMap. A natural breaks classification was used to group the values into the four classes. The closer a

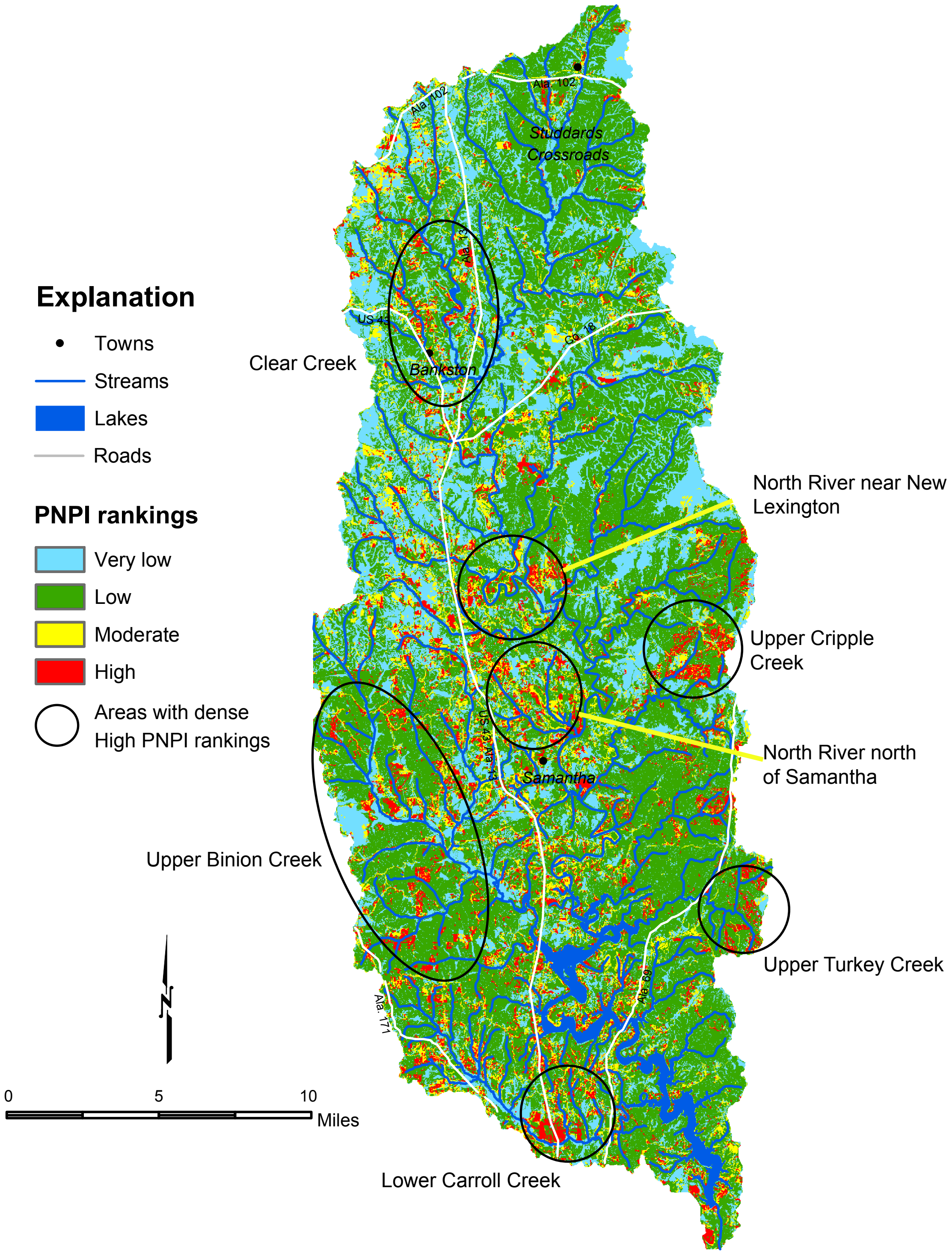


Figure 12. Potential nonpoint source pollution index (PNPI) rankings for the North River watershed

grid cell was to the stream network, the higher the value. The LCI was the most influential indicator of the PNPI equation. The LCI (USDA/NRCS, 2008) was scaled according to the pollution generation potential of the land management practices for each land cover type. For example, densely populated areas and intensively cultivated crop lands were given the highest values-4, whereas natural and unaltered zones were placed at the opposite end of the scale (Munafo and others 2005).

After establishing the three indicator grids, the following equation described by Munafo and others (2005) was applied using the raster calculator in ArcMap 9.3:

$$PNPI = 5 * LCI + 3 * DI + 2 * ROI.$$

The results of the above equation are illustrated with the PNPI index in figure 12. The Natural Breaks classification was used to separate the continuous numerical raster data into four classes based on the natural groupings of the data values. Natural Breaks arranges data with class breaks determined statistically by finding adjacent feature pairs, between which there is a relatively large difference in data value (ESRI Inc., 2008).

The range of data values of the four classes of the PNPI index are as follows: 5 – 16 (very low), 17 – 21 (low), 22 – 27 (moderate), and 28 – 48 (high). The higher the value of the pixel, the greater the risk of producing nonpoint source pollution. Areas ranked high potential are displayed in red in figure 12. Areas with the highest PNPI rankings include developed, crop land, and barren land with impermeable soils that are located on rugged terrain that is close to a stream. These areas have a high probability of producing rain runoff that carries pollutants such as pesticides, *E. coli* bacteria, heavy metals, and excessive amounts of sediment to adjacent water sources.

CONCLUSIONS AND RECOMMENDATIONS

The North River watershed is a significant natural resource in west Alabama. It serves primarily as the water source for Lake Tuscaloosa but also has a significant role as a repository of imperiled aquatic mussel species and is one of only two known locations for the dark pigtoe, *Pleurobema furvum*. The poor condition of the North River's mussel populations in places is directly related to poor habitat quality and should serve as a warning that water resource conditions are likely degrading. Obviously, habitat and stream conditions are of such diminished quality that mussel populations have declined from levels observed 15 years earlier.

The relatively recent finding of elevated *E. coli* bacteria concentrations in Lake Tuscaloosa and the struggle to locate the source of contamination, combined with the fact that Lake Tuscaloosa is becoming more productive of algae in the summer months, illustrates that we lack a comprehensive understanding of the Lake Tuscaloosa-North River watershed and that there are no effective region-wide stakeholder/government relationships to collectively solve problems of this scope. National experience in watershed assessment, protection, and management has led to a common understanding that a regional or watershed perspective is the best way to maintain water quality for the widest group of users and to provide protection for all other resource components including wildlife, habitat, and water supply. Landowners, lake users, and all local and city governments should view Lake Tuscaloosa and the North River watershed as a single functioning system and commit to developing a comprehensive environmental understanding of the system and a regional watershed approach for its protection, management, and development.

To recover and restore mussel populations, an action plan to address specific watershed issues and assess resource conditions should be devised, implemented, and monitored.

MONITORING AND ASSESSMENT ACTIVITIES

- ❏ Additional surveys for mussels should be conducted in the Clear Creek system and in the main channel of North River between Tuscaloosa Co. Hwy. 38 and Fayette Co. Hwy. 30. These surveys would refine our knowledge of the distribution of mussels in these areas and help quantify population densities through systematic sampling.
- ❏ Nutrient status loading in the system, both in the flowing reaches and in Lake Tuscaloosa, should be evaluated through a comprehensive water quality survey in order to pinpoint nutrient sources.
- ❏ The current level of mine drainage entering North River should also be evaluated as part of the nutrient survey. This will allow identification of water quality-impaired small tributaries and provide a background for initiation of restoration activities to lessen sediment runoff and mine drainage.
- ❏ Overall stream health should be periodically monitored at fixed stations throughout the watershed using the fish community IBI.

HABITAT RESTORATION AND BEST MANAGEMENT PRACTICES

- ❏ Clear Creek originates in the Coker Formation and, as such, naturally has a predominantly sand and gravel substrate. Ditches draining unpaved roads in this watershed are significant sources of sediment bedload, particularly in Deadwater Creek, when storm water transports loose sand and gravel from hilltops to stream channels. Because Bugs Lake acts as a sedimentation basin for sand and gravel moving downstream, aquatic habitats in a portion of the lower reaches of Clear Creek support a varied and healthy mussel population. The impacts of sediment bedload extend from Fayette Co. Hwy. 93-site 35 downstream to the mouth of Deadwater Creek. The Fayette County Engineering Department should be contacted and engaged in finding economical ways to reduce the loading of sediment to Deadwater Creek from unpaved roads.

- ❑ Land along Deadwater Creek and Clear Creek downstream of Bugs Lake needs to be evaluated for riparian buffer improvement to better protect the remaining high quality mussel habitat and to locate any large-scale source of sediment input to these streams.
- ❑ The degree of poultry production in the watershed needs to be evaluated along with litter composting and disposal procedures. Projects to lessen water quality impacts of poultry production should begin as soon as sources are identified.
- ❑ The extent of large animal production in the watershed should be evaluated and projects initiated to assist landowners in developing alternate watering facilities away from stream channels.

EDUCATIONAL ACTIVITIES

- ❑ Educational activities are an important part of any watershed management plan for protecting the hydrologic systems that supply water for drinking, irrigation of crops, industrial processes, and protection of fish and wildlife. These educational activities should be implemented in schools, among landowners, government officials, engineering firms, contractors, land management professionals, land developers, economic development professionals, and anyone who works in or has development activities in the watershed.
- ❑ Activities can include school visits to teach water science, groundwater festivals, stream and lake cleanups, water resources classes for students, canoe adventures, nonpoint source pollution seminars for water professionals and developers, demonstrations of best management practices for farmers and timber growers/harvesters, and organizing lake watch and watershed watch programs.

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APPENDIX A

Collection data for mussel sampling sites in the North River
(see table 4 for sampling site locations)

Data sources:

1 - McGregor and Wynn (2008);

2 - unpublished notes from McGregor

3 - Pierson (1992), McGregor and Pierson (1999)

4 - Freda (1992)

Abbreviations:

DS - downstream, US - upstream

lv - live, fd - fresh dead, wd - weathered dead

Sampling site	5. North River at Cripple Creek mouth	7. Cripple Creek at Co. Hwy 38	8. Cripple Creek at mouth of Johnson Branch	9. North River at Co. Hwy. 38	9. North River at Co. Hwy. 38	10. North River US of Co. Hwy. 38
Sample date	9-Jul-08	9-Jul-08	9-Jul-08	22-Aug-93	4-Jun-08	19-Jun-08
Data source	1	1	1	2	1	1
Species - common name						
Amblema plicata - Threeridge	--	--	--	1 fd	1 wd	--
Anodontoides radiatus - Rayed Creekshell	--	No	--	--	--	--
Elliptio arca - Alabama Spike	--	unionid	--	--	--	--
Elliptio arctata - Delicate Spike	--	mussels	--	1 wd	--	--
Hamiota perovalis - Orangenacre Mucket	--	found	--	1 lv	1 fd	--
Lampsilis ornata - Southern Pocketbook	--	--	--	1 fd, 1 wd	1 fd	--
Lampsilis straminea - Southern Fatmucket	--	--	--	--	--	--
Lampsilis teres - Yellow Sandshell	--	--	--	--	--	--
Pleurobema furvum - Dark Pigtoe	--	--	--	--	--	--
Pyganodon grandis - Giant Floater	--	--	--	--	--	--
Quadrula asperata - Alabama Orb	3 wd	--	--	2 lv, 2 fd, 5 wd	7 fd	1 wd
Quadrula verrucosa - Pistolgrip	2 fd	--	--	1 wd	9 fd	1 wd
Strophitus subvexus - Southern Creekmussel	--	--	1 lv	2 lv, 1 fd	--	--
Uniomerus tetralasmus - Pondhorn	--	--	--	--	--	--
Villosa lienosa - Little Spectaclecase	1 wd	--	--	--	--	--
Villosa vibex - Southern Rainbow	--	--	--	--	1 fd, 1 wd	--

Sampling site	11. North River near Bear Creek mouth	12. North River at Bear Creek	14. North River near Tyro Creek mouth	17. Boone Creek at Co. Hwy. 55	18. Boone Creek at Co. Hwy. 63	19. North River at Wittson Bridge
Sample date	19-Jun-08	19-Jun-08	19-Jun-08	21-Apr-05	21-Apr-05	10-Nov-91
Data source	1	1	1	1	1	3
Species - common name						
Amblema plicata - Threeridge	--	--	--	--	--	--
Anodontoides radiatus - Rayed Creekshell	No	--	--	--	--	--
Elliptio arca - Alabama Spike	unionid	--	--	--	--	--
Elliptio arctata - Delicate Spike	mussels	--	--	--	--	--
Hamiota perovalis - Orangenacre Mucket	found	--	--	--	--	--
Lampsilis ornata - Southern Pocketbook	--	--	--	--	--	--
Lampsilis straminea - Southern Fatmucket	--	--	--	--	--	--
Lampsilis teres - Yellow Sandshell	--	--	--	--	--	--
Pleurobema furvum - Dark Pigtoe	--	--	--	--	--	--
Pyganodon grandis - Giant Floater	--	--	--	--	1 wd	--
Quadrula asperata - Alabama Orb	--	1 fd	1 wd	--	--	1 fd
Quadrula verrucosa - Pistolgrip	--	--	--	--	--	1 fd
Strophitus subvexus - Southern Creekmussel	--	1 wd	--	1 fd	--	1 wd
Uniomerus tetralasmus - Pondhorn	--	--	--	--	--	--
Villosa lienosa - Little Spectaclecase	--	1 fd	--	1 wd	--	--
Villosa vibex - Southern Rainbow	--	--	--	--	--	--

Sampling site	19. North River at Wittson Bridge	20. North River DS of Tusc. Co. Hwy. 63	21. North River at Tusc. Co. Hwy. 63	22. North River US of Co. Hwy. 63	23. North River at Cedar Creek mouth	23. North River at Cedar Creek mouth
Sample date	5-Jun-08	10-Nov-91	3-Oct-93	10-Nov-91	20-Oct-91	22-Aug-93
Data source	1	3	2	3	3	2
Species - common name						
Amblema plicata - Threeridge	--	--	--	--	--	--
Anodontoides radiatus - Rayed Creekshell	--	--	--	--	--	--
Elliptio arca - Alabama Spike	--	--	2 wd	--	--	--
Elliptio arctata - Delicate Spike	--	1 fd	--	1 wd	--	--
Hamiota perovalis - Orangenacre Mucket	--	--	--	--	1 wd	5 lv
Lampsilis ornata - Southern Pocketbook	--	--	--	--	6 fd	3 wd
Lampsilis straminea - Southern Fatmucket	--	--	1 lv	--	2 fd, 1 wd	1 wd
Lampsilis teres - Yellow Sandshell	--	--	--	--	--	--
Pleurobema furvum - Dark Pigtoe	--	--	1 lv	--	15 fd	6 lv
Pyganodon grandis - Giant Floater	--	--	--	--	--	--
Quadrula asperata - Alabama Orb	--	1 wd	--	--	8 fd	6 lv
Quadrula verrucosa - Pistolgrip	1 wd	--	--	--	1 wd	1 lv
Strophitus subvexus - Southern Creekmussel	--	--	--	1 fd	5 fd	1 lv
Uniomerus tetralasmus - Pondhorn	--	--	--	--	--	--
Villosa lienosa - Little Spectaclecase	--	--	--	--	--	1 lv
Villosa vibex - Southern Rainbow	--	1 wd	--	--	--	--

Sampling site	23. North River at Cedar Creek mouth	24. Cedar Creek near mouth	24. Cedar Creek near mouth	27. North River US of Cedar Creek	28. North River at Ala. Hwy. 18	28. North River at Ala. Hwy. 18
Sample date	5-Jun-08	29-Nov-91	5-Jun-08	29-Nov-91	2-Nov-91	4-Jun-08
Data source	1	3	1	3	3	1
Species - common name						
Amblema plicata - Threeridge	--	--	--	--	--	--
Anodontoides radiatus - Rayed Creekshell	--	--	No	--	--	--
Elliptio arca - Alabama Spike	--	1 fd	unionid	--	--	--
Elliptio arctata - Delicate Spike	--	--	mussels	--	--	--
Hamiota perovalis - Orangenacre Mucket	--	--	found	1 fd	1 fd	--
Lampsilis ornata - Southern Pocketbook	--	1 fd	--	--	--	--
Lampsilis straminea - Southern Fatmucket	--	2 fd	--	1 fd	1 wd	--
Lampsilis teres - Yellow Sandshell	--	1 wd	--	--	--	--
Pleurobema furvum - Dark Pigtoe	--	--	--	2 fd	--	--
Pyganodon grandis - Giant Floater	--	--	--	--	--	--
Quadrula asperata - Alabama Orb	1 wd	--	--	6 fd, wd	1 fd	--
Quadrula verrucosa - Pistolgrip	--	--	--	4 wd	1 wd	1 wd
Strophitus subvexus - Southern Creekmussel	--	4 wd	--	2 wd	2 fd	3 lv, 1 fd
Uniomerus tetralasmus - Pondhorn	--	--	--	--	--	--
Villosa lienosa - Little Spectaclecase	--	2 wd	--	3 wd	--	--
Villosa vibex - Southern Rainbow	--	1 wd	--	--	--	--

Sampling site	29. North River DS of Clear Creek	30. Clear Creek at Ala. Hwy. 13	30. Clear Creek at Ala. Hwy. 13	30. Clear Creek at Ala. Hwy. 13	32. Deadwater Creek nr RR tracks	35. Clear at Co. Hwy. 93
Sample date	12-Jun-08	24-Nov-91	1-Sep-92	12-Jun-08	7-Jul-08	22-Sep-08
Data source	1	3	4	1	1	1
Species - common name						
Amblema plicata - Threeridge	--	--	--	--	--	--
Anodontoides radiatus - Rayed Creekshell	No	--	--	--	--	--
Elliptio arca - Alabama Spike	unionid	--	--	--	--	--
Elliptio arctata - Delicate Spike	mussels	--	--	--	--	--
Hamiota perovalis - Orangenacre Mucket	found	--	3 lv	1 lv, 1 wd	--	--
Lampsilis ornata - Southern Pocketbook	--	2 fd	1 wd	--	--	--
Lampsilis straminea - Southern Fatmucket	--	6 fd	6 lv, 9 wd	2 lv	1 fd	1 fd, 1 wd
Lampsilis teres - Yellow Sandshell	--	--	--	--	--	--
Pleurobema furvum - Dark Pigtoe	--	1 fd	--	1 lv, 1 fd	--	--
Pyganodon grandis - Giant Floater	--	--	--	--	--	--
Quadrula asperata - Alabama Orb	--	--	2 wd	2 lv	--	--
Quadrula verrucosa - Pistolgrip	--	--	--	--	--	--
Strophitus subvexus - Southern Creekmussel	--	2 wd	14 lv, 5 wd	2 fd, 1 lv	5 lv, 2 fd, 3 wd	1 lv
Uniomerus tetralasmus - Pondhorn	--	--	--	--	--	--
Villosa lienosa - Little Spectaclecase	--	2 wd	1 lv, 4 wd	--	1 fd	1 fd
Villosa vibex - Southern Rainbow	--	1 fd	2 lv, 2 wd	1 lv	3 wd	--

Sampling site	35. Clear at Co. Hwy. 93	36. Clear Creek at Lowery Road	37. Clear Creek DS of Bugs Lake	39. Clear Creek at Clear Creek Road	41. North River at Co. Hwy. 30	41. North River at Co. Hwy. 30
Sample date	24-Nov-91	19-Sep-08	22-Sep-08	30-Sep-08	13-Oct-91	30-Sep-08
Data source	3	1	1	1	3	1
Species - common name						
Amblema plicata - Threeridge	--	--	--	--	--	--
Anodontoides radiatus - Rayed Creekshell	--	2 lv, 2 wd	--	No	--	--
Elliptio arca - Alabama Spike	--	--	--	unionid	--	--
Elliptio arctata - Delicate Spike	--	33 lv	1 lv, 2 wd	mussels	--	--
Hamiota perovalis - Orangenacre Mucket	--	1 lv	2 wd	found	--	--
Lampsilis ornata - Southern Pocketbook	--	--	1 fd	--	--	--
Lampsilis straminea - Southern Fatmucket	1 wd	13 lv, 3 fd, 3 wd	2 lv	--	2 fd	--
Lampsilis teres - Yellow Sandshell	--	--	1 lv	--	--	--
Pleurobema furvum - Dark Pigtoe	--	--	--	--	--	--
Pyganodon grandis - Giant Floater	--	--	--	--	--	--
Quadrula asperata - Alabama Orb	--	--	1 lv	--	1 lv	1 lv
Quadrula verrucosa - Pistolgrip	--	--	--	--	--	--
Strophitus subvexus - Southern Creekmussel	1 wd	6 lv	2 lv	--	7 lv, fd	3 lv
Uniomerus tetralasmus - Pondhorn	--	--	--	--	--	--
Villosa lienosa - Little Spectaclecase	2 fd	3 lv, 2 fd, 2 wd	--	--	--	--
Villosa vibex - Southern Rainbow	1 fd	7 lv	1 wd	--	1 fd	1 lv

Sampling site	43. North River DS of Fayette Co. dam site	44. North River at Fayette Co. dam site	45. Star Branch at dam site	46. North River DS of Cane Creek	47. Cane Creek near mouth	48. Cane Creek at Co. Hwy. 63
Sample date	18-Oct-91	18-Oct-91	18-Oct-91	13-Oct-91	18-Oct-91	23-Jul-08
Data source	3	3	3	3	3	1
Species - common name						
Amblema plicata - Threeridge	--	--	--	--	--	--
Anodontoides radiatus - Rayed Creekshell	--	--	No	--	No	No
Elliptio arca - Alabama Spike	--	--	unionid	--	unionid	unionid
Elliptio arctata - Delicate Spike	--	--	mussels	--	mussels	mussels
Hamiota perovalis - Orangenacre Mucket	--	--	found	--	found	found
Lampsilis ornata - Southern Pocketbook	--	--	--	1 wd	--	--
Lampsilis straminea - Southern Fatmucket	--	--	--	--	--	--
Lampsilis teres - Yellow Sandshell	--	--	--	--	--	--
Pleurobema furvum - Dark Pigtoe	--	--	--	--	--	--
Pyganodon grandis - Giant Floater	--	--	--	--	--	--
Quadrula asperata - Alabama Orb	--	--	--	--	--	--
Quadrula verrucosa - Pistolgrip	--	--	--	--	--	--
Strophitus subvexus - Southern Creekmussel	1 wd	1 wd	--	3 lv, fd	--	--
Uniomerus tetralasmus - Pondhorn	--	--	--	--	--	--
Villosa lienosa - Little Spectaclecase	--	2 wd	--	--	--	--
Villosa vibex - Southern Rainbow	--	--	--	1 fd	--	--

Sampling site	49. North River near Laney Branch	50. North River DS of Jenkins Cemetery	51. North River US of Jenkins Cemetery	52. Beaver Creek	53. George Creek near mouth	54. George Creek at Co. Hwy. 63
Sample date	18-Oct-91	18-Oct-91	13-Oct-91	22-Jul-08	25-Oct-91	27-Oct-91
Data source	3	3	3	1	3	3
Species - common name						
Amblema plicata - Threeridge	--	--	--	--	--	--
Anodontoides radiatus - Rayed Creekshell	--	--	--	No	--	--
Elliptio arca - Alabama Spike	--	--	--	unionid	--	--
Elliptio arctata - Delicate Spike	--	--	--	mussels	--	--
Hamiota perovalis - Orangenacre Mucket	--	--	--	found	--	--
Lampsilis ornata - Southern Pocketbook	--	--	--	--	--	--
Lampsilis straminea - Southern Fatmucket	--	4 fd	4 lv, fd	--	1 wd	--
Lampsilis teres - Yellow Sandshell	--	--	--	--	--	--
Pleurobema furvum - Dark Pigtoe	--	--	--	--	--	--
Pyganodon grandis - Giant Floater	1 fd	--	--	--	--	--
Quadrula asperata - Alabama Orb	--	--	--	--	--	--
Quadrula verrucosa - Pistolgrip	--	--	--	--	--	--
Strophitus subvexus - Southern Creekmussel	3 fd	3 fd, wd	4 lv, fd	--	2 fd	1 fd
Uniomerus tetralasmus - Pondhorn	--	--	--	--	--	--
Villosa lienosa - Little Spectaclecase	--	3 fd	--	--	1 wd	--
Villosa vibex - Southern Rainbow	--	1 fd	3 lv, fd	--	2 wd	--

Sampling site	54. George Creek at Co. Hwy. 63	55. North River upstream George Creek (1)	56. North River upstream George Creek (2)	57. North River upstream George Creek (3)	58. North River at Lowery Branch	58. North River at Lowery Branch
Sample date	22-Jul-08	25-Oct-91	25-Oct-91	25-Oct-91	27-Oct-91	23-Jul-08
Data source	1	3	3	3	3	1
Species - common name						
Amblema plicata - Threeridge	--	--	--	--	--	--
Anodontoides radiatus - Rayed Creekshell	No	--	--	--	--	1 lv
Elliptio arca - Alabama Spike	unionid	--	--	--	--	--
Elliptio arctata - Delicate Spike	mussels	--	--	--	--	--
Hamiota perovalis - Orangenacre Mucket	found	--	--	--	--	--
Lampsilis ornata - Southern Pocketbook	--	--	--	--	--	--
Lampsilis straminea - Southern Fatmucket	--	--	--	--	--	--
Lampsilis teres - Yellow Sandshell	--	--	--	--	--	--
Pleurobema furvum - Dark Pigtoe	--	--	--	--	--	--
Pyganodon grandis - Giant Floater	--	--	--	--	--	--
Quadrula asperata - Alabama Orb	--	--	--	--	--	--
Quadrula verrucosa - Pistolgrip	--	--	--	--	--	--
Strophitus subvexus - Southern Creekmussel	--	--	1 wd	1 wd	1 wd	--
Uniomerus tetralasmus - Pondhorn	--	--	--	--	--	1 lv
Villosa lienosa - Little Spectaclecase	--	--	--	--	--	1 lv
Villosa vibex - Southern Rainbow	--	1 wd	1 wd	1 lv	3 fd, wd	--

Sampling site	59. North River at Fayette Co. Hwy 63	59. North River at Fayette Co. Hwy 63	60. Hendon Creek nr. Co. Hwy. 63	60. Hendon Creek nr. Co. Hwy. 63	61. North River at Ala. Hwy. 102	61. North River at Ala. Hwy. 102
Sample date	27-Oct-91	22-Jul-08	27-Oct-91	22-Jul-08	2-Nov-91	22-Jul-08
Data source	3	1	3	1	3	1
Species - common name						
Amblema plicata - Threeridge	--	--	--	--	--	--
Anodontoides radiatus - Rayed Creekshell	--	1 lv, 1 wd	No	No	No	No
Elliptio arca - Alabama Spike	--	--	unionid	unionid	unionid	unionid
Elliptio arctata - Delicate Spike	--	--	mussels	mussels	mussels	mussels
Hamiota perovalis - Orangenacre Mucket	--	--	found	found	found	found
Lampsilis ornata - Southern Pocketbook	--	--	--	--	--	--
Lampsilis straminea - Southern Fatmucket	2 lv	--	--	--	--	--
Lampsilis teres - Yellow Sandshell	--	--	--	--	--	--
Pleurobema furvum - Dark Pigtoe	--	--	--	--	--	--
Pyganodon grandis - Giant Floater	--	--	--	--	--	--
Quadrula asperata - Alabama Orb	--	--	--	--	--	--
Quadrula verrucosa - Pistolgrip	--	--	--	--	--	--
Strophitus subvexus - Southern Creekmussel	1 wd	--	--	--	--	--
Uniomerus tetralasmus - Pondhorn	--	--	--	--	--	--
Villosa lienosa - Little Spectaclecase	--	5 lv, 1 fd, 2 wd	--	--	--	--
Villosa vibex - Southern Rainbow	1 wd	--	--	--	--	--

Sampling site	North River from Fayette Co. dam site to 1.5 miles DS of dam	North River from 1.5 miles DS dam site to Co. Hwy. 30	North River from Co. Hwy. 30 to Ala. Hwy. 18	North River from Whittson Bridge to Co. Hwy. 38
Sample date	20-Aug-92	31-Aug-92	13-Sep-92	23-Jun-96
Data source	4	4	4	2
Species - common name				
Amblema plicata - Threeridge	--	--	--	
Anodontoides radiatus - Rayed Creekshell	--	--	--	
Elliptio arca - Alabama Spike	--	--	--	
Elliptio arctata - Delicate Spike	--	--	--	
Hamiota perovalis - Orangenacre Mucket	2 lv, 1 wd	1 wd	2 wd	
Lampsilis ornata - Southern Pocketbook	--	--	1 wd	
Lampsilis straminea - Southern Fatmucket	1 wd	3 lv	2 lv, 4 wd	1 wd
Lampsilis teres - Yellow Sandshell	--	--	--	
Pleurobema furvum - Dark Pigtoe	--	--	--	
Pyganodon grandis - Giant Floater	--	--	--	
Quadrula asperata - Alabama Orb	1 lv, 4 wd	--	1 lv, 1 wd	2 lv
Quadrula verrucosa - Pistolgrip	--	--	--	1 fd, 1 wd
Strophitus subvexus - Southern Creekmussel	1 lv, 3 wd	3 lv, 2 wd	5 lv, 6 wd	1 lv
Uniomerus tetralasmus - Pondhorn	--	--	--	
Villosa lienosa - Little Spectaclecase	3 wd	--	--	
Villosa vibex - Southern Rainbow	--	--	--	

APPENDIX B

Collection data for fish sampling sites in the North River
(see table 4 for sampling site locations)

Site No.	1	2	4	6	9	13
Sample date	28-Apr-09	28-Apr-09	14-Jul-09	14-Jul-09	23-Jul-08	28-Apr-09
GSA catalog No.	2008	2009	2071	2072	2002	2011
Petromyzontidae - lampreys						
Ichthyomyzon gagei, southern brook lamprey	--	5	--	--	--	--
Lampetra aepyptera, least brook lamprey	--	--	--	--	--	2
Lepisosteidae - gars						
Lepisosteus osseus, longnose gar	--	--	--	--	1	--
Cyprinidae - carps and minnows						
Campostoma oligolepis, largescale stoneroller	--	--	70	70	149	20
Cyprinella callistia, Alabama shiner	--	--	9	1	20	--
Cyprinella venusta, blacktail shiner	2	--	--	15	31	20
Luxilus chrysocephalus, striped shiner	5	6	--	--	24	32
Lythrurus bellus x L. alegnotus intergrades, pretty x Warrior shiner	28	9	--	--	--	42
Nocomis leptocephalus, bluehead chub	1	5	--	1	--	4
Notemigonus crysoleucas, golden shiner	--	--	--	--	--	--
Notropis asperifrons, burrhead shiner	--	--	--	--	--	10
Notropis baileyi, rough shiner	--	29	--	--	--	1
Notropis stilbius, silverstripe shiner	--	--	--	25	59	5
Notropis texanus, weed shiner	10	--	2	--	--	--
Notropis volucellus, mimic shiner	--	--	--	--	1	--
Opsopoeodus emiliae, pugnose minnow	--	--	--	--	--	--
Pimephales notatus, bluntnose minnow	1	--	--	--	--	2
Pimephales vigilax, bullhead minnow	--	--	--	--	--	2
Semotilus atromaculatus, creek chub	--	--	4	8	1	2
Catostomidae - suckers						
Erimyzon oblongus, creek chubsucker	--	--	1	1	--	--
Hypentelium etowanum, Alabama hog sucker	--	--	--	9	1	2
Minytrema melanops, spotted sucker	--	--	1	2	--	--
Moxostoma erythrurum, golden redhorse	--	--	--	--	--	--
Moxostoma poecilurum, blacktail redhorse	--	--	--	3	4	13
Ictaluridae - North American catfishes						
Ameiurus natalis, yellow bullhead	2	--	--	1	1	--
Ictalurus punctatus, channel catfish	--	--	--	--	1	--
Noturus funebris, black madtom	--	5	--	--	--	--
Noturus gyrinus, tadpole madtom	2	--	--	--	--	--
Noturus leptacanthus, speckled madtom	4	1	1	1	--	--
Pylodictis olivaris, flathead catfish	--	--	--	--	--	--
Esocidae - pikes and pickerels						
Esox niger, chain pickerel	--	--	--	--	--	--
Aphredoderidae - pirate perches						
Aphredoderus sayanus, pirate perch	--	--	--	--	--	2
Fundulidae - topminnows						
Fundulus olivaceus, blackspotted topminnow	29	--	--	2	5	5
Poeciliidae - livebearers						
Gambusia affinis, western mosquitofish	--	--	1	1	--	--

Site No.	1	2	4	6	9	13
Sample date	28-Apr-09	28-Apr-09	14-Jul-09	14-Jul-09	23-Jul-08	28-Apr-09
GSA catalog No.	2008	2009	2071	2072	2002	2011
Centrarchidae - sunfishes						
Ambloplites ariommus, shadow bass	--	--	--	--	1	--
Lepomis cyanellus, green sunfish	5	--	32	10	8	15
Lepomis gulosus, warmouth	4	--	--	--	--	--
Lepomis macrochirus, bluegill	59	1	3	21	43	--
Lepomis megalotis, longear sunfish	33	1	--	51	76	25
Lepomis microlophus, redear sunfish	1	--	--	2	2	--
Lepomis miniatus, redspotted sunfish	--	--	--	--	--	2
hybrid *Lepomis*	--	--	--	--	1	--
Micropterus punctulatus, spotted bass	1	--	--	4	4	--
Micropterus salmoides, largemouth bass	1	2	--	--	--	--
Pomoxis nigromaculatus, black crappie	--	--	--	--	--	--
Percidae - darters and perches						
Etheostoma artesiae, redspot darter	--	--	1	6	--	8
Etheostoma lachneri, Tombigbee darter	--	4	--	--	--	--
Etheostoma stigmaeum, speckled darter	90	--	--	11	17	33
Etheostoma swaini, gulf darter	59	--	--	--	--	--
Percina caprodes, logperch	--	--	--	--	3	--
Percina kathae, Mobile logperch	121	4	1	8	--	8
Percina maculata, blackside darter	--	--	--	--	3	--
Percina nigrofasciata, blackbanded darter	8	2	6	8	63	3
Total species	21	13	13	23	24	23
Total individuals	466	74	132	261	519	258

Site No. Sample date GSA catalog No.	16 14-Jul-09 2070	21 22-Jul-08 2003	23 3-Sep-09 1930	24 23-Jul-08 2001	31 22-Jul-08 2004	32 2-Sep-09 1925
Petromyzontidae - lampreys						
Ichthyomyzon gagei , southern brook lamprey	--	--	--	--	4	7
Lampetra aepyptera , least brook lamprey	--	--	--	--	--	--
Lepisosteidae - gars						
Lepisosteus osseus , longnose gar	--	1	1	--	--	--
Cyprinidae - carps and minnows						
Campostoma oligolepis, largescale stoneroller	14	113	4	90	3	1
Cyprinella callistia, Alabama shiner	--	19	1	1	--	--
Cyprinella venusta, blacktail shiner	--	13	11	3	11	7
Luxilus chrysocephalus, striped shiner	7	31	7	63	38	42
Lythrurus bellus x L. alegnotus intergrades, pretty x Warrior shiner	25	--	8	3	40	39
Nocomis leptocephalus, bluehead chub	--	--	--	4	8	11
Notemigonus crysoleucas, golden shiner	--	--	--	1	--	--
Notropis asperifrons, burrhead shiner	32	--	--	--	--	--
Notropis baileyi, rough shiner	--	5	--	--	29	37
Notropis stilbius, silverstripe shiner	18	209	36	95	1	2
Notropis texanus, weed shiner	--	38	18	7	29	17
Notropis volucellus, mimic shiner	1	--	--	--	--	--
Opsopoeodus emiliae, pugnose minnow	--	--	--	--	--	--
Pimephales notatus, bluntnose minnow	--	--	--	--	--	1
Pimephales vigilax, bullhead minnow	--	--	--	--	--	--
Semotilus atromaculatus, creek chub	--	--	--	26	2	6
Catostomidae - suckers						
Erimyzon oblongus, creek chubsucker	--	--	--	--	--	1
Hypentelium etowanum, Alabama hog sucker	--	8	1	2	7	10
Minytrema melanops, spotted sucker	--	--	2	--	1	--
Moxostoma erythrurum, golden redhorse	1	--	--	--	5	--
Moxostoma poecilurum, blacktail redhorse	2	4	2	7	2	--
Ictaluridae - North American catfishes						
Ameiurus natalis, yellow bullhead	--	--	--	1	--	--
Ictalurus punctatus, channel catfish	--	1	--	--	--	--
Noturus funebris, black madtom	--	--	--	--	--	1
Noturus gyrinus, tadpole madtom	--	--	1	2	--	--
Noturus leptacanthus, speckled madtom	--	--	7	--	2	--
Pylodictis olivaris, flathead catfish	--	--	--	--	--	--
Esocidae - pikes and pickerels						
Esox niger, chain pickerel	--	--	1	--	1	1
Aphredoderidae - pirate perches						
Aphredoderus sayanus, pirate perch	--	7	2	3	4	2
Fundulidae - topminnows						
Fundulus olivaceus, blackspotted topminnow	6	7	8	22	1	4
Poeciliidae - livebearers						
Gambusia affinis, western mosquitofish	--	--	--	2	1	--

Site No.	16	21	23	24	31	32
Sample date	14-Jul-09	22-Jul-08	3-Sep-09	23-Jul-08	22-Jul-08	2-Sep-09
GSA catalog No.	2070	2003	1930	2001	2004	1925
Centrarchidae - sunfishes						
Ambloplites ariommus, shadow bass	--	--	--	--	1	--
Lepomis cyanellus, green sunfish	2	2	5	18	8	2
Lepomis gulosus, warmouth	--	1	--	2	--	--
Lepomis macrochirus, bluegill	1	12	4	10	12	9
Lepomis megalotis, longear sunfish	21	51	18	105	88	36
Lepomis microlophus, redear sunfish	--	--	--	--	--	--
Lepomis miniatus, redspotted sunfish	--	--	--	--	--	--
hybrid *Lepomis*	--	--	--	--	--	--
Micropterus punctulatus, spotted bass	4	13	6	2	6	1
Micropterus salmoides, largemouth bass	--	--	1	8	2	--
Pomoxis nigromaculatus, black crappie	--	--	--	--	--	--
Percidae - darters and perches						
Etheostoma artesiae, redspot darter	7	--	6	13	--	1
Etheostoma lachneri, Tombigbee darter	--	--	--	--	--	--
Etheostoma stigmaeum, speckled darter	12	42	41	12	17	46
Etheostoma swaini, gulf darter	--	--	8	--	3	1
Percina caprodes, logperch	--	3	--	3	3	--
Percina kathae, Mobile logperch	1	--	3	--	--	2
Percina maculata, blackside darter	--	1	3	--	--	--
Percina nigrofasciata, blackbanded darter	5	27	33	23	16	43
Total species	17	22	27	27	29	26
Total individuals	159	608	238	528	345	330

Site No. Sample date GSA catalog No.	34 14-Aug-08 2007	35 2-Sep-09 1926	37 2-Sep-09 1927	39 16-Sep-09 1928	41 14-Aug-08 2005	48 14-Aug-09 2084
Petromyzontidae - lampreys						
Ichthyomyzon gagei , southern brook lamprey	--	3	--	2	--	--
Lampetra aepyptera , least brook lamprey	--	--	--	--	--	--
Lepisosteidae - gars						
Lepisosteus osseus , longnose gar	--	--	--	--	--	--
Cyprinidae - carps and minnows						
Campostoma oligolepis, largescale stoneroller	7	30	161	18	43	85
Cyprinella callistia, Alabama shiner	--	--	14	--	9	--
Cyprinella venusta, blacktail shiner	2	6	4	29	8	1
Luxilus chrysocephalus, striped shiner	43	9	--	46	18	5
Lythrurus bellus x L. alegnotus intergrades, pretty x Warrior shiner	14	28	7	65	19	1
Nocomis leptocephalus, bluehead chub	6	--	--	--	4	--
Notemigonus crysoleucas, golden shiner	--	--	--	--	--	--
Notropis asperifrons, burrhead shiner	--	--	--	--	--	--
Notropis baileyi, rough shiner	--	--	--	189	1	--
Notropis stilbius, silverstripe shiner	--	--	1	--	5	--
Notropis texanus, weed shiner	20	9	--	--	32	3
Notropis volucellus, mimic shiner	--	--	--	--	--	--
Opsopoeodus emiliae, pugnose minnow	--	--	--	--	--	--
Pimephales notatus, bluntnose minnow	--	--	--	--	--	--
Pimephales vigilax, bullhead minnow	--	--	--	--	--	--
Semotilus atromaculatus, creek chub	3	--	--	17	--	12
Catostomidae - suckers						
Erimyzon oblongus, creek chubsucker	--	--	--	5	--	3
Hypentelium etowanum, Alabama hog sucker	2	3	--	--	6	1
Minytrema melanops, spotted sucker	--	--	--	--	3	--
Moxostoma erythrurum, golden redhorse	5	--	--	--	7	--
Moxostoma poecilurum, blacktail redhorse	5	--	6	--	3	--
Ictaluridae - North American catfishes						
Ameiurus natalis, yellow bullhead	--	1	--	1	--	6
Ictalurus punctatus, channel catfish	--	--	--	--	--	--
Noturus funebris, black madtom	--	--	5	4	--	--
Noturus gyrinus, tadpole madtom	--	--	--	7	--	--
Noturus leptacanthus, speckled madtom	--	15	3	--	--	--
Pylodictis olivaris, flathead catfish	--	--	1	--	--	--
Esocidae - pikes and pickerels						
Esox niger, chain pickerel	--	--	--	--	1	--
Aphredoderidae - pirate perches						
Aphredoderus sayanus, pirate perch	1	1	--	3	4	4
Fundulidae - topminnows						
Fundulus olivaceus, blackspotted topminnow	15	2	1	--	12	3
Poeciliidae - livebearers						
Gambusia affinis, western mosquitofish	5	4	--	--	19	--

Site No.	34	35	37	39	41	48
Sample date	14-Aug-08	2-Sep-09	2-Sep-09	16-Sep-09	14-Aug-08	14-Aug-09
GSA catalog No.	2007	1926	1927	1928	2005	2084
Centrarchidae - sunfishes						
Ambloplites ariommus, shadow bass	--	2	2	--	7	--
Lepomis cyanellus, green sunfish	--	--	--	1	27	42
Lepomis gulosus, warmouth	1	2	2	--	3	3
Lepomis macrochirus, bluegill	10	40	56	2	5	84
Lepomis megalotis, longear sunfish	46	45	21	14	109	20
Lepomis microlophus, redear sunfish	--	--	1	--	--	--
Lepomis miniatus, redspotted sunfish	--	--	--	--	10	2
hybrid *Lepomis*	--	--	--	--	--	--
Micropterus punctulatus, spotted bass	2	1	12	2	2	1
Micropterus salmoides, largemouth bass	5	--	5	1	--	25
Pomoxis nigromaculatus, black crappie	--	--	1	--	--	--
Percidae - darters and perches						
Etheostoma artesiae, redspot darter	--	4	2	17	10	12
Etheostoma lachneri, Tombigbee darter	--	--	--	--	--	--
Etheostoma stigmaeum, speckled darter	12	6	4	41	9	--
Etheostoma swaini, gulf darter	1	1	3	7	1	--
Percina caprodes, logperch	--	--	--	--	--	--
Percina kathae, Mobile logperch	1	2	2	1	6	--
Percina maculata, blackside darter	--	--	--	--	--	--
Percina nigrofasciata, blackbanded darter	20	29	27	29	14	1
Total species	22	22	23	22	29	20
Total individuals	226	243	341	501	397	314

Site No. Sample date GSA catalog No.	51 7-Aug-09 2085	58 7-Aug-09 2086	61 3-Sep-09 1929	Total collected	Percent
Petromyzontidae - lampreys					
Ichthyomyzon gagei , southern brook lamprey	--	--	--	21	0.28
Lampetra aepyptera , least brook lamprey	--	--	--	2	0.03
Lepisosteidae - gars					
Lepisosteus osseus , longnose gar	--	--	--	3	0.04
Cyprinidae - carps and minnows					
Campostoma oligolepis, largescale stoneroller	10	37	156	1,081	14.48
Cyprinella callistia, Alabama shiner	--	--	--	74	0.99
Cyprinella venusta, blacktail shiner	1	1	--	165	2.21
Luxilus chrysocephalus, striped shiner	38	46	56	516	6.91
Lythrurus bellus x L. alegnotus intergrades, pretty x Warrior shiner	477	111	2	918	12.3
Nocomis leptocephalus, bluehead chub	7	--	--	51	0.68
Notemigonus crysoleucas, golden shiner	--	--	--	1	0.01
Notropis asperifrons, burrhead shiner	4	2	--	48	0.64
Notropis baileyi, rough shiner	1	--	--	292	3.91
Notropis stilbius, silverstripe shiner	--	--	--	456	6.11
Notropis texanus, weed shiner	10	10	--	205	2.75
Notropis volucellus, mimic shiner	3	--	--	5	0.07
Opsopoeodus emiliae, pugnose minnow	3	--	--	3	0.04
Pimephales notatus, bluntnose minnow	1	12	3	20	0.27
Pimephales vigilax, bullhead minnow	--	--	--	2	0.03
Semotilus atromaculatus, creek chub	1	17	69	168	2.25
Catostomidae - suckers					
Erimyzon oblongus, creek chubsucker	1	7	28	47	0.63
Hypentelium etowanum, Alabama hog sucker	--	--	--	52	0.7
Minytrema melanops, spotted sucker	--	--	--	9	0.12
Moxostoma erythrurum, golden redhorse	2	11	14	45	0.6
Moxostoma poecilurum, blacktail redhorse	1	1	--	53	0.71
Ictaluridae - North American catfishes					
Ameiurus natalis, yellow bullhead	--	5	1	19	0.25
Ictalurus punctatus, channel catfish	--	--	--	2	0.03
Noturus funebris, black madtom	1	--	--	16	0.21
Noturus gyrinus, tadpole madtom	2	--	--	14	0.19
Noturus leptacanthus, speckled madtom	1	--	--	35	0.47
Pylodictis olivaris, flathead catfish	--	--	--	1	0.01
Esocidae - pikes and pickerels					
Esox niger, chain pickerel	2	--	--	6	0.08
Aphredoderidae - pirate perches					
Aphredoderus sayanus, pirate perch	6	5	4	48	0.64
Fundulidae - topminnows					
Fundulus olivaceus, blackspotted topminnow	12	12	25	171	2.29
Poeciliidae - livebearers					
Gambusia affinis, western mosquitofish	--	--	--	33	0.44

Site No. Sample date GSA catalog No.	51 7-Aug-09 2085	58 7-Aug-09 2086	61 3-Sep-09 1929	Total collected	Percent
Centrarchidae - sunfishes					
Ambloplites ariommus, shadow bass	--	--	--	13	0.17
Lepomis cyanellus, green sunfish	2	15	26	220	2.95
Lepomis gulosus, warmouth	2	5	--	25	0.33
Lepomis macrochirus, bluegill	3	4	25	404	5.41
Lepomis megalotis, longear sunfish	31	16	13	820	10.98
Lepomis microlophus, redear sunfish	--	--	--	6	0.08
Lepomis miniatus, redspotted sunfish	--	4	--	18	0.24
hybrid *Lepomis*	--	--	--	1	0.01
Micropterus punctulatus, spotted bass	--	--	--	61	0.82
Micropterus salmoides, largemouth bass	5	--	--	55	0.74
Pomoxis nigromaculatus, black crappie	--	--	--	1	0.01
Percidae - darters and perches					
Etheostoma artesiae, redspot darter	25	23	37	172	2.3
Etheostoma lachneri, Tombigbee darter	--	--	--	4	0.05
Etheostoma stigmaeum, speckled darter	18	13	3	427	5.72
Etheostoma swaini, gulf darter	12	2	--	98	1.31
Percina caprodes, logperch	--	--	--	12	0.16
Percina kathae, Mobile logperch	1	--	--	161	2.16
Percina maculata, blackside darter	2	3	2	14	0.19
Percina nigrofasciata, blackbanded darter	14	--	--	371	4.97
Total species	32	23	16		
Total individuals	699	362	464	7,465	100

APPENDIX C

Habitat evaluation forms

ADEM-FIELD OPERATIONS-MONTGOMERY BRANCH
RIFFLE/RUN HABITAT ASSESSMENT FIELD DATA SHEET

Name of Waterbody ______________________________ Date: ______________

Station Number ______________ Investigators ______________________________

Habitat Parameter	Category: Optimal	Suboptimal	Marginal	Poor
1 **Instream Cover**	>50% mix of boulder, cobble, submerged logs, undercut banks, or other stable habitat.	50-30% mix of boulder, cobble, or other stable habitat; adequate habitat.	30-10% mix of boulder, cobble, or other stable habitat; habitat availability less than desirable.	<10% mix of boulder, cobble, or other stable habitat; lack of habitat is obvious.
Score ______	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2 **Epifaunal surface**	Well-developed riffle and run; riffles as wide as stream and length is 2x the width of stream; abundance of cobble.	Riffle is as wide as stream, but length is <2 times width; abundance of cobble; boulders and gravel common.	Run area may be lacking; riffle not as wide as stream and its length is <2 times the stream width; gravel or large boulders and bedrock prevalent; some cobble present.	Riffles or run virtually nonexistent; large boulders and bedrock prevalent; cobble lacking.
Score ______	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3 **Embeddedness**	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble and boulder particles are >75% surrounded by fine sediment.
Score ______	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4 **Velocity/Depth Regimes**	All 4 velocity/depth regimes present (slow-deep, slow-shallow, fast-shallow, fast-deep).	Only 3 of 4 regimes present. (if fast-shallow is missing, score lower.)	Only 2 of 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/depth regime (usually slow-deep).
Score ______	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5 **Man-made Channel Alteration**	No channelization or dredging present.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization (>20 years) may be present, but not recent.	New embankments present on both banks; and 40 - 80% of stream reach is channelized and disrupted.	Banks shored with gabion or cement; >80% of the stream reach channelized and disrupted.
Score ______	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
6 **Sediment Deposition**	Little or no enlargement of islands or point bars and less than 5 % of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from coarse gravel; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel or coarse sand on old and new bars; 30-50% of the bottom affected; sediment deposits at obstruction, constriction, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; > 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
Score ______	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7 **Frequency of Riffles** (Distance between riffles/ stream width)	<5 5 6 7	8 9 11 13 15	16 18 21 23 25	26 28 30 32 34 ≥ 35
Score ______	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8 **Channel flow Status**	Water reaches base of both lower banks.	Water fills >75% of the available channel.	Water fills 75 - 25% of the available channel and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
Score ______	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
9 **Condition of Banks**	Banks stable; no evidence (<5%) of erosion or bank failure.	Moderately stable; infrequent, small areas (5-30%) of erosion mostly healed over.	Moderately unstable; 30-60% of banks in reach have areas of erosion.	Unstable; many eroded areas; "raw" areas frequent Along straight section and bends; on side slopes, 60-100% of bank has erosional scars.
Score ______	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
10 **Bank Vegetative Protection**	>90% of the streambank surfaces covered by vegetation.	90-70% of the streambank surfaces covered by vegetation.	70-50% of the streambank surfaces covered by vegetation.	<50% of the streambank surfaces covered by vegetation.
Score (LB) ______	10 9 8	7 6	5 4 3	2 1 0
Score (RB) ______	10 9 8	7 6	5 4 3	2 1 0
11 **Grazing or other disruptive pressure**	Vegetative disruption, through grazing or mowing, minimal or not evident; almost all plants allowed to grow naturally.	Disruption evident but not affecting full plant growth potential to any great extent; >1/2 of the potential plant stubble height remaining.	Disruption obvious; patches of bare soil or closely cropped vegetation common; < 1/2 of the potential plant stubble height remaining.	Disruption of streambank vegetation is very high; vegetation has been removed to ≤ 2 inches average stubble height.
Score (LB) ______	10 9 8	7 6	5 4 3	2 1 0
Score (RB) ______	10 9 8	7 6	5 4 3	2 1 0
12 **Riparian vegetative zone (each bank)**	Width of riparian zone >60 feet; human activities (i.e., parking lots, roadbeds, clearcuts, lawns, or crops) have not impacted zone.	Width of riparian zone 60 - 40 feet; human activities have impacted zone only minimally.	Width of riparian zone 40 - 20 feet; human activities have impacted zone a great deal.	Width of riparian zone <20 feet; little or no riparian vegetation due to human activities.
Score (LB) ______	10 9 8	7 6	5 4 3	2 1 0
Score (RB) ______	10 9 8	7 6	5 4 3	2 1 0

ADEM-FIELD OPERATIONS-MONTGOMERY BRANCH
GLIDE/POOL HABITAT ASSESSMENT FIELD DATA SHEET

Name of Waterbody ______________________________ Date: ____________________

Station Number ______________ Investigators ______________________________

Habitat Parameter	Optimal	Suboptimal	Marginal	Poor
1 **Instream Cover**	> 50% mix of snags, submerged logs, undercut banks, or other stable habitat; rubble, gravel may be present.	50-30% mix of stable habitat; adequate habitat for maintenance of populations.	30-10% mix of stable habitat; habitat availability less than desirable.	<10% stable habitat; lack of habitat is obvious.
Score ______	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2 **Pool Substrate Characterization**	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay or sand bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root mat or vegetation.
Score ______	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3 **Pool Variability**	Even mix of large-shallow, large-deep, small-shallow, small-deep pools present.	Majority of pools large-deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or pools absent.
Score ______	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4 **Man-made Channel Alteration**	No channelization or dredging present.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization (>20 years) may be present, but not recent.	New embankments present on both banks; channelization may be extensive, usually in urban or agriculture lands; and > 80% of stream reach is channelized and disrupted.	Extensive channelization; banks shored with gabion or cement; heavily urbanized areas; instream habitat greatly altered or removed entirely.
Score ______	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5 **Sediment Deposition**	<20% of bottom affected; minor accumulation of fine and coarse material at snags and submerged vegetation; little or no enlargement of islands or point bars.	20-50% affected; moderate accumulation; substantial sediment movement only during major storm event; some new increase in bar formation.	50-80% affected; major deposition; pools shallow, heavily silted; embankments may be present on both banks; frequent and substantial sediment movement during storm events.	Channelized; mud, silt, and/or sand in braided or non-braided channels; pools almost absent due to deposition.
Score ______	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
6 **Channel Sinuosity**	Bends in stream increase stream length 3 to 4 times longer than if it was in a straight line.	Bends in stream increase stream length 2 to 3 times longer than if it was in a straight line.	Bends in stream increase the stream length 2 to 1 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a long distance.
Score ______	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7 **Channel flow Status**	Water reaches base of both lower banks and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel.	Water fills 25-75% of the available channel and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
Score ______	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8 **Condition of Banks**	Banks stable; no evidence of erosion or bank failure; <5% affected.	Moderately stable; infrequent, small areas of erosion mostly healed over; 5-30% affected.	Moderately unstable; 30-60% of banks in reach have areas of erosion.	Unstable; many eroded areas; "raw" areas frequent along straight section and bends; on side slopes, 60-100% of bank has erosional scars.
Score ______	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
9 **Bank Vegetative Protection (each bank)**	> 90% of the streambank surfaces covered by vegetation.	90-70% of the streambank surfaces covered by vegetation.	70-50% of the streambank surfaces covered by vegetation.	<50% of the streambank surfaces covered by vegetation.
Score (LB) ______	10 9 8	7 6	5 4 3	2 1 0
Score (RB) ______	10 9 8	7 6	5 4 3	2 1 0
10 **Grazing or other disruptive pressure (each bank)**	Vegetative disruption, through grazing or mowing, minimal or not evident; almost all plants allowed to grow naturally.	Disruption evident but not affecting full plant growth potential to any great extent; >1/2 of the potential plant stubble height remaining.	Disruption obvious; patches of bare soil or closely cropped vegetation common; <1/2 of the potential plant stubble height remaining.	Disruption of streambank vegetation is very high; vegetation has been removed to ≤ 2 inches average stubble height.
Score (LB) ______	10 9 8	7 6	5 4 3	2 1 0
Score (RB) ______	10 9 8	7 6	5 4 3	2 1 0
11 **Riparian vegetative zone Width (each bank)**	Width of riparian zone >60 feet; human activities (i.e., parking lots, roadbeds, clearcuts, lawns, or crops) have not impacted zone.	Width of riparian zone 60 - 40 feet; human activities have impacted zone only minimally.	Width of riparian zone 40 - 20 feet; human activities have impacted zone a great deal.	Width of riparian zone <20 feet; little or no riparian vegetation due to human activities.
Score (LB) ______	10 9 8	7 6	5 4 3	2 1 0
Score (RB) ______	10 9 8	7 6	5 4 3	2 1 0

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