2005 Cahaba River Report

Results of Macroinvertebrate Community Assessments

July 2012

**Environmental Indicators Section –
Field Operations Division**

Executive Summary

Between 1996 and 1998, the Alabama Department of Environmental Management (ADEM) and Region 4 of the U.S. Environmental Protection Agency (EPA R4) listed four segments of the Cahaba River as impaired for nutrients, sediment, and habitat alteration under §303(d) of the Clean Water Act (ADEM 2002a). The segments were listed in large part to improve habitat conditions for ten endangered or threatened fish and mollusk species whose historic ranges included the Cahaba River. The impaired segment extends from Alabama Highway 82 at Centreville upstream approximately 105 river miles to Highway 59 at Trussville and encompasses an area of 1,027 mi^2.

Macroinvertebrate community bioassessments were conducted at six segments within the Cahaba River Basin using Hatchet Creek, a tributary of the Tallapoosa River, as a reference watershed. The objectives of these assessments were to:

1. Evaluate the use of Hatchet Creek as a reference watershed for the Cahaba River;
2. Assess the condition of the macroinvertebrate communities in the Cahaba River watershed using ADEM's intensive-level macroinvertebrate bioassessment (MB-I) method; and,
3. Provide baseline macroinvertebrate bioassessment data that can be used to strengthen the existing nutrient and sediment targets for the Cahaba River TMDLs, measure any changes in water quality due to the implementation of these TMDLs, and to monitor the overall health of Cahaba River and Hatchet Creek.

Macroinvertebrate community results indicated biological conditions at CABJ-1 and C-3 to be in *fair* condition and all other Cahaba stations to be in *poor* or *very poor* condition. Despite the different index period, these results are consistent with the 2004 Cahaba River bioassessment results, with conditions at CABJ-6 and C-3 rated as *fair*, and C-2 and CAHS-1 rated as *poor* or *very poor*. The rating of biological conditions at CABB-2a changed from *fair* in 2004 to *very poor* in 2005, due to the very high percent nutrient tolerant organisms, and relatively low number of EPT and clinger taxa. Additional sampling should be conducted to verify biological conditions at this location.

Several measures of taxa richness, community composition, and community tolerance appeared to respond to increased median TP concentrations. The median concentration at which metric results indicated declining biological conditions ranged from 0.05-0.06 mg/L. This range is consistent with the reference guidelines for the Piedmont, Ridge and Valley, and Southwestern Appalachian ecoregions, but slightly higher than the 2004 total phosphorus nutrient target of 0.035 mg/L developed for the Cahaba River and the corresponding total phosphorus nutrient criteria of 0.040 mg/L established by EPA and the Tennessee Department of Environment and Conservation for streams in three Ridge and Valley sub-ecoregions.

The Cahaba River is listed as impaired by sedimentation due to the indirect effects of excessive bed load sedimentation covering stream substrates and filling the interstitial spaces critical for reproduction and feeding. There was no relationship between macroinvertebrate metric results and total suspended solids or turbidity. However, sampling could not be conducted once flows at C-3 exceeded 200 cfs, when sediment

loads would be expected to be most elevated. Habitat assessment and pebble count estimates have shown heavy siltation at several reaches along the Cahaba River, but it may be critical to collect water quality parameters at stream gages in order to measure maximum suspended and dissolved solids, turbidity, and conductivity.

Average percent of bottom substrate covered by filamentous algae also showed no clear distinction between the Hatchet Creek and Cahaba River sites due to extremely high peak stream flows in the Cahaba River scouring substrates clean of filamentous algae. Although preliminary, diatom community assessment results showed distinct differences between Cahaba River and Hatchet Creek. Based on the 2004 and some 2005 data, results showed the diatom communities within the Cahaba River to be characterized by species tolerant of nutrient enriched conditions and low dissolved oxygen. Results of four metrics showed positive relationships between these factors and percent developed land within the watershed of each site. ADEM's diatom samples collected 2005-2007 should also be analyzed to evaluate how accurately and consistently diatom community assessments assess nutrient enrichment in urban streams.

In 2005, the ADEM revised its monitoring strategy to provide data to assess the chemical, physical, and biological conditions of non-navigable, flowing waters in the state. The strategy is a watershed-based monitoring program designed to provide data that link watershed condition and assessment results. A Watershed Disturbance Gradient (WDG), based on landuse and other factors, was developed in 2004 to classify each potential monitoring location by the level of disturbance within its watershed. ADEM's wadeable Rivers and Streams Monitoring Program uses this information to plan biological monitoring activities along a full disturbance gradient to produce a dataset representing both the full stressor gradient and the full biological condition gradient. A primary goal of this monitoring design was to provide stressor-response data that can be used to develop criteria and indicators.

ADEM's monitoring strategy has focused on wadeable streams and rivers, but a similar approach could be used to support the Cahaba River nutrient TMDL, as well as to establish nutrient criteria for nonwadeable streams and rivers statewide. Sampling should include a range of watershed conditions, as well as additional reference watersheds.

In 2004, when the numeric nutrient target was developed, biological, chemical, and physical data from least-impaired rivers supporting viable populations of the ten threatened and endangered species were not available. Recently, however, the Upper Cahaba Strategic Habitat Unit (SHU) has been categorized as critical habitat for 36 fish and mussel species identified as extirpated, endangered, threatened, or a high conservation concern. Ten SHUs in the Mobile-Tombigbee basin and 14 SHUs in the Alabama River basin share five to 14 of these species with the Cahaba River. Additional reference watersheds for the Cahaba River may be identified in these SHUs. Monitoring should include water chemisty and biological communities at multiple locations along a longitudinal stream-river continuum to refine stream size classes and monthly or seasonal sampling to more precisely define the best index period for detecting biological impairment in nonwadeable rivers and streams, and for developing appropriate indices for these waterbodies. It is important to maintain consistency among bioassessments and understand the relationship between sampling methods as ADEM moves forward with development of methods and nutrient criteria for this waterbody type.

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Background

Between 1996 and 1998, the Alabama Department of Environmental Management (ADEM) and Region 4 of the U.S. Environmental Protection Agency (EPA R4) listed four segments of the Cahaba River as impaired for nutrients, sediment, and habitat alteration under §303(d) of the Clean Water Act (ADEM 2002a). The segments were listed in large part to improve habitat conditions for ten endangered or threatened fish and mollusk species whose historic ranges included the Cahaba River. The impaired segment extends from Alabama Highway 82 at Centreville upstream approximately 105 river miles to Highway 59 at Trussville and encompasses an area of 1,027 mi^2.

In 2004, ADEM restructured its assessment unit IDs to more precisely identify and track waterbody segments with respect to designated uses and to be consistent with new listing and reporting guidelines under Sections 303(d) and 305(b) of the Clean Water Act. As a result, the original four listed segments were divided into eight. However, all use classifications and the corresponding water quality criteria to protect those uses remained the same.

Table 1 and Figure 1 show the listed segments along with the causes of impairment listed for each segment. Table 2 shows the threatened and endangered species cited by US Fish and Wildlife Service (USFWS) as being impacted in the upper Cahaba River watershed. Populations of these species are either extirpated or seriously threatened within the Cahaba River due to attached filamentous algae and excessive bed load sedimentation covering stream substrates and filling the interstitial spaces critical for reproduction and feeding (O'Neil 2002, EPA 2002). In 2003, USFWS designated critical habitat in the Cahaba River extending from AL Hwy 82 at Centreville to Jefferson County Rd. 143 and a few tributaries, for the southern acornshell, ovate clubshell, southern clubshell, upland combshell, triangular kidneyshell, Alabama moccasinshell, fine-lined pocketbook, and orange-nacre mucket mussels (USFWS, 2004).

Table 1. §303(d) Listed Segments within the Upper Cahaba River Watershed

Waterbody Name	Miles	Designated Uses	Causes of Impairment	Original Listing	Segment Location (Downstream to Upstream)
Cahaba River – Segment 1 (AL03150202-0101-102)	3.13	OAW / F&W	Siltation & Other Habitat Alteration	1998	US Hwy 11 to I-59
Cahaba River – Segment 2 (AL03150202-0104-102)	21.11	F&W	Siltation & Other Habitat Alteration	1998	Grants Mill Road to US Hwy 11
Cahaba River – Segment 3 (AL03150202-0201-102)	13.45	OAW / PWS	Siltation & Other Habitat Alteration	1998	Dam near US Hwy 280 to Grants Mill Road
Cahaba River – Segment 4 (AL03150202-0201-101)	17.46	F&W	Siltation	1998	Buck Creek to Dam near US Hwy 280
Cahaba River – Segment 5 (AL03150202-0203-102)	3.62	F&W	Siltation, Pathogens, & Other Habitat Alteration	1996	Shelby County Road 52 to Buck Creek
Cahaba River – Segment 6 (AL03150202-0203-101)	23.61	OAW / F&W	Siltation, Pathogens, & Other Habitat Alteration	1996	Shades Creek to Shelby County Road 52
Cahaba River – Segment 7 (AL03150202-0405-100)	13.51	OAW / F&W	Siltation & Other Habitat Alteration	1998	Lower Little Cahaba River to Shades Creek
Cahaba River – Segment 8 (AL03150202-0503-102)	10.58	OAW / S	Siltation & Other Habitat Alteration	1998	AL Hwy 82 to Lower Little Cahaba River

Table 2. List of Existing or Extirpated Threatened and Endangered Species in the §303(d) listed Segments of the Cahaba River (USFR, 1998)

Listed Species	Common Name	Type	ESA Status	Found in Cahaba Basin
Lampsilis altilis	Fine-Lined Pocketbook	Mussel	Threatened	Yes
Ptychobranchus greeni	Triangular Kidneyshell	Mussel	Endangered	Yes
Lioplax cyclostomaformis	Cylindrical Lioplax	Snail	Endangered	Yes
Lepyrium showalteri	Flat Pebblesnail	Snail	Endangered	Yes
Leptoxis ampla	Round Rocksnail	Snail	Threatened	Yes
Medionidus acutissimus	Alabama Moccasinshell	Mussel	Threatened	No, Extirpated since 1973
Pleurobema decisum	Southern Clubshell	Mussel	Endangered	No, Extirpated since 1973
Epioblasma metatstiata	Upland Combshell	Mussel	Endangered	No, Extirpated since 1973
Notropis cahabae	Cahaba Shiner	Fish	Endangered	Yes
Percina aurolineata	Goldline Darter	Fish	Threatened	Yes
Lampsilis perovalis	Orange-nacre Mucket	Mussel	Threatened	Yes

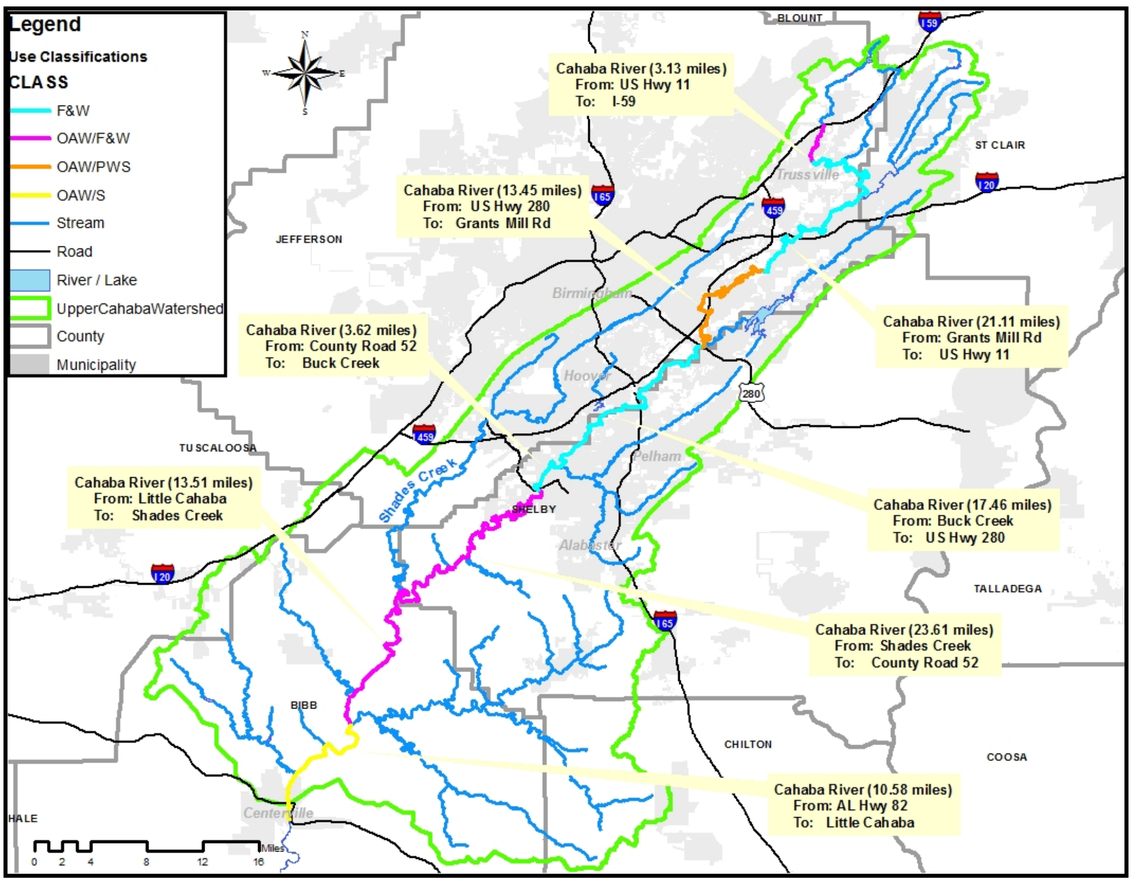

Figure 1. §303(d) Listed Reaches of the Cahaba River

The ADEM is responsible for developing a total maximum daily load (TMDL) for each listed segment and pollutant. The Cahaba River nutrient TMDLs were completed and approved by EPA R4 in September 2006. The siltation TMDLs were drafted and submitted for public comment in October 2003 but were not finalized.

The nutrient TMDL was developed based on a numeric nutrient target (ADEM 2004a) established using a reference condition approach consistent with EPA guidance (EPA 2000). The reference condition approach uses ambient water quality data from minimally-impaired reference streams. Optimally, reference streams should be similar to the study streams in drainage area, gradient, natural substrate and vegetation to serve as examples of physical, chemical, and biological conditions in the absence of impairment. The reference streams are monitored over time to establish a baseline to which other waters can be compared.

In 2004, when the numeric nutrient target was developed, biological, chemical, and physical data from least-impaired rivers supporting viable populations of the ten threatened and endangered species was not available. However, ADEM had established five least-impaired reference streams in the Ridge and Valley ecoregion, where the Cahaba River is located. Streams located within the same ecoregion are expected to have similar climate, landform, soil, natural vegetation, hydrology, and other ecologically relevant factors (Griffith et al. 2001). Water quality data from these least-impaired reference streams were used to develop the target (Appendix A). The numeric nutrient target derived from these data was consistent with EPA's recommendations (Stevenson 2003, ADEM 2006a) and provided a target inherently protective of designated uses because it was based on data from reference reaches that supported designated uses in the reference waters (ADEM 2006a).

The TMDL recommended continued biological and water quality monitoring to provide data that could be used to support an effects-based approach to both refine the Cahaba River nutrient target and to develop nutrient criteria for wadeable streams and rivers statewide. It also recommended identifying and monitoring rivers similar to the Cahaba River in drainage area, gradient, and natural substrate.

In 2004, the ADEM and EPA R4 identified Hatchet Creek, a tributary of the Tallapoosa River, as a potential reference watershed for the Cahaba River. Biological and water quality surveys have found it to be an excellent candidate for ecoregional reference watershed status (ADEM 2000, EARPDC 2000, and O'Neil and Shepard 2005). It is physically similar to the Cahaba River in drainage area, width, depth, and substrate composition (Figures 2 and 3), but located within a different ecoregion. Several studies have found ecoregion (ADEM 2004, Pond et al. 2003, Feminella 2000) and drainage area (Grubaugh et al. 1996, Grubaugh et al. 1997, Flotemersch et al. 2006) to be factors influencing taxonomic composition of macroinvertebrate communities in southeastern rivers and streams.

To help investigate these issues, the ADEM conducted macroinvertebrate bioassessments at six segments of the Cahaba River using Hatchet Creek as a reference watershed in 2004. The objectives of these bioassessments were to assess and document habitat and biological conditions within the Cahaba River Basin. Analysis of the 2004 data supported the use of Hatchet Creek as a reference watershed for Cahaba River. Results of the study suggested impaired biological conditions at all Cahaba River stations. Nutrient tolerant taxa comprised >50% of the total number of organisms collected at two of the six Cahaba River stations. Sediment deposition appeared to contribute to the degraded condition of macroinvertebrate communities at the upstream Cahaba River reaches. (ADEM 2006b)

A similar investigation was conducted in 2005 to provide additional data from the Cahaba River and Hatchet Creek watersheds. Four stations were added within the Hatchet Creek watershed to better characterize the biological communities within this stream system. A station was also established on Shades Creek in the Cahaba River basin to monitor nutrient and sediment inputs from this tributary.

Objectives

Macroinvertebrate community bioassessments were conducted at six segments within the Cahaba River Basin and six segments within the Hatchet Creek watershed. The objectives of these assessments were to:

1. Evaluate the use of Hatchet Creek as a reference watershed for the Cahaba River;
2. Assess the condition of the macroinvertebrate communities in the Cahaba River watershed using ADEM's intensive-level macroinvertebrate bioassessment (MB-I) method; and,
3. Provide baseline macroinvertebrate bioassessment data that can be used to strengthen the existing nutrient and sediment targets for the Cahaba River TMDLs, measure any changes in water quality due to the implementation of these TMDLs, and to monitor the overall health of Cahaba River and Hatchet Creek.

Figure 2. Cahaba River at the "Cahaba Lily" reach (CABB-2A) within the Cahaba River National Wildlife Refuge.

Figure 3. Hatchet Creek at the "Cahaba Lily" reach at HATC-4.

Methods

Sampling locations: Habitat and macroinvertebrate assessments were conducted at six locations on the Cahaba River and six locations on Hatchet Creek (Figure 4). Station descriptions are provided in Table 3. Reach characteristics of each of the twelve stations are summarized in Tables 4a (Cahaba River) and 4b (Hatchet Creek).

Study area: Watershed characteristics of each of the Cahaba River stations are summarized in Table 4a. The Cahaba River drainage encompasses 1,825 mi^2 in central Alabama (Figure 4). It flows approximately 191 miles from western St. Clair County to Dallas County, where it joins the Alabama River. The upper Cahaba, where this study was conducted, is located in the Ridge and Valley (67) Ecoregion; the lower Cahaba flows through the Coastal Plain. The variety of distinct habitats within this river system has produced very diverse macroinvertebrate and fish communities (Harris et al. 1984, Shepard et al. 1994 and Pierson et al. 1989, Graves and Ward 2011). The river is also critical habitat for several rare plant, mollusk, and fish species. Because of this diversity, several segments of the river have been classified as Outstanding Alabama Waters (Figure 4, ADEM 2006b). Since 1996, segments of the river from US Highway 11 in Trussville downstream to Alabama Highway 82 in Centreville have been included on Alabama's Clean Water Act (CWA) §303(d) list of impaired waters for nutrient enrichment, siltation, and other habitat alteration from municipal, urban runoff/storm sewers, and land development (ADEM 2006a).

Watershed characteristics of each of the Hatchet Creek stations are summarized in Table 4b. The Hatchet Creek drainage encompasses 358 mi^2 in Tallapoosa, Clay, and Coosa Counties (Figure 4). It is located in the Southern Inner Piedmont (45a) Ecoregion. Biological surveys conducted within the watershed have found very diverse mollusk and fish communities, as well as several rare or endandered taxa (Bogan and Pierson 1993, DeVries 1998, Mirarchi et al. 2004). The entire watershed was classified as an Outstanding Alabama Water in 2000 (ADEM 2000).

Both the Cahaba River and Hatchet Creek systems have diverse and abundant aquatic plant communities dominated by *Justicia* spp. (Water Willow) and *Podostemum* spp. (River Weed). Both systems have stretches characterized by stands of *Hymenocallis* *coronaria* (Shoal or Cahaba Lily; Figures 2 and 3). O'Neil and Shepard (2005) found the two watersheds to have similar stream flow characteristics. Percent urban area ranged from 2-7% in the Hatchet Creek watersheds and 17-61% in the Cahaba River watersheds.

Evaluation of Hatchet Creek as a reference watershed for Cahaba River: Biological community assessments are routinely used to assess nutrient and sediment impacts in streams. Using macroinvertebrate bioassessments and water quality monitoring helps scientists relate nutrient and sediment concentrations to overall biological community conditions and identify the concentrations at which biological conditions begin to decline. It is therefore important that the macroinvertebrate community of a reference watershed be similar to the macroinvertebrate community in the study area under least-impaired conditions and that the two communities have comparable responses to impairment.

Macroinvertebrate taxa lists were used to compare the similarity of wadeable (≤30 mi^2 and nonwadeable reference reaches (≥60 mi^2) within the Piedmont and Ridge and Valley ecoregions. Currently, ADEM has established seven reference reaches in the Ridge and Valley ecoregion where the Cahaba River is located. The drainage areas for these stations range from 3-23 mi^2. Since nonwadeable reference reaches have only been established in the Piedmont and Southwestern Appalachian ecoregions, the data from seventeen additional wadeable and nonwadeable reference reaches within these ecoregions were also included for comparison. Appendix A lists the ecoregional reference reaches included in these analyses.

The total number of organisms in each taxon was converted into the percentage of total number of organisms collected. The percentages were then square root transformed. Bray-Curtis similarities were calculated. Non-metric multi-dimensional scaling (NMDS) was used to evaluate patterns in macroinvertebrate community composition among reference sites. Within the NMDS plot, each site was identified using Level 3 and 4 ecoregion, wadeablity/drainage area, stream width, substrate, and sampling season to examine how these factors affect similarity among these sites.

The primary goal of these macroinvertebrate assessments is to determine nutrient targets protective of biological community health and water quality. For this purpose, nutrient conditions of a reference watershed must also be similar to those in the study area under least-impaired conditions. Box-and-whisker plots were used to compare the median concentrations of total nitrogen and total phosphorus among wadeable and nonwadeable reference reaches in the Piedmont, Ridge and Valley, and Southwestern Appalachian ecoregions.

Habitat assessments: General observations and a habitat assessment were completed at each site during the 2005 macroinvertebrate assessment. In comparison with reference reaches in the same ecoregion, these data give an indication of the physical conditions at all twelve sites. These data also helped determine the similarity and comparability of the Cahaba River and Hatchet Creek sites and helped evaluate impacts from sedimentation and habitat degradation. All assessments were conducted using ADEM's Standard Operating Procedures and Quality Assurance Manual, Volume II-Freshwater Macroinvertebrate Biological Assessment (ADEM 1999).

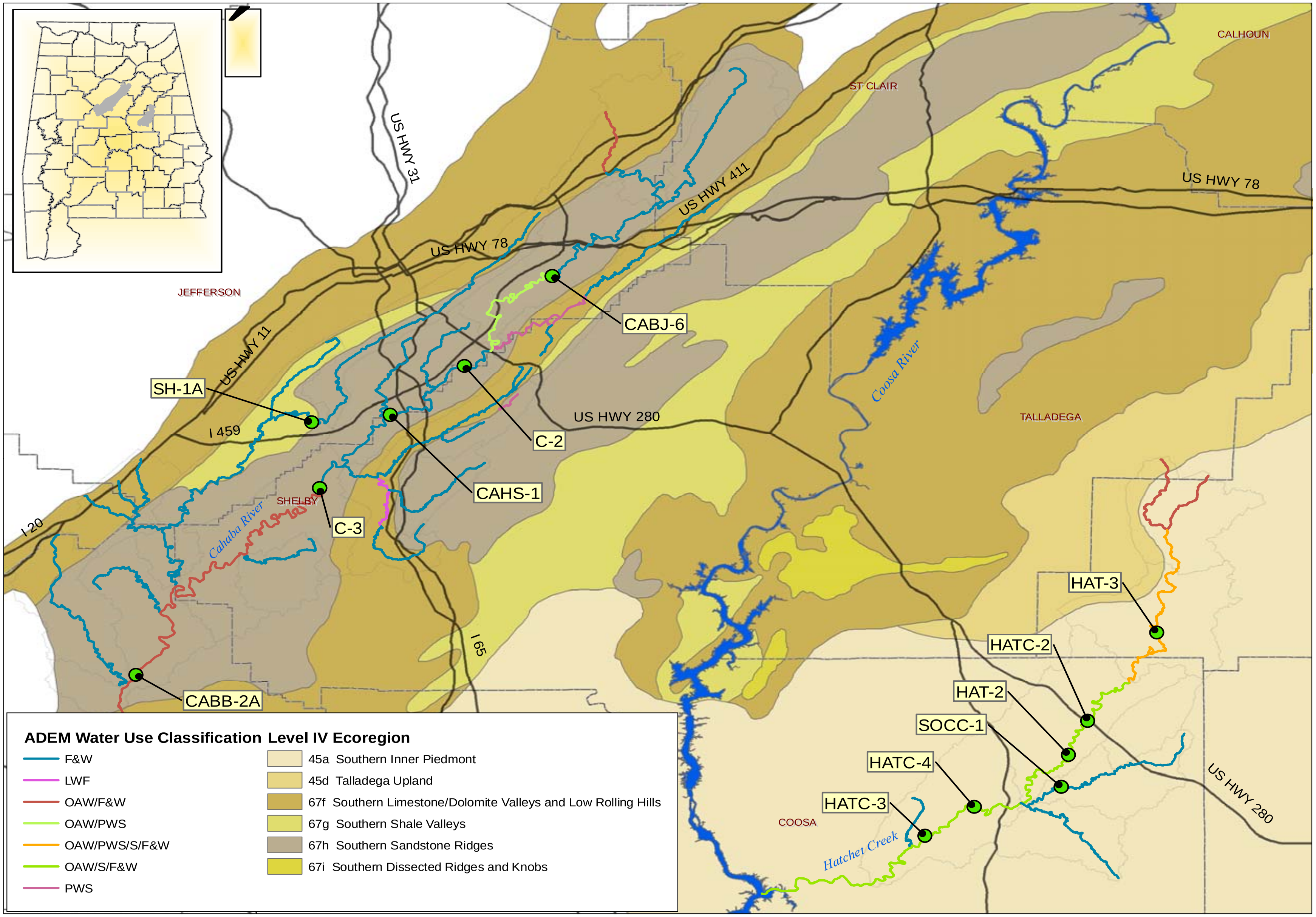

Figure 4. Sampling location, ecoregion, and use classification within the Hatchet Creek and Cahaba River watersheds.

Table 3. Location of ADEM's 2005 biological assessment stations. Other macroinvertebrate and fish[a] community assessments are also listed.

Stream	Station ID	Other studies	County	Station Description	Lat Dec	Lon Dec	11-digit HUC		
Cahaba R	C-2	Howell and Davenport 2001, EPA 2002, O'Neil and Shepard 2005[a]; ADEM 2006a	Shelby	Cahaba River at Shelby County Road 29 (Caldwell Mill Rd) Caldwell Ford Bridge	33.41546	-86.74002	0315	0202	030
Cahaba R	C-3	Howell and Davenport 2001, EPA 2002, Oronato et al. 1998[a], O'Neil 2002[a]; ADEM 2006a	Shelby	Cahaba River at Shelby County Road 52 Bridge west of Helena	33.284	-86.88193	0315	0202	050
Cahaba R	CABB-2A	Howell and Davenport 2001; ADEM 2006a	Bibb	Cahaba River ~ 1 mile d/s of Bibb CR 24 (Piper Bridge) (19N/12E/28)	33.0963	-87.0549	0315	0202	070
Cahaba R	CABJ-6	Oronato et al. 1998[a], O'Neil 2002[a], O'Neil and Shepard 2005[a]; ADEM 2006a	Jefferson	Cahaba River at Grants Mill Road	33.51168	-86.65303	0315	0202	030
Cahaba R	CAHS-1	Howell and Davenport 2001, EPA 2002, Oronato et al. 1998[a], O'Neil 2002[a]; ADEM 2006a	Shelby	Cahaba River at Shelby County Road 175 Bains Bridge (Old Montomery Highway)	33.3635	-86.8132	0315	0202	030
Shades Cr	SH-1A	O'Neil and Shepard 2005[a]	Jefferson	Shades Creek at Jefferson County Road 6 (Parkwood Drive)	33.35527	-86.890556	0315	0202	030
Hatchet Cr	HAT-2	O'Neil and Shepard 2005[a]	Coosa	Hatchet Creek at Dunham Property	32.9998	-86.1425	0315	0107	070
Hatchet Cr	HAT-3	O'Neil and Shepard 2005[a]	Clay	Hatchet Creek at East Mill (County Road 4)	33.1305	-86.055	0315	0107	070
Hatchet Cr	HATC-2		Coosa	Hatchet Creek at US Highway 280	33.03639	-86.12333	0315	0107	070
Hatchet Cr	HATC-3	ADEM 2006a	Coosa	Hatchet Cr. at Tyler Ford (22N/18E/8)	32.9133	-86.28442	0315	0107	130
Hatchet Cr	HATC-4	O'Neil and Shepard 2005[a]; ADEM 2006a	Coosa	Hatchet Cr approx. 4 mi us of Coosa County Road 18 (23N/18E/26)	32.94392	-86.23579	0315	0107	130
Socapatoy Cr	SOCC-1	O'Neil and Shepard 2005[a]	Coosa	Socapatoy Creek at Coosa County Road 30	32.9656	-86.1496	0315	0107	070

a. Ichthyofaunal study

Table 4a. Physical and habitat characteristics of ADEM's 2005 Cahaba River biological assessment stations.

		CABJ-6	C-2	CAHS-1	C-3	CABB-2a	SH-1A
Drainage area (mi^2)		129	201	229	334	594	45
Level IV Ecoregion (Griffith et. al 2001)		67h	67h	67h	67h	67h	67g
2005 Sampling Date (mm/dd)		8/12	10/12	7/5	10/13	7/5	10/13
Percent Landuse (National Land Cover Dataset 2006)							
Forest (Total)		64	59	55	52	56	36
Deciduous		*46*	*43*	*39*	*38*	*36*	*25*
Evergreen		*12*	*11*	*11*	*9*	*15*	*7*
Mixed		*5*	*5*	*5*	*5*	*5*	*4*
Shrub/scrub		3	3	2	2	3	1
Grassland/herbaceous		5	4	4	3	4	1
Open water		1	2	2	1	1	<1
Woody wetland		1	1	1	1	1	<1
Developed (Total)		17	24	29	35	29	61
Open space		*10*	*13*	*16*	*17*	*15*	*27*
Low intensity		*5*	*8*	*10*	*12*	*10*	*22*
Medium intensity		*2*	*3*	*3*	*4*	*3*	*9*
High intensity		*<1*	*<1*	*1*	*1*	*1*	*3*
Barren land (rock/sand/clay)		1	1	1	1	1	<1
Pasture/hay		8	6	6	5	5	1
Cultivated crops		2	1	1	1	1	<1
Population/km (2010 US Census)		92	145	206	253	199	279
Number of NPDES Permits (ADEM 2009)		523	906	1106	1663	2296	241
401 Water Quality Certification		10	14	18	28	40	3
Construction Stormwater		477	813	996	1492	2007	200
Mining		3	5	5	14	48	1
Industrial General		12	27	31	56	90	18
Industrial Individual		1	2	2	3	11	6
Municipal Individual		14	36	44	59	78	9
Underground Injection Control		6	9	10	11	22	4
Physical Characateristics[a]							
Width (ft)		55	20	50	100	550	30
Gradient		M	M	L	M	M	M
Canopy cover[b]		MO	MO	O	O	O	MS
Depth (ft)	Riffle	0.4	0.3		0.5	1.5	0.3
	Run	1.5	0.5	2.0	1.5	2.0	1.0
	Pool	1.0	1.5	3.0	3.0	3.0	1.5
% Habitat	Riffle	20	70		33	35	25
	Run	75	20	20	37	45	50
	Pool	5	10	80	30	20	25
% Substrate	Bedrock	23		3	60	43	3
	Boulder	8	10	15	5	20	2
	Cobble	35	20	5	5	5	8
	Gravel	10	60	25	15	15	35
	Sand	15	5	35	5	15	40
	Silt	3	3	15	7		5
	Clay						
	Organic matter	5	2	2	3	2	7
	Mud/muck	1					
Habitat Assessments[a]							
Form[c]		RR	RR	GP	RR	RR	RR
Habitat survey (% maximum)							
	Instream habitat quality	78	78	65	85	85	70
	Sediment deposition	69	72	61	71	90	61
	Sinuosity	80	83	38	68	80	65
	Bank and vegetative stability	58	59	43	54	83	41
	Riparian measurements	100	75	58	80	81	83
% Maximum		76	70	56	74	85	63
Habitat Assessment		Optimal	Sub-optimal	Marginal	Optimal	Optimal	Sub-optimal

a. Completed during macroinvertebrate assessment

b. Canopy cover: S=shaded; MS=mostly shaded; 50/50=50% shaded; MO=mostly open; O=open

c. Habitat assessment form: RR=riffle/run (Barbour et al. 1999); GP=glide/pool (Barbour et al. 1999)

Table 4b. Physical and habitat characteristics of ADEM's 2005 biological assessment stations.

		HAT-3	HATC-2	HAT-2	HATC-4	HATC-3	SOCC-1
Drainage area (mi^2)		60	117	132	237	268	46
Level IV Ecoregion (Griffith et. al 2001)		45a	45a	45a	45a	45a	45a
2005 Sampling Date (mm/dd)		10/11	10/11	10/11	10/12	10/12	6/23
Percent Landuse (National Land Cover Dataset 2006)							
Forest (Total)		81	77	78	76	77	67
	Deciduous	*52*	*51*	*51*	*48*	*49*	*38*
	Evergreen	*27*	*25*	*25*	*27*	*28*	*28*
	Mixed	*1*	*1*	*1*	*1*	*1*	*1*
Shrub/scrub		3	3	3	4	3	5
Grassland/herbaceous		7	10	9	10	10	12
Open water		<1	<1	<1	<1	<1	<1
Woody wetland		3	3	2	2	2	3
Developed (Total)		2	3	4	4	4	7
	Open space	*2*	*3*	*3*	*4*	*4*	*6*
	Low intensity			*<1*	*<1*	*<1*	*1*
	Medium intensity						*<1*
	High intensity						
Barren land (rock/sand/clay)		<1	<1	<1	<1	<1	<1
Pasture/hay		4	5	4	4	4	5
Cultivated crops		<1			<1		
Population/km (2010 US Census)		3		39	9	8	18
Number of NPDES Permits (ADEM 2009)		4		12	34	37	13
401 Water Quality Certification							
Construction Stormwater		4		8	18	18	6
Mining						3	
Industrial General				1	2	2	
Industrial Individual				3	4	4	
Municipal Individual					4	4	3
Underground Injection Control					6	6	4
Physical Characateristics[a]							
Width (ft)		45	50	83	170	180	65
Gradient		M	M	M	M	M	M
Canopy cover[b]		MO	MO	MO	O	MO	O
Depth (ft)	Riffle	0.7	0.8	1.0	0.6	0.8	1.3
	Run	1.5	1.5	1.4	1.8		1.5
	Pool	3.0	2.5	2.0	3.5	2.0	2.5
% Habitat	Riffle	45	5	50	3	70	40
	Run	20	60	40	50		40
	Pool	35	35	10	47	30	20
% Substrate	Bedrock	10	25	5	30	50	27
	Boulder	10	35	25	2	15	20
	Cobble	25	10	30	1	10	15
	Gravel	35	10	22	10	5	10
	Sand	8	10	10	50	15	25
	Silt	5	5	5	2	2	1
	Clay				2		
	Organic matter	7	5	3	2	3	2
	Mud/muck				1		
Habitat Assessments[a]							
Form[c]		RR	RR	RR	RR	RR	RR
Habitat survey (% maximum)							
	Instream habitat quality	83	78	88	58	86	83
	Sediment deposition	75	71	82	76	80	81
	Sinuosity	83	72	85	75	90	90
	Bank and vegetative stability	70	86	86	69	78	86
	Riparian measurements	90	90	90	90	85	90
% Maximum		80	80	86	89	83	85
Habitat Assessment		Optimal	Optimal	Optimal	Optimal	Optimal	Optimal

a. Completed during macroinvertebrate assessment

b. Canopy cover: S=shaded; MS=mostly shaded; 50/50=50% shaded; MO=mostly open; O=open

c. Habitat assessment form: RR=riffle/run (Barbour et al. 1999); GP=glide/pool (Barbour et al. 1999)

Periphyton assessments: Nutrients indirectly impact macroinvertebrate and fish communities through their effects on primary production, increased plant and algal biomass, and taxonomic composition of periphyton (algae) in streams. Nutrient enrichment negatively impacts macroinvertebrate and fish communities by altering food resources and habitat structure. Attached filamentous algae and excessive bedload sediment are listed as the primary causes of impairment to habitat critical for reproduction and feeding of endangered mussel and fish species.

Periphyton assessments were conducted in accordance with ADEM's 2005 Revised Periphyton Protocol (ADEM 2005a). Periphyton assessments were conducted bi-monthly, April through October at each of the five Cahaba River sites, Shades Creek, and two Hatchet Creek locations (HATC-4 and HATC-3). Periphyton bioassessments were conducted once April-October at the four remaining stations in the Hatchet Creek watershed. Percent of bottom substrates covered by filamentous algae, which causes habitat degradation and habitat smothering, is presented in this report. Observations from 2004, 2006, and 2007 are also presented for comparison.

Macroinvertebrate assessments: All macroinvertebrate samples were collected, processed, and identified in accordance with ADEM's Standard Operating Procedures and Quality Assurance Manual, Volume II-Freshwater Macroinvertebrate Biological Assessment (ADEM 1999). However, assessments were conducted October 11 through October 13, 2005, outside of ADEM's established macroinvertebrate sampling period because of a series of high flow events in July, August, and late September and a statewide halt on non-essential travel during September in the aftermath of Hurricane Katrina (Figure 5). Replicate samples were collected at one station to ensure consistency of sampling methods.

Sampling outside of ADEM's established macroinvertebrate sampling period does not affect the results of this study, which are based on a direct comparison between six study stations and six reference stations sampled during the same week. However, this may prevent direct comparison with the 2004 macroinvertebrate assessment results, as well as with ADEM's established macroinvertebrate indices (ADEM 2009). NMDS plots were used to evaluate the similarity of taxa lists collected at HATC-3 and HATC-4 in spring 2004 and fall 2005. Metric results were also compared.

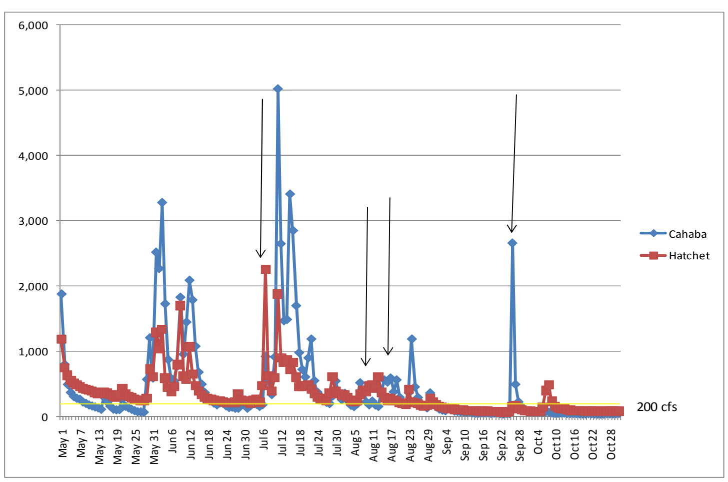

Figure 5. Mean daily flows measured at C-3 and HATC-1, May 1-October 31, 2005 (http://waterdata.usgs.gov/al/nwis/rt). Arrows indicate sampling events scheduled prior to October 11-13.

Results of five metrics are presented in this report. They have been shown to be correlated with indicators of water quality conditions by ADEM (ADEM 2004; Jessup et al. 2008), the Kentucky Dept. of Water (Brumley et al. 2003; Pond et al. 2003), and the Tennessee Dept. of Environment and Conservation (D. Arnwine, personal communication). The metrics include EPT taxa richness, percent non-insect taxa, number of clinger taxa, Beck's Community Tolerance Index, and percent nutrient tolerant taxa. Table 5a provides a definition of each metric and a summary of how each metric was scored.

Final site ratings are based on a modified version of EPA's Biological Condition Scoring Criteria (BCSC; Plafkin et al. 1989) to compare each of the six Cahaba River reaches to the Hatchet Creek stations. The reference condition of metrics that decrease with declining water quality was defined as the 10th percentile of results from the six Hatchet Creek stations; the reference condition of metrics that increase with declining water quality was defined as the 90th percentile of results from the six Hatchet Creek stations (Figure 6). Metric results were also compared to results from eighteen historical bioassessments conducted July through October at eleven riffle-run stream reaches with large drainage areas located in the Ridge and Valley, Piedmont, or Southwestern Appalachian ecoregions (Appendices B-G).

The final BCSC ratings were based on the sum of these scores, with a maximum of 30 points (Table 5b). An excellent rating was defined as the 10th percentile of results from the six Hatchet Creek stations. Good (≥80%), fair (60-79%), poor (40-59%), and very poor (<40%) were defined as a ratio of each station to the 10th percentile of results from the Hatchet Creek sites.

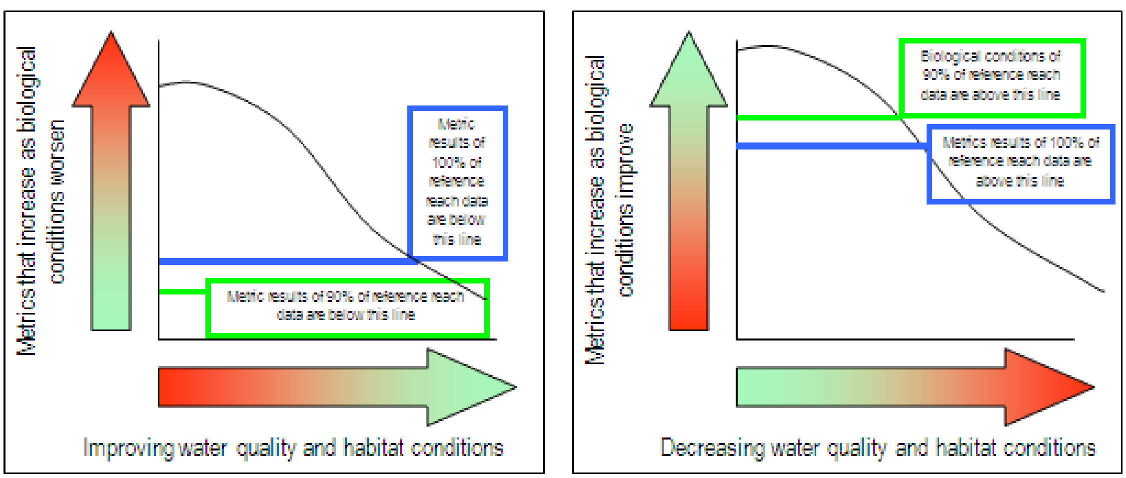

Figure 6. Graphic representation of how reference conditions were calculated for metrics that increase as conditions improve and metrics that increase as conditions degrade. For metrics that increase as conditions degrade, the 90th percentile of metric values is used to define reference conditions. For metrics that increase as biological conditions improve, the 10th percentile of metric values is used to define the value encompassing 90% of all reference reach data and reference conditions.

Table 5a. Interpretation of metrics and scoring criteria used for the 2005 Cahaba River and Hatchet Creek macroinvertebrate bioassessments.

Metrics	Metric Interpretation	Biological Condition Scoring Criteria			
		6	4	2	0
EPT taxa richness	EPT taxa richness (# EPT) is the total number of distinct taxa (genera) within three generally pollution-sensitive orders: Ephemeroptera (E), Plecoptera (P), and Trichoptera (T). This metric generally increases with increasing water quality, but may also increase due to low-level organic enrichment (Lenat 1994).	≥24	19-23	14-18	<14
Becks community tolerance index	Beck's community tolerance index (Becks) is a weighted count of the most sensitive and moderately sensitive taxa (tolerance value ≤3.5) as defined in ADEM (2009). This metric generally decreases as stressors increase.	≥24	16-23	8-15	<8
# Clinger Taxa	Number of taxa designated as "clingers". These taxa remain stationery on stable bottom substrates in flowing water. This metric generally decreases as stressors increase. Although a general metric, results also have been shown to reflect impacts from sedimentation.	≥28	18-27	9-17	<9
Percent non-insect taxa	Percent non-insect taxa is the percent contribution of total taxa that are not insects. This metric generally increases as stressors increase.	≤10.5	10.6-14.3	14.4-17.8	>17.8
Percent nutrient-tolerant taxa	Percent contribution of thirteen taxa generally found to be tolerant of nutrient enriched conditions, including *Baetis* , *Stenacron* , *Cheumatopsyche* , *Chironomus* , *Polypedilum* , *Rheotanytarsus* , *Cricotopus* , *Simulium* , *Psephenus* , *Stenelmis* , *Lirceus* , *Physella* , *Elimia* , Oligochaeta (Brumley et al. 2003). ADEM modified this metric by using percent contribution of the families Baetidae, Simuliidae, and Physidae	≤39	40-60	61-80	>80

Table 5b. Scoring and narrative ratings used for the 2005 Cahaba River and Hatchet Creek macroinvertebrate bioassessments.

Modified BCSC	
Rating	**Score**
Excellent	≥27
Good	22-26
Fair	16-21
Poor	11-16
Very poor	<11

Water chemistry: In situ measurements and water samples were collected monthly during March through October of 2005 to characterize nutrient and sediment conditions at each site and to help identify any potential stressors to the biological communities. Water quality samples for laboratory analysis were collected, preserved, and transported to the ADEM Laboratory as described in ADEM Field Operations Standard Operating Procedures and Quality Control Assurance Manual, Volume I - Physical/Chemical (2000f). Replicate measurements of in situ parameters were taken during ten percent of the sampling events. Replicate samples were collected during five percent of the sampling events.

Individual measurements of dissolved oxygen, temperature, and pH were compared to established criteria for these parameters (Table 6a). For parameters without established criteria, the median concentration measured at each station was compared to the 90th or median (conductivity and hardness) concentration of reference reach data collected in the appropriate ecoregion (Table 6b). Individual turbidity measurements were considered violations of established criteria if the value was >50 NTU above the 90th percentile of reference reach data (Table 6b). Additionally, untransformed water quality data and metric results from the twelve 2005 Cahaba and Hatchet Creek bioassessments and fifteen historical bioassessments conducted at eleven stations were graphed to give a better indication of the nutrient and sediment concentrations affecting biological communities in large, riffle-run streams. Bioassessments conducted at three of the 2005 Cahaba River stations in 1991 were also included in the analyses. A total of 96 graphs showing the relationship between eight macroinvertebrate bioassessment metrics and twelve water quality parameters were created (Table 7). Only graphs that appeared to show a relationship between the biological metric and water quality parameter were included in this report.

Table 6a. Established temperature, dissolved oxygen, and pH water quality criteria for waterbodies within each use classification.

	Established Criteria			
Parameter	**F&W**	**Swimming**	**PWS**	**OAW**
Temperature (^{o}C)	Max temp in streams, lakes, reservoirs in the Tennessee, Cahaba, and Tallapoosa (tailrace of Thurlow Dam to junction of Coosa/Tallapoosa Rivers only) <86^{o}F (<30^{o}C)			
Dissolved Oxygen (mg/L)	5.0			5.5
pH (standard units)	6.0-8.5			

Table 6b. Comparison of the 90th percentile or median concentrations of all reference reach data collected March-November in the Ridge and Valley (67), Piedmont (45) and Southwestern Appalachians (68) ecoregions (Level 3) and subregions (Level 4).

Parameter	Reference condition	Ecoregion					
		Level 4 67h	Level 3 67	Level 4 45a	Level 3 45	Level 4 68e	Level 3 68
Turbidity (NTU)	90th %ile	10.8	7.2	21.7	15.0	9.0	10.1
Total Dissolved Solids (mg/L)	90th %ile	79.4	152.0	67.9	80.0	84.8	97.2
Total Suspended Solids (mg/L)	90th %ile	12.7	11.8	16.0	15.0	10.0	14.0
Conductivity (μmhos)	Median	51.8	219.8	51.6	52.0	106.3	90.7
Hardness (mg/L)	Median	13.4	115.1	14.9	16.7	54.0	50.3
Total Alkalinity (mg/L)	90th %ile	16.4	117.7	21.8	23.0	44.2	42.2
NH_3-N (mg/L)	90th %ile	0.031	0.035	0.008	0.011	0.094	0.101
NO_3+NO_2-N (mg/L)	90th %ile	0.089	0.240	0.124	0.097	0.456	0.619
Total Kjehldahl Nitrogen (mg/L)	90th %ile	0.511	0.583	0.405	0.284	0.660	0.733
Total Nitrogen (mg/L)	90th %ile	0.694	0.711	0.531	0.400	0.918	1.417
Dissolved Reactive Phosphorus (mg/L)	90th %ile	0.016	0.017	0.021	0.024	0.019	0.018
Total Phosphorus (mg/L)	90th %ile	0.043	0.057	0.066	0.060	0.050	0.050
CBOD-5 (mg/L)	90th %ile	2.6	2.3	2.6	2.4	1.9	1.9
Chlorine (mg/L)	90th %ile	3.61	3.89	4.78	4.50	1.05	6.37
Chlorophyll *a* (mg/L)	90th %ile	2.09	2.32	5.02	2.67	2.46	2.67

Table 7. List of macroinvertebrate metrics and water quality parameters graphed to evaluate the relationship between biological and water quality conditions.

Biological metrics	Water quality parameters
EPT taxa richness	Annual median nitrate-nitrite nitrogen (mg/L)
Ephemeroptera taxa richness	Annual median total nitrogen (mg/L)
Plecoptera taxa richness	Annual median total phosphorus (mg/L)
Trichoptera taxa richness	Annual median conductivity (μmhos at 25°C)
Becks community tolerance index	Annual maximum conductivity (μmhos at 25°C)
# Clinger Taxa	Annual median hardness (mg/L)
Percent non-insect taxa	Annual median total dissolved solids (mg/L)
Percent nutrient-tolerant taxa	Annual maximum total dissolved solids (mg/L)
	Annual maximum total suspended solids (mg/L)
	Annual minimum dissolved oxygen (mg/L)
	Annual maximum water temperature (°C)
	Annual maximum turbidity (NTU)

Chain of Custody: To ensure the integrity of all samples collected, sample handling and chain-of-custody procedures outlined in ADEM Field Operations Standard Operating Procedures and Quality Control Assurance Manual, Volumes I and II were used to collect, preserve, and process all biological and chemical samples (ADEM 1999f, ADEM 2000f).

Results

Evaluation of Hatchet Creek as a reference watershed for Cahaba River: The NMDS plots used to evaluate patterns in macroinvertebrate community composition among reference sites are presented in Figures 7a-7d. The NMDS plot showed no difference among samples when categorized by ecoregion (Figure 7a), but showed clear distinctions among samples when stations were categorized by drainage area (Figure 7a) and stream width (Figure 7b). Substrate composition (Figure 7c) may influence macroinvertebrate taxonomic composition.

There also appeared to be a smaller seasonal affect, with samples collected in large watersheds in the spring distinct from samples collected in large watersheds in the fall, even when the samples were collected at the same location (Figure 7d). Although taxa richness measures (EPT taxa richness, number of clinger taxa) were relatively stable, results of other metrics varied between the Spring 2004 and Fall 2005 macroinvertebrate bioassessments (ADEM 2006b). Based on these analyses, further comparisons of the 2004 Hatchet Creek and Cahaba River data collected in the spring and 2005 Hatchet Creek and Cahaba River data collected in the fall were not included in this report.

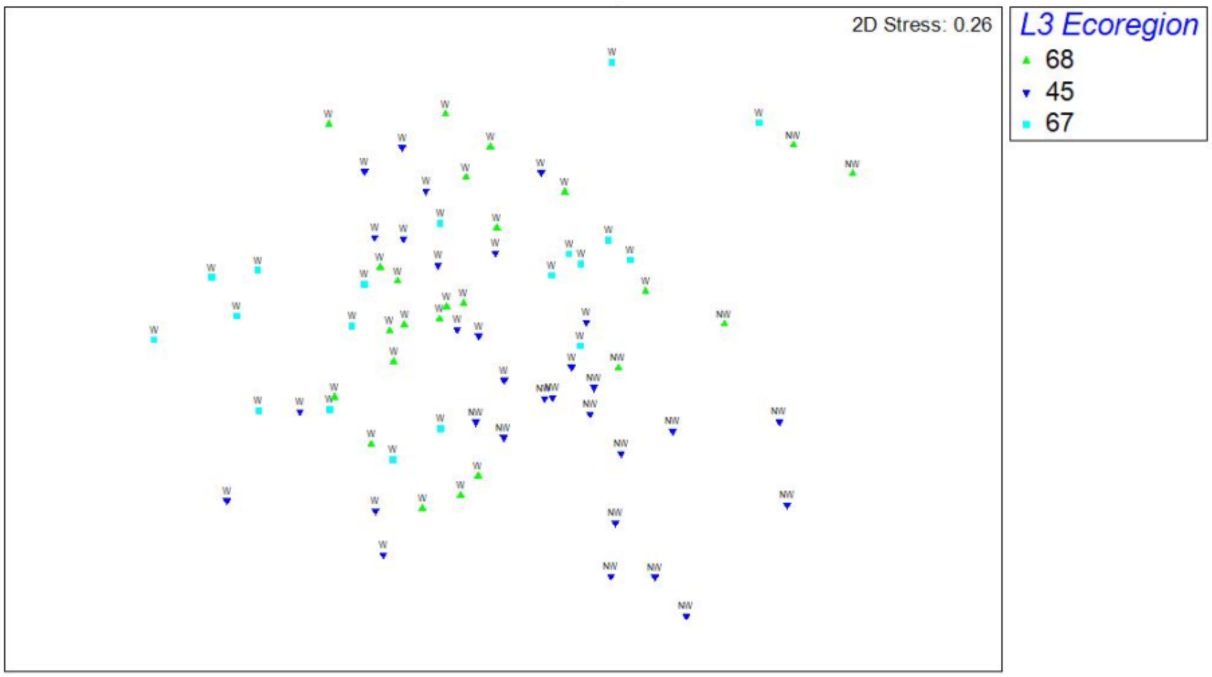

Figure 7a. Non-metric multi-dimensional scaling (NMDS) of wadeable (W; ≤30 mi^2) and nonwadeable (NW; ≥60 mi^2) ecoregional reference reaches in the Piedmont (45; dark blue), Ridge and Valley (67; light blue) and Southwestern Appalachian (68; green) Ecoregions.

Appendices C-G compare metric results from the twelve 2005 Cahaba River and Hatchet Creek sites with eighteen historical bioassessments conducted July through October at eleven large (L) (≥70mi^2), riffle-run stream reaches located in the Ridge and Valley, Piedmont, or Southwestern Appalachian ecoregions. Taxa richness (Appendices C and G) and community tolerance metrics (Appendix E) were highest within the Hatchet Creek stations. Percent non-insect taxa (Appendix D) and percent nutrient tolerant organisms (Appendix F) also showed the six reaches to be in *excellent* or *good* condition. Metric results tended to group sites by watershed conditions, rather than by ecoregion.

Box-and-whisker plots of total phosphorus (TP) concentrations at eighteen reference sites are presented in Figure 8a. TP concentrations were higher within the Hatchet Creek watershed (45L) than any of the other reference reach populations. The median concentration (0.038 mg/L) was similar to the Cahaba River nutrient target, which was based on the 75th percentile of data collected in six smaller ecoregional reference reaches, most located within the Ridge and Valley ecoregion (Appendix A; ADEM 2006a).

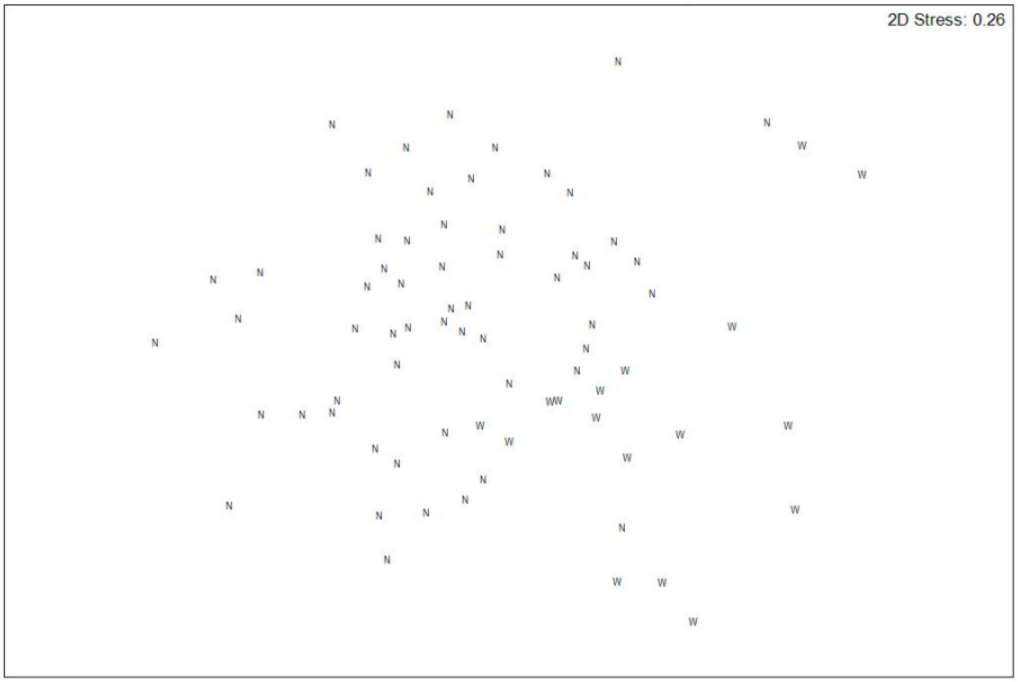

Figure 7b. Non-metric multi-dimensional scaling (NMDS) of ecoregional reference reaches in the Piedmont (45), Ridge and Valley (67) and Southwestern Appalachian Ecoregions plotted by stream width: N=12-38 ft.; W=50-175 ft.

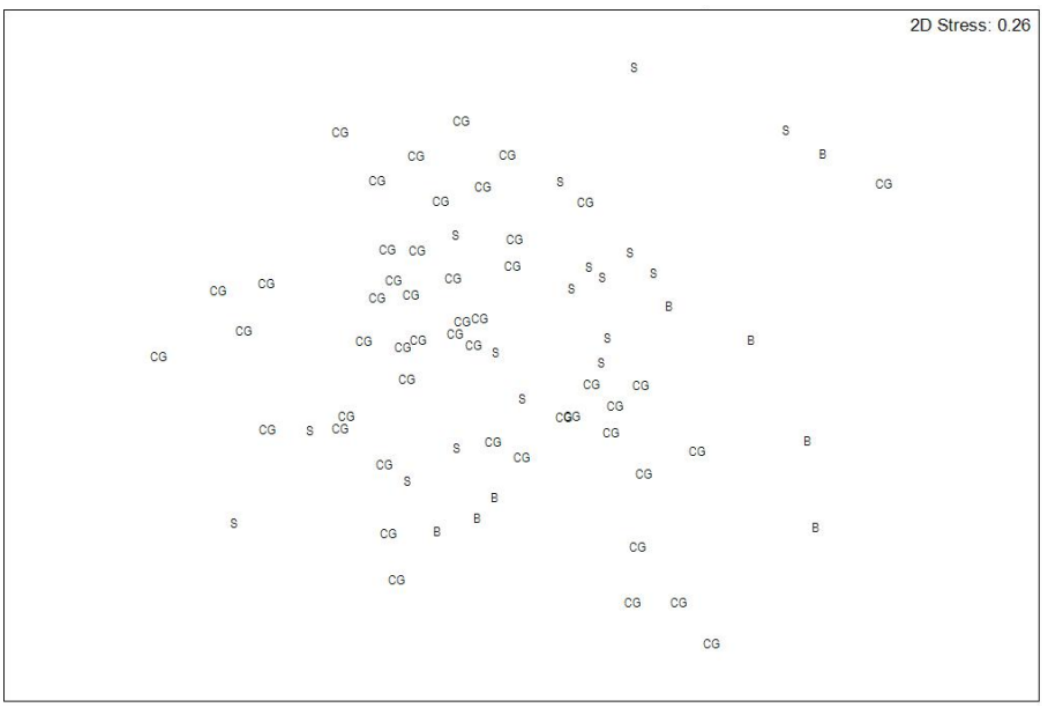

Figure 7c. Non-metric multi-dimensional scaling (NMDS) of ecoregional reference reaches in the Piedmont (45), Ridge and Valley (67) and Southwestern Appalachian Ecoregions plotted by dominant substrate: BE=Bedrock; CG=Cobble/gravel; S=Sand

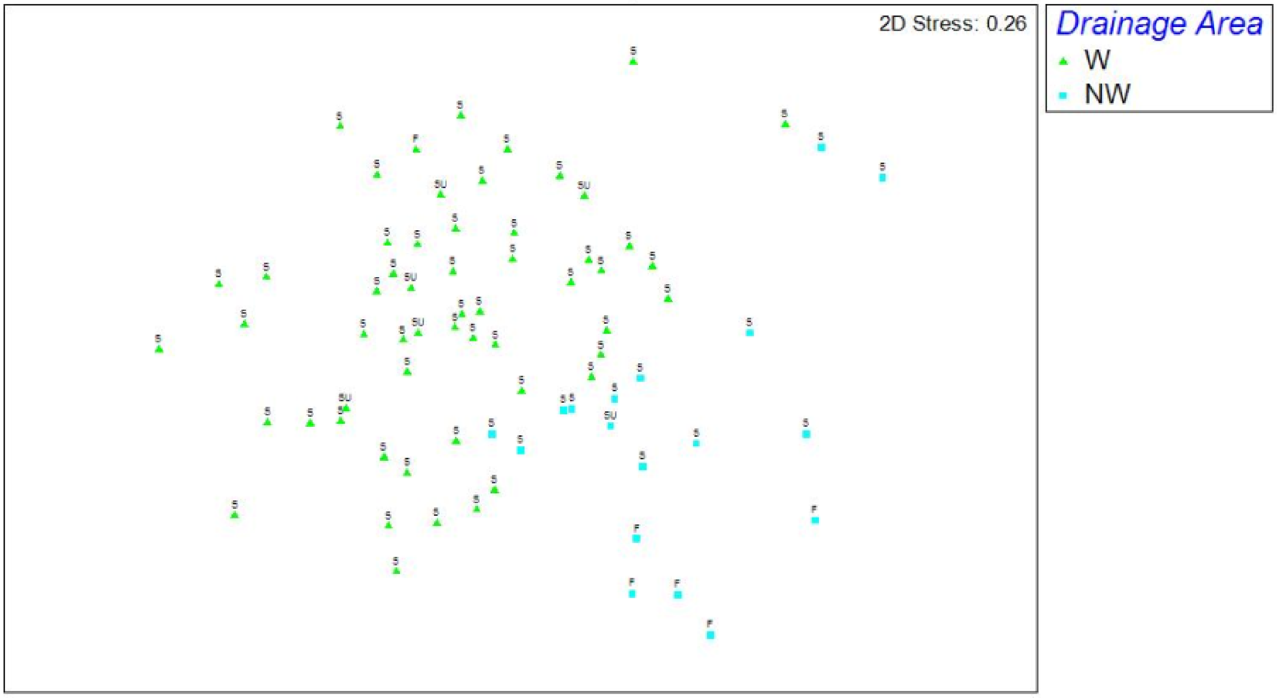

Figure 7d. Non-metric multi-dimensional scaling (NMDS) of wadeable (blue) and nonwadeable (green) ecoregional reference reaches in the Piedmont (45), Ridge and Valley (67) and Southwestern Appalachian Ecoregions plotted by sampling season: S=May/June; SU=July; F=October

TP concentrations were very similar among small (S) (≤60 mi^2) reference reaches in the Ridge and Valley and Piedmont ecoregions. For both the Piedmont and Southwestern Appalachian ecoregions, TP concentrations varied between large and small watersheds within the same ecoregion. The relationship of TP concentrations between large and small watersheds was not consistent, but data collected at large watersheds within the Southwestern Appalachian ecoregions is very limited.

Box-and-whisker plots of total nitrogen (TN) concentrations at eighteen reference sites are presented in Figure 8b. TN concentrations were very similar among reference reaches located in the same ecoregion, regardless of stream size. TN concentrations were lowest in the Piedmont, and highest within the Southwestern Appalachians.

Habitat assessments: Relative habitat assessment results are presented in Tables 4a (Cahaba) and 4b (Hatchet). Percent of maximum habitat assessment scores ranged from 80-89 for the Hatchet Creek stations, indicating optimal habitat conditions at each location. Percent of maximum habitat assessment scores were lower at C-2, CAHS-1, and SH-1A. Instream cover was sub-optimal at HATC-4, due to the high percentages of sand and bedrock substrates and limited riffle habitat. Sediment deposition was rated as sub-optimal at C-2 and marginal at CAHS-1 and SH-1A.

Periphyton bioassessments: Average percent of bottom substrate covered by filamentous algae is presented in Figure 9. These estimates are based on rapid periphyton survey results obtained at each site, April through October 2005. The highest maximum percent filamentous algae was observed in Hatchet Creek. Average percent filamentous cover did not differ between Hatchet Creek and Cahaba River.

Similar results obtained during the 2004, 2006, and 2007 Cahaba River and Hatchet Creek periphyton assessments. Comparison with other ADEM data collected during the same time frame do not show any relationship between percent algal cover and median total phosphorus, median total nitrogen concentrations or average stream flows (Figure 9). However, comparison with USGS gage data from C-3 and a location approximately 0.5 miles upstream of HATC-3 suggest that that periphyton biomass was reduced within Hatchet and Cahaba during high flow events, which are both characterized by high percent bedrock substrate and flashy stream flows. However, peak stream flows were much higher in the Cahaba River than in Hatchet Creek and most likely have scoured substrates clean of filamentous algae. (Appendix H)

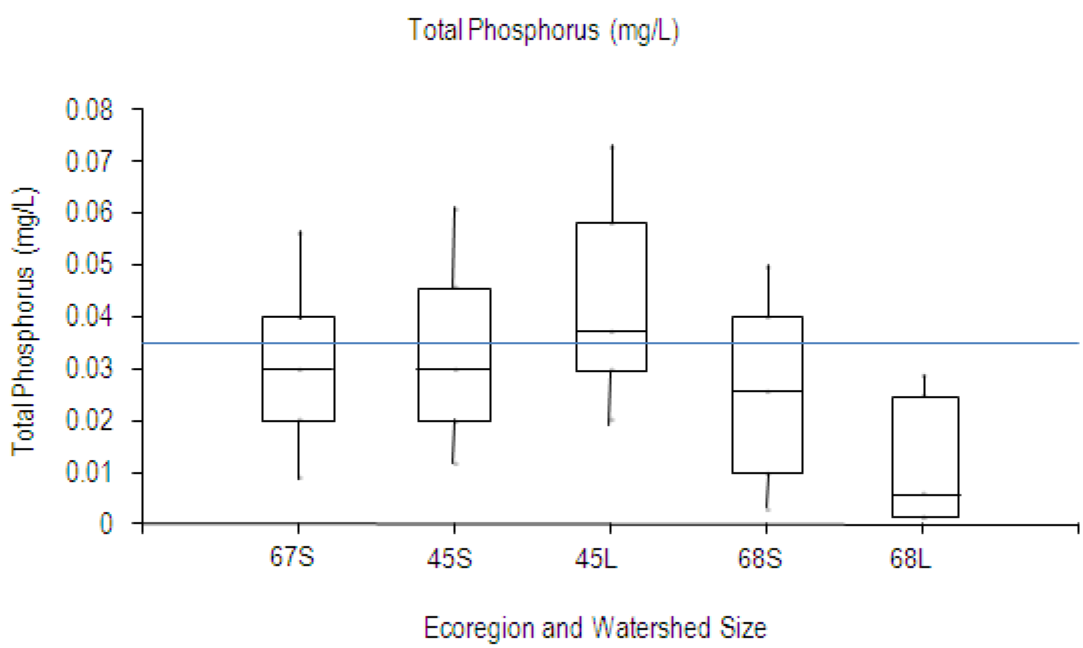

Figure 8a. Comparison of median, 25th, and 75th total phosphorus concentrations in large (L) and small (S) ecoregional reference reaches in the Piedmont (45), Ridge and Valley (67) and Southwestern Appalachians. The tails indicate the 10th and 90th percentiles of reference reach concentrations. The blue line shows the 2006 Cahaba River nutrient target.

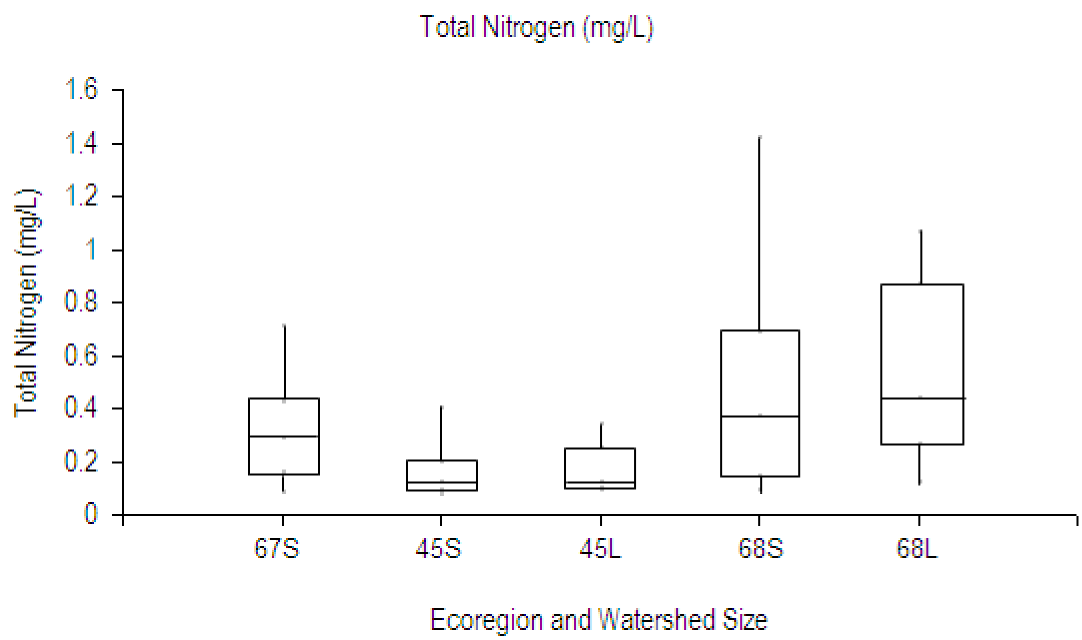

Figure 8b. Comparison of total nitrogen concentrations in large (L) and small (S) ecoregional reference reaches in the Piedmont (45), Ridge and Valley (67) and Southwestern Appalachian Ecoregions.

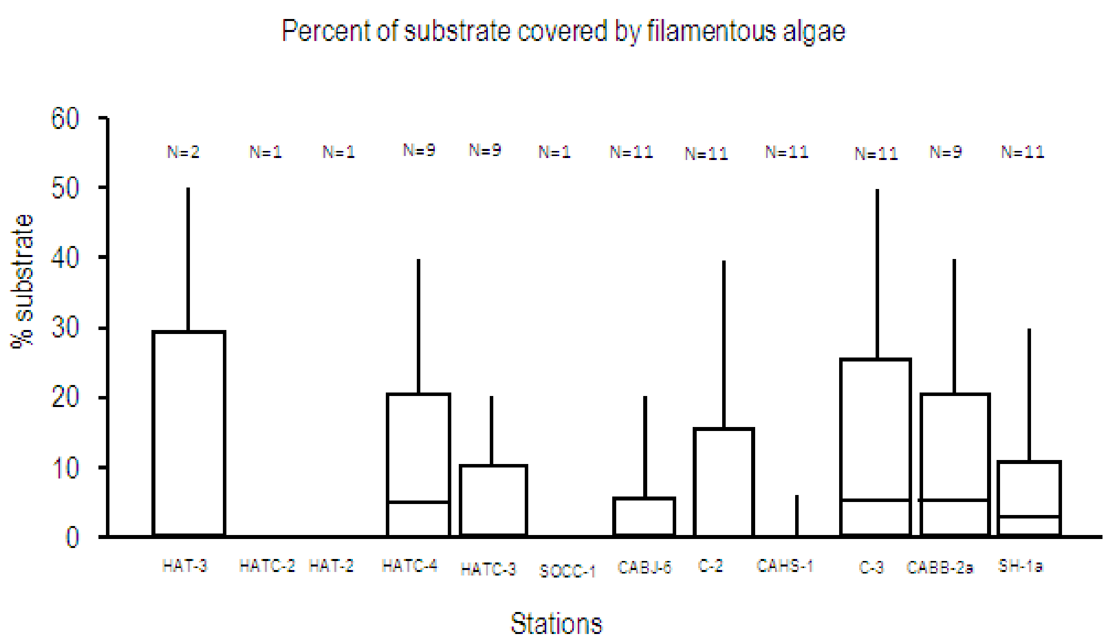

Figure 9. Box-and-whisker plot of the 10^{th}, 25^{th}, median, 75^{th} and 90^{th} percentile of percent filamentous algal cover. Upstream to downstream sampling locations are displayed from left to right.

Macroinvertebrate bioassessments: Taxa collected at the twelve Cahaba River and Hatchet Creek sites are listed in Appendix I. Final site ratings based on the modified BCSC are presented in Figure 10. The macroinvertebrate community at HATC-2 was rated as *good*. The macroinvertebrate communities within all other Hatchet Creek sites were rated as *excellent*. The macroinvertebrate communities at CABJ-6 and C-3 were rated as *fair*, while the macroinvertebrate communities at the remaining Cahaba stations were rated as *poor* or *very poor*.

EPT taxa richness results are presented in Figure 11. This metric ranged from 24 to 31 at Hatchet Creek stations. EPT taxa richness within the Cahaba River stations ranged from 11-20, 46-83% of EPT taxa richness within the Hatchet Creek stations. The number of Trichoptera taxa was consistently lower in the Cahaba River than in Hatchet Creek. Plecopteran taxa were completely absent from all Cahaba River stations.

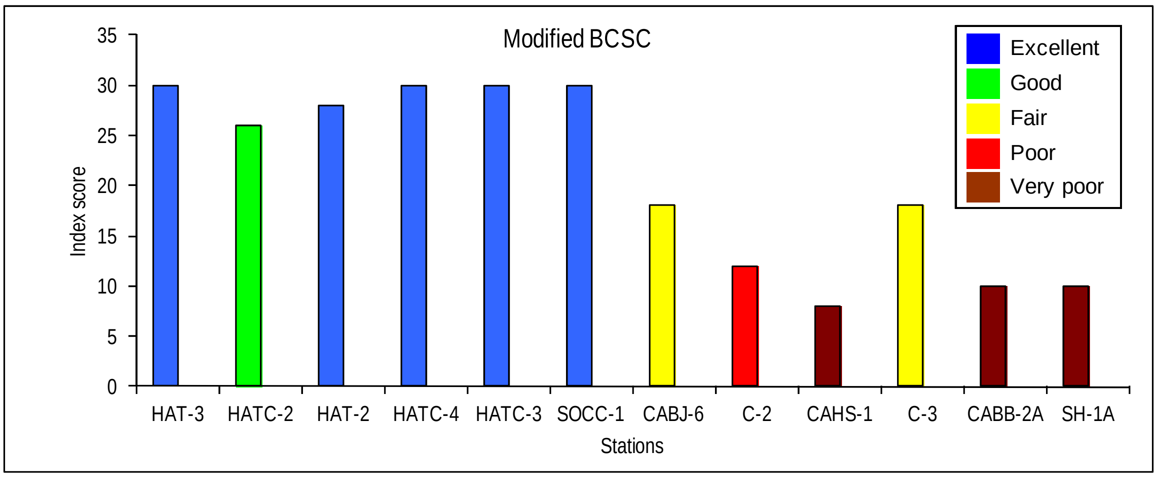

Figure 10. Results of the modified BCSC index. Upstream to downstream sampling locations are displayed from left to right.

Bioassessments were conducted at C-2, C-3, and SH-1A during 1990. Comparison of metric results between the two years indicated an increase in EPT taxa richness from 1990 to 2005 at C-3 and SH-1A. At C-2, EPT taxa richness decreased from 17 in 1990 to 11 in 2005. (Appendix C)

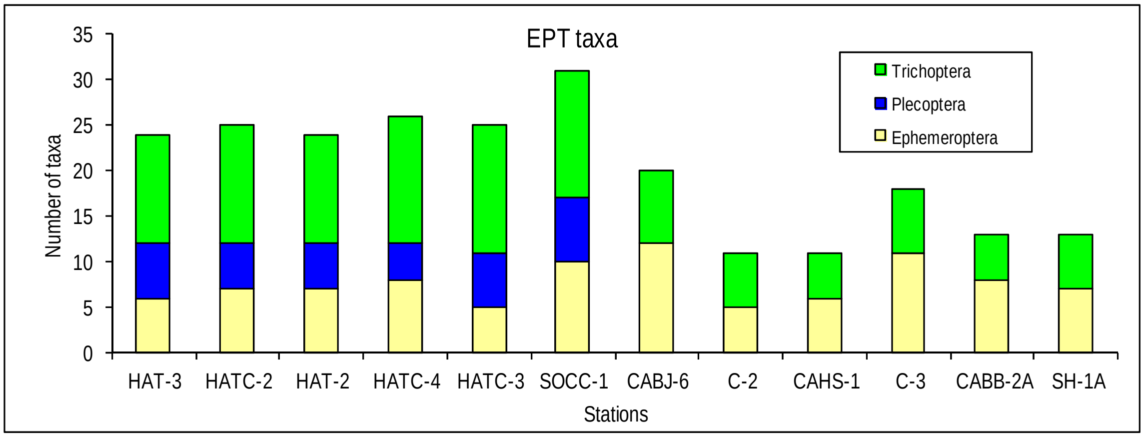

Figure 11. Comparison of Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa richness of macroinvertebrate samples collected from the Hatchet Creek and Cahaba River stations. Upstream to downstream sampling locations are displayed from left to right. Results from tributary stations within each watershed are shown last. ***Metric interpretation***: *EPT taxa richness (# EPT) is the total number of distinct taxa (genera) within three generally pollution-sensitive orders: Ephemeroptera (E), Plecoptera (P), and Trichoptera (T). This metric generally increases with increasing water quality, but may also increase due to low-level organic enrichment (Lenat 1994).*

Percent non-insect taxa ranged from six to ten percent within the Hatchet Creek stations. Percent non-insect taxa results were consistently higher within the Cahaba River stations, ranging from 12 to 17 percent. (Figure 12)

Bioassessments conducted at C-2, C-3, and SH-1A during 1990 and 2005 indicated very consistent results between the two years. However, metric results at all three stations show a small decrease in percent non-insect taxa from 1990 to 2005. (Appendix D)

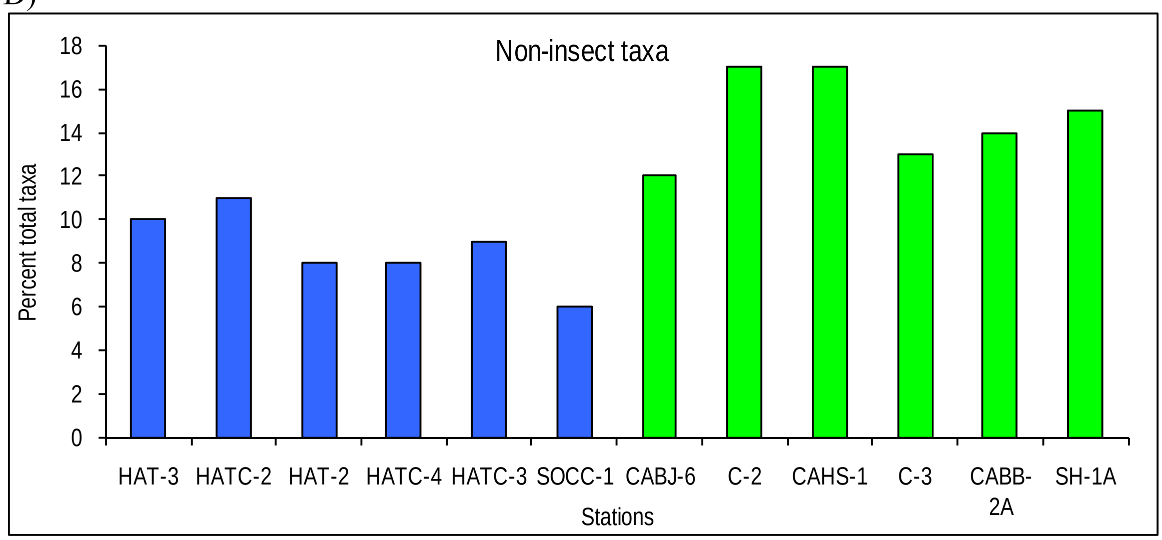

Figure 12. Comparison of percent non-insect taxa collected from the Hatchet Creek (blue) and Cahaba River (green) stations. Upstream to downstream sampling locations are displayed from left to right. Results from tributary stations within each watershed are shown last. ***Metric Interpretation***: *Percent non-insect taxa is the percent contribution of total taxa that are not insects. This metric generally increases as stressors increase.*

Becks community tolerance index ranged from 24 to 28 within the Hatchet Creek stations. Results of this metric were consistently lower for the Cahaba River stations, ranging from three to 13. (Figure 13)

Bioassessments were conducted at C-2, C-3, and SH-1A during 1990. Comparison of metric results between the two years indicated a small increase from 1990 to 2005 at SH-1A. At C-3, Becks community tolerance decreased from 20 in 1990 to 11 in 2005. Results decreased from 16 in 1990 to 10 in 2005 at C-2. (Appendix E)

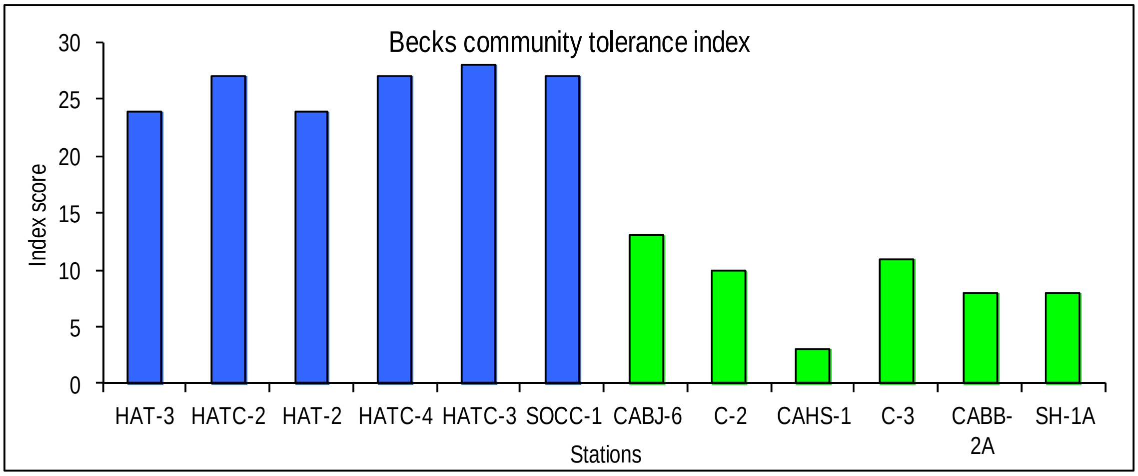

Figure 13. Comparison of Beck's community tolerance index (Becks) of macroinvertebrate samples collected from the Hatchet Creek (blue) and Cahaba River (green) stations. Upstream to downstream sampling locations are displayed from left to right. Results from tributary stations within each watershed are shown last. ***Metric Interpretation***: *Becks is a weighted count of the most sensitive and moderately sensitive taxa (tolerance value ≤3.5) as defined in ADEM (2009). This metric generally decreases as stressors increase.*

Figure 14 summarizes percent nutrient tolerant taxa results. Percent nutrient tolerant taxa ranged from 9 to 37% within the Hatchet Creek stations and 34 to 71% within the Cahaba River stations. Simuliidae, a nutrient-tolerant Dipteran family, comprised 61% of the organisms collected at CABB-2A. *Stenelmis* (Coleoptera: Elmidae) comprised 12% and 22% of the total number of organisms at HAT-3 and HATC-2, respectively. *Cheumatopsyche* (Trichoptera: Hydropsychidae) was also a common nutrient tolerant taxon at HAT-3 (10%) and HATC-2 (14%).

Comparison of metric results between the two years indicated a decrease in percent nutrient tolerant taxa from 1990 to 2005 at C-3 and C-2. At SH-1A, percent nutrient tolerant taxa increased from 34% in 1990 to 45% in 2005, primarily due to an increase in *Stenelmis*. (Appendix F)

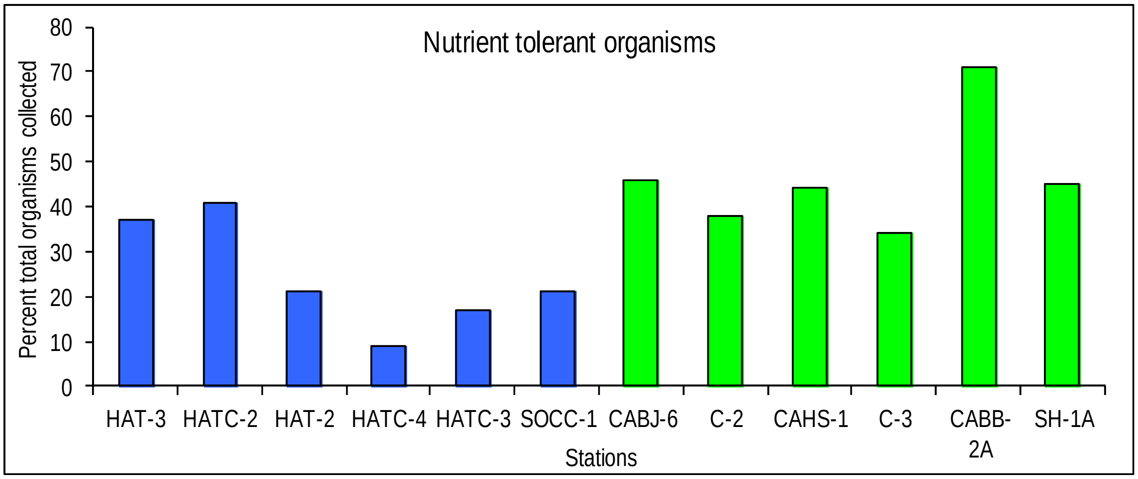

Figure 14. Comparison of percent nutrient tolerant taxa of macroinvertebrate samples collected from the Hatchet Creek (blue) and Cahaba River (green) stations. Upstream to downstream sampling locations are displayed from left to right. Results from tributary stations within each watershed are shown last. ***Metric Interpretation***: *Percent contribution of thirteen taxa generally found to be tolerant of nutrient enriched conditions, including Baetidae, Stenacron, Cheumatopsyche, Chironomus, Polypedilum, Rheotanytarsus, Cricotopus, Simuliidae, Psephenus, Stenelmis, Lirceus, Physidae, Elimia, Oligochaeta. This metric generally increases as nutrient levels increase.*

Results of the number of clinger taxa ranged from 26 at HAT-2 to 36 at SOCC-1 within the Hatchet Creek stations. The number of clinger taxa was lower within the Cahaba River stations, ranging from 13 at CAHS-1 to 21 at CABJ-6. (Figure 15)

Bioassessments conducted at SH-1A during 1990 and 2005 indicated a similar number of clinger taxa between the two years. At C-3, the number of clinger taxa decreased from 25 in 1990 to 19 in 2005. At C-2, the number decreased from 25 in 1990 to 14 in 2005. (Appendix G)

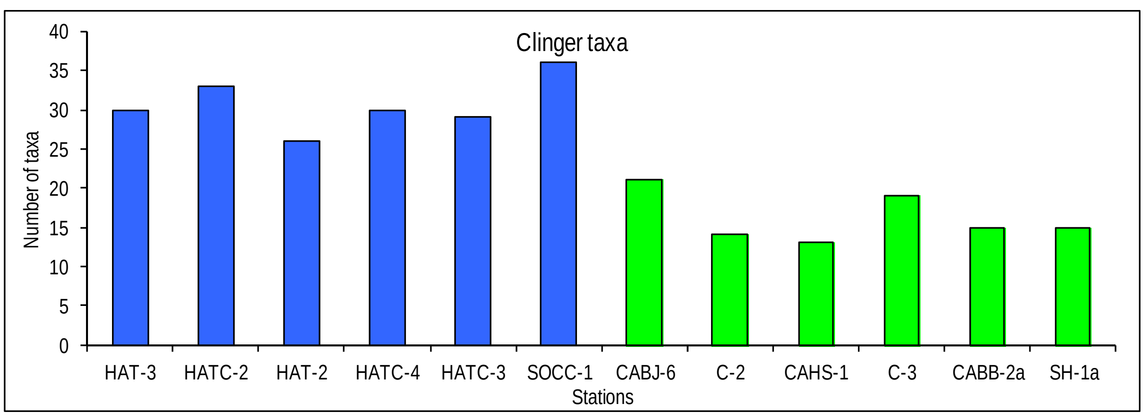

Figure 15. Comparison of the number of clinger taxa collected in samples from the Hatchet Creek (blue) and Cahaba River (green) stations. Upstream to downstream sampling locations are displayed from left to right. Results from tributary stations within each watershed are shown last. ***Metric Interpretation***: *Number of taxa designated as "clingers". These taxa remain stationery on stable bottom substrates in flowing water. This metric generally decreases as stressors increase. Although a general metric, results also have been shown to reflect impacts from sedimentation.*

Water Chemistry: Individual measurements of temperature, pH, dissolved oxygen, and turbidity were compared to established criteria. Table 8 summarizes maximum water temperature, pH, and turbidity measurements and minimum pH and dissolved oxygen concentrations measured at the twelve Cahaba River and Hatchet Creek sites, March through October 2005. The table presents median concentrations of all other parameters for comparison to ADEM's 2010 ecoregional reference guidelines based on data collected at ADEM's reference reaches in the Ridge and Valley and Piedmont ecoregions. Graphs of untransformed water quality data and metric results from the twelve 2005 Cahaba River and Hatchet Creek stations and eighteen historical bioassessments are presented in Appendix J.

NO_3+NO_2-N: Within the Cahaba River basin, median nitrate-nitrite nitrogen (NO_3+NO_2-N) concentrations ranged from 0.238 mg/L at CABJ-6 to 0.716 mg/L at C-3. Median NO_3+NO_2-N concentrations were generally lower within the Hatchet Creek watershed, ranging from 0.046 mg/L at HATC-3 to 0.113 mg/L at SOCC-1. (Table 8)

The number of EPT, Plecoptera, Trichoptera, and clinger taxa and Becks Community Tolerance Index appeared to decrease as median NO_3+NO_2-N concentrations increased. Percent non-insect taxa increased as median NO_3+NO_2-N concentrations increased. Based on graphs of untransformed water quality data and metric results from the twelve 2005 Cahaba River and Hatchet Creek stations and eighteen historical bioassessments, the number of Plecoptera taxa and percent non-insect taxa showed a decline in biological conditions at a median NO_3+NO_2-N concentration of 0.16 mg/L. This concentration is most similar to the Piedmont ecoregional reference guideline. Results for EPT taxa richness, number of Trichoptera taxa, number of clinger taxa, and Becks community tolerance index indicated declining conditions at 0.238 mg/L, very similar to the Ridge and Valley ecoregional reference guideline. (Appendix J)

TN: Median total nitrogen (TN) concentrations ranged from 0.412 mg/L at CABJ-6 to 1.086 mg/L at C-3 in the Cahaba River basin; within the Hatchet Creek watershed, median concentrations ranged from 0.142 mg/L at HATC-2 to 0.506 mg/L at HATC-4. (Table 8)

EPT taxa richness, Plecoptera taxa richness, and Trichoptera taxa richness and Becks Community Tolerance Index appeared to decrease as median TN concentrations increased. Based on graphs of untransformed water quality data and metric results from the twelve 2005 Cahaba River and Hatchet Creek stations and eighteen historical bioassessments, the median TN concentration at which biological conditions declined ranged from 0.303 mg/L - 0.398 mg/L, most similar to the Piedmont ecoregional reference guideline. (Appendix J)

TP: Median total phosphorus (TP) concentrations ranged from 0.050 mg/L at CABJ-6, CABB-2a, and SH-1a to 0.206 mg/L at C-3 in the Cahaba River basin; within the Hatchet Creek watershed, median concentrations ranged from 0.030 mg/L at HATC-2 to 0.111 mg/L at HATC-4. (Table 8)

Several measures of taxa richness, community composition, and community tolerance appeared to respond to increased median TP concentrations. Based on graphs of untransformed water quality data and metric results from the twelve 2005 Cahaba River and Hatchet Creek stations and eighteen historical bioassessments, the median concentration at which metric results indicated declining biological conditions ranged from 0.05-0.06 mg/L. This range is consistent with the reference guidelines for the Piedmont, Ridge and Valley, and Southwestern Appalachian ecoregions, but slightly higher than the 2004 total phosphorus nutrient target of 35 μg/L developed for the Cahaba River. (Appendix J)

Chl a: Within the Cahaba River basin, water column chlorophyll *a* ranged from 1.6 mg/L at CAHS-1 to 3.80 mg/L at CABB-2a. Water column chlorophyll a concentrations were more variable within Hatchet Creek, ranging from 0.53 mg/L at HATC-3 to 4.27 mg/L at HATC-4. The ecoregional reference guideline for chlorophyll *a* was also almost double for Piedmont streams as compared to Ridge and Valley streams. (Table 8)

Conductivity: Median conductivity within the Cahaba River basin ranged from 197.4 μmhos at $25^{o}C$ at CABJ-6 to 257.1 μmhos at $25^{o}C$ at SH-1a; within the Hatchet Creek watershed, median concentrations ranged from 34.5 μmhos at $25^{o}C$ at HATC-2 to 47.5 μmhos at $25^{o}C$ at HATC-4. (Table 8)

Several measures of taxa richness, community composition, and community tolerance appeared to respond to increased median conductivity. The median concentration at which metric results indicated declining biological conditions was consistently between 46 and 80 μmhos at $25^{o}C$ (Appendix J). This is comparable to the ecoregional reference guideline for Piedmont streams, and lower than the Ridge and Valley guidelines (Table 8).

Hardness: Median hardness concentrations within the Cahaba River basin ranged from 59.7 mg/L at CABJ-6 to 108.0 mg/L at C-3; within the Hatchet Creek watershed, median concentrations ranged from 11.1 mg/L at HATC-3 to 18.3 mg/L at SOCC-1. (Table 8)
Several measures of taxa richness, community composition, and community tolerance appeared to respond to increased median hardness concentrations. The median concentration at which metric results indicated declining biological conditions varied. Plecoptera taxa richness, percent non-insect taxa, and percent nutrient tolerant individuals declined when median hardness concentrations reached between 38-60 mg/L. EPT taxa richness, Trichoptera taxa richness, number of clinger taxa, and Becks community tolerance index appeared to decline at lower median hardness concentrations (13-33 mg/L). (Appendix J)

TDS: Median total dissolved solids (TDS) concentrations within the Cahaba River basin ranged from 111.0 mg/L at CABJ-6 to 173.0 mg/L at SH-1a; within the Hatchet Creek watershed, median concentrations ranged from 33.0 mg/L at HATC-3 to 70.0 mg/L at SOCC-1. (Table 8)

Several measures of taxa richness, community composition, and community tolerance appeared to respond to increased median TDS concentrations. The median concentration at which metric results indicated declining biological conditions was consistently between 60-80 mg/L. Number of clinger taxa, percent non-insect taxa, and percent nutrient tolerant organisms also responded to increased maximum TDS concentrations, with both percent non-insect taxa and percent nutrient tolerant organisms indicating declining biological conditions at maximum TDS concentrations between 137-169 mg/L and number of clinger taxa decreasing at maximum TDS concentrations between 70-137 mg/L. (Appendix J).

TSS: Median concentrations of total suspended solids (TSS) within the Cahaba River basin ranged from 6.0 mg/L to 17.5 mg/L. Median TSS concentrations were similar within the Hatchet Creek sites.

Table 8. Results of water quality sampling conducted at the twelve Cahaba River and Hatchet Creek stations during 2005. Concentrations within the Cahaba River basin that were higher than the Level 3 Ridge and Valley (67) guidelines based on the 90th percentile of all ecoregional reference reach data are shown in yellow. Concentrations within the Hatchet Creek watershed that were higher than the Level 3 Piedmont (45) ecoregional guidelines based on the 90th percentile of all ecoregional reference

			Ridge and Valley (67) Ecoregion									Piedmont (45) Ecoregion							
					Cahaba River Stations								Hatchet Creek Stations					
Parameters	Basis of comparison	Result to compare	75th Ecoregional Reference Guideline	90th Ecoregional Reference Guideline	CABJ-6	C-2	CAHS-1	C-3	CABB-2A	SH-1A	75th Ecoregional Reference Guideline	90th Ecoregional Reference Guideline	HAT-3	HATC-2	HAT-2	HATC-4	HATC-3	SOCC-1
Water temperature (oC)	WQC	Maximum			30.0	30.0	29.0	29.0	30.0	29.0			26.0	25.0	26.0	28.0	28.0	27.0
Dissolved Oxygen (mg/L)	WQC	Minimum			7.5	6.3	6.1	6.6	6.8	6.2			7.0	8.2	8.0	6.8	7.3	7.8
pH (su)	WQC	Minimum			6.9	6.9	6.9	7.0	7.5	7.1			6.7	6.9	7.0	6.2	6.2	6.8
pH (su)	WQC	Maximum			8.2	8.0	7.9	8.0	8.6	8.3			7.6	7.7	7.9	8.3	8.1	8.1
Turbidity (ntu)	90th %ile	Maximum	5.0	7.2	17.5	55.5	55.7	290.0	87.1	43.6	6.4	15.0	25.5	22.6	34.8	350.0	48.2	54.1
Total Dissolved Solids (mg/L)	90th %ile	Median	124.0	152.0	111.0	136.0	138.0	161.5	146.0	173.0	56.0	80.0	42.0	34.0	39.5	69.0	33.0	70.0
Total Suspended Solids (mg/L)	90th %ile	Median	8.0	11.8	8.0	9.0	17.0	15.0	17.5	6.0	9.0	15.0	11.0	9.0	12.0	14.0	8.0	11.0
Conductivity (µmhos at 25°C)	Median	Median	209.1	219.8	197.4	218.2	242.2	256.3	198.4	257.1	46.2	52.0	38.1	34.5	38.2	47.5	41.8	45.2
Hardness (mg/L)	Median	Median	98.9	115.1	59.7	81.8	90.2	108.0	74.4	100.4	13.5	16.7	10.8	13.2	12.8	14.4	11.1	18.3
Total Alkalinity (mg/L)	90th %ile	Median	107.9	117.7	57.5	75.5	84.2	106.5	87.8	97.7	15.7	23.0	9.9	8.4	10.4	16.1	9.7	16.7
NH3-N (mg/L)	90th %ile	Median	0.008	0.035	0.008	0.008	0.008	0.008	0.008	0.008	0.007	0.011	0.008	0.008	0.008	0.021	0.015	0.008
NO_3+NO_2-N (mg/L)	90th %ile	Median	0.167	0.240	0.238	0.386	0.516	0.716	0.302	0.376	0.064	0.097	0.065	0.067	0.050	0.095	0.046	0.113
Total Kjehldahl Nitrogen (mg/L)	90th %ile	Median	0.317	0.583	0.188	0.308	0.412	0.262	0.283	0.237	0.075	0.284	0.075	0.075	0.206	0.450	0.075	0.191
Total Nitrogen (mg/L)	90th %ile	Median	0.421	0.711	0.412	0.801	0.986	1.086	0.605	0.576	0.193	0.400	0.148	0.142	0.260	0.506	0.193	0.436
Dissolved Reactive Phosphorus (mg/L)	90th %ile	Median	0.013	0.017	0.014	0.070	0.124	0.105	0.018	0.010	0.017	0.024	0.004	0.006	0.004	0.007	0.002	0.014
Total Phosphorus (mg/L)	90th %ile	Median	0.040	0.057	0.050	0.082	0.156	0.206	0.050	0.050	0.040	0.060	0.041	0.030	0.036	0.111	0.054	0.072
CBOD-5 (mg/L)	90th %ile	Median	1.4	2.3	0.4	0.8	0.6	0.6	0.5	0.5	2.0	2.4	1.4	1.0	1.6	2.2	0.5	1.7
Chlorophyll *a* (µg/L)	90th %ile	Median	1.40	2.32	2.94	3.47	1.60	2.24	3.80	2.40	1.60	2.67	2.14	0.71	3.020	4.270	0.53	1.60

There did not appear to be a relationship between macroinvertebrate metric results and TSS. However, sampling could not be conducted during high flow events when TSS would be most elevated.

Turbidity: Maximum turbidity concentrations within the Cahaba River basin ranged from 17.5 NTU at CABJ-6 to 290.0 NTU at C-3; within the Hatchet Creek watershed, median concentrations ranged from 34.5 µmhos at 25^{o}C at HATC-2 to 47.5 µmhos at 25^{o}C at HATC-4. Turbidity exceeded ecoregion-specific criteria at C-3 and CABB-2a during high-flows on March 23, 2005. High turbidities were also measured during high flows at CABB-2a on September 28, 2005 and HATC-4 on June 28, 2005. (Table 8)

There did not appear to be a relationship between macroinvertebrate metric results and turbidity. However, sampling could not be conducted during high flow events when turbidity would be most elevated.

Discussion

The 2004 Cahaba River nutrient target was developed using data from six of ADEM's least-impaired ecoregional reference reaches (ADEM 2006a). Data from five of these sites were used because they are located within the same ecoregion as the Cahaba River, and are therefore characterized by similar landform, hydrology, and natural vegetation, that in turn, shape the chemical, physical, and biological conditions of streams and rivers in the absence of impairment. Although these data represented the best available reference dataset for the Cahaba River at the time, the ADEM recognized that the chemical, physical, and biological conditions of large rivers and small streams are affected as much by their drainage areas, widths, and depths as they are by their climate, soils, and other regional characteristics, and began sampling Hatchet Creek as a potential reference watershed for the Cahaba River and other large, nonwadeable rivers and streams.

Analysis of the 2005 macroinvertebrate data presented in this report showed macroinvertebrate communities to be more similar among streams and rivers in the same size class than among streams and rivers in the same ecoregion, supporting ADEM's use of Hatchet Creek as a reference watershed for nonwadeable streams and rivers. Similarly, analysis of data from more than 500 fish community bioassessments collected statewide, 2005-2012, indicated the Piedmont and Ridge and Valley ecoregions to constitute one ichthyofaunal region, characterized by fish communities with similar species richness and diversity, and community structure and function (O'Neil and Shepard 2007). Additionally, Hatchet Creek and the Upper Cahaba River have both recently been designated as Strategic Habitat Units (SHUs) by the U.S. Fish and Wildlife Service, the Geological Survey of Alabama, and the Department of Conservation and Natural Resources (Wynn et al. 2012), supporting five of the same endangered fish and mussel species.

Results of the 2005 water quality sampling showed nutrient concentrations to be elevated at SOCC-1 and HATC-4. The elevated concentrations at SOCC-1 are likely caused by the Goodwater Lagoon wastewater treatment plant discharge, which is approximately 12.3 mi upstream of the site (ADEM 2012). Nutrient concentrations at HATC-4 are also elevated in comparison to ADEM's established ecoregional guidelines, as well as to the other monitoring locations on Hatchet Creek. Monitoring should continue to identify the source(s) of these elevated concentrations.

Several previous studies have documented degraded biological conditions within the

Cahaba River basin (Baldwin 1973, Pierson 1991, Shepard et al. 1997, Oronato et al. 1998, Oronato et al. 2000, EPA 2002, O'Neil 2002). Based on comparison with Hatchet Creek, the macroinvertebrate communities were in *fair* condition at CABJ-1 and C-3 and *poor* or *very poor* condition at all other Cahaba stations. Despite the different index period, these results are consistent with the 2004 Cahaba River bioassessment results, with conditions at CABJ-6 and C-3 rated as *fair*, and C-2 and CAHS-1 rated as *poor* or *very poor*. The rating of biological conditions at CABB-2a changed from *fair* in 2004 to *very poor* in 2005, due to the very high percent nutrient tolerant organisms, and relatively low number of EPT and clinger taxa. Additional sampling should be conducted to verify biological conditions at this location.

Plecopteran taxa, a pollution intolerant order of aquatic insects, was completely absent from all Cahaba River stations in both ADEM's Spring 2004 and Fall 2005 collections. Plecoptera were also entirely absent from bioassessments conducted within the river by Samford University in 2001 (Howell and Devenport 2001) and EPA in 2002 (EPA 2002). By contrast, Graves and Ward (2011) collected four hundred and twenty-one adult stoneflies in 18 species, 10 genera, and four families from seven locations along the mainstem of the river, from Trussville to Suttle (155 miles).

This discrepancy is due at least in part to the condition of the locations sampled during the survey conducted by Graves and Ward (2011) and ADEM's 2005 Cahaba River bioassessments. Graves and Ward (2011) selected sites sampled during previous intensive biodiversity studies of the Cahaba River to maximize mayfly and stonefly diversity. They did not sample the suburbanized portions of the river near Birmingham, where most of ADEM's sites were located.

However, Graves and Ward (2011) did collect adult plecopterans of nine species, six genera, and three families at West Blocton, which was sampled by ADEM in 2005 (CABB-2a). Additionally, they collected one species, *Perlesta decipiens* (Walsh) at Whites Chapel, which ADEM sampled in July 1992, July 1993, June 2004, and May 2007 using ADEM's WMB-I multi-habitat assessment method. No plecopteran taxa were collected during any of ADEM's bioassessments.

These results suggest that the higher plecopteran taxa richness observed by Graves and Ward (2011) also reflects differences in level of effort between biological assessment methods and intensive taxonomic surveys. Ward and Williams (2011) collected adult specimens during thirty-five separate sampling dates, April-October 2004 and March-May 2005, using four different methods: light-trapping, sweep-netting, rearing, and hand-picking. These methods and sampling frequency were selected to provide a complete inventory of the Ephemeroptera and Plecoptera taxa of the Cahaba River. ADEM's WMB-I multi-habitat assessment method standardizes both the area sampled and the number of organisms identified so that metric results from different locations and sampling dates, etc. can be compared.

Although less extensive, comparison of bioassessment results from Cahaba River to Hatchet Creek, and other least-impaired reference reaches suggest that standardized bioassessment methods are rigorous enough to adequately and accurately assess biological conditions in the Cahaba River. While no plecopteran taxa were collected within any of the Cahaba River stations, plecopteran taxa richness ranged from four to six in the Hatchet Creek stations using the same bioassessment collection methods during both Spring 2004 and Fall 2005.

Similar bioassessment methods have also been used by the Tennessee Department of Environment and Conservation to establish the only least-impaired, large (502 mi^2) reference site (TN-LRR) within the entire Ridge and Valley (67) ecoregion. Observations made by Tennessee since 2000 show TN-LRR to be a riffle-run reach characterized by boulder, cobble, and gravel substrates and pools varying in depth from one to four feet, similar to the Cahaba River and Hatchet Creek. Quarterly temperature data collected 2004 through 2006 indicate TN-LRR to be cooler than temperatures at both C-3 and HATC-3. Conductivity measured quarterly at TN-LRR during the same time frame was much higher than those measured at the two Alabama sites. (Table 16b).

Plecopteran taxa were collected in five (83%) of the six bioassessments conducted at TN-LRR by TDEC during the fall (October-November) index period and in four (100%) of four bioassessments conducted during the spring (March-May). As many as five plecopteran families were collected in both the spring and fall, very comparable to plecopteran taxa richness in Alabama's nonwadeable Piedmont reference reaches.

The Cahaba River is listed as impaired by nutrients and sedimentation due to the indirect effects of attached filamentous algae and excessive bed load sedimentation covering stream substrates and filling the interstitial spaces critical for reproduction and feeding. However, average percent of bottom substrate covered by filamentous algae showed no clear distinction between the Hatchet Creek and Cahaba River sites. Percent of bottom substrate covered by filamentous algae was very variable within both systems and similar to results obtained by EPA in the spring and summer of 2002 (EPA 2002). Comparison with USGS gage data suggest that the extremely high peak stream flows in the Cahaba River scour substrates clean of filamentous algae.

Although preliminary, diatom community assessment results showed distinct differences between Cahaba River and Hatchet Creek (Stevenson, unpublished data; Appendix K). Autoecological information has been reported for many diatom species. Species optima and tolerances to several environmental conditions have been developed using abundance and environmental data from every location where a species is found. Based on the 2004 and some 2005 data, results showed the diatom communities within the Cahaba River to be characterized by species tolerant of nutrient enriched conditions and low dissolved oxygen. Results of four metrics showed positive relationships between these factors and percent developed land within the watershed of each site (Appendix K). The remaining 2005-2007 samples should be analyzed to evaluate how accurately and consistently diatom community assessments assess nutrient enrichment in urban streams.

A similar approach was used in Appendix J to help visualize the effect of stressors on several measures of taxa richness, community composition, and community tolerance. The graphs compare water quality data from the twelve 2005 Cahaba River and Hatchet Creek bioassessments and fifteen historical bioassessments conducted between July and October at eleven large, riffle-run streams located within the Piedmont, Ridge and Valley, and Southwestern Appalachians ecoregions.

These graphs showed several measures of taxa richness, community composition, and community tolerance that appeared to respond to increased median TP concentrations. The median concentration at which metric results indicated declining biological conditions ranged from 0.05-0.06 mg/L. This range is consistent with the reference guidelines for the Piedmont, Ridge and Valley, and Southwestern Appalachian ecoregions, but slightly higher than the 2004 total phosphorus nutrient target of 0.035

mg/L developed for the Cahaba River and the corresponding total phosphorus nutrient criteria of 0.040 mg/L established by EPA and the Tennessee Department of Environment and Conservation for streams in three Ridge and Valley sub-ecoregions.

EPT taxa richness, Plecoptera taxa richness, and Trichoptera taxa richness and Becks Community Tolerance Index also appeared to decrease as median TN increased. The median TN concentration at which biological conditions declined ranged from 0.303 mg/L - 0.398 mg/L, most similar to the Piedmont ecoregional reference guideline.

The number of Plecoptera taxa and percent non-insect taxa showed a decline in biological conditions at a median NO_3+NO_2-N concentration of 0.16 mg/L. This concentration is most similar to the Piedmont ecoregional reference guideline. Results for EPT taxa richness, number of Trichoptera taxa, number of clinger taxa, and Becks community tolerance index indicated declining conditions at 0.238 mg/L, very similar to the Ridge and Valley ecoregional reference guideline. These concentrations are much lower than the corresponding NO_3+NO_2-N nutrient criteria of 1.22 mg/L established by EPA and the Tennessee Department of Environment and Conservation for streams in three Ridge and Valley sub-ecoregions.

There was no relationship between macroinvertebrate metric results and total suspended solids or turbidity. However, sampling could not be conducted once flows at C-3 exceeded 200 cfs, when sediment loads would be expected to be most elevated. Habitat assessment and pebble count estimates have shown heavy siltation at several reaches along the Cahaba River, but it may be critical to collect water quality parameters at stream gages in order to measure maximum suspended and dissolved solids, turbidity, and conductivity.

In 2005, the ADEM revised its monitoring strategy to provide data to assess the chemical, physical, and biological conditions of non-navigable, flowing waters in the state. The strategy is a watershed-based monitoring program designed to provide data that links watershed condition and assessment results. A Watershed Disturbance Gradient (WDG), based on landuse and other factors, was developed in 2004 to classify each potential monitoring location by the level of disturbance within its watershed. ADEM's wadeable Rivers and Streams Monitoring Program uses this information to plan biological monitoring activities along a full disturbance gradient to produce a dataset representing both the full stressor gradient and the full biological condition gradient. A primary goal of this monitoring design was to provide stressor-response data that can be used to develop criteria and indicators.

Habitat assessment and physical characterization information from the 2005, 2007, and 2010 monitoring strategy stations were used to select eleven additional stations with widths, depths, and drainage areas similar to the 2005 Cahaba River stations (Appendix L-1). The annual median concentration of total phosphorus concentrations were calculated for each station and sampling date. The data from these stations were added to the of water quality data from the twelve 2005 Cahaba River and Hatchet Creek bioassessments and fifteen historical bioassessments conducted between July and October at eleven large, riffle-run streams located within the Piedmont, Ridge and Valley, and Southwestern Appalachians ecoregions. The correlation between median TP and several biological metrics remained consistent with the larger datset (Appendix L-2).

ADEM's 2005 monitoring strategy focused on wadeable streams and rivers, but a similar approach could be used to support the Cahaba River nutrient TMDL, as well as to establish nutrient criteria for nonwadeable streams and rivers statewide. Sampling should include a range of watershed conditions, as well as additional reference watersheds.

In 2004, when the numeric nutrient target was developed, biological, chemical, and physical data from least-impaired rivers supporting viable populations of the ten threatened and endangered species was not available. Recently, however, the Upper Cahaba SHU has been categorized as critical habitat for 36 fish and mussel species identified as extirpated, endangered, threatened, or a high conservation concern (Wynn et al. 2012). Ten SHUs in the Mobile-Tombigbee basin and 14 SHUs in the Alabama River basin share five to 14 of these species with the Cahaba River (Appendices M-1 and M-2). Additional reference watersheds for the Cahaba River may be identified in these SHUs. Monitoring should include water chemisty and biological communities at multiple locations along a longitudinal stream-river continuum to refine stream size classes and monthly or seasonal sampling to more precisely define the best index period for detecting biological impairment in nonwadeable rivers and streams, and for developing appropriate indices for these waterbodies. It is important to maintain consistency among bioassessments and understand the relationship between sampling methods as ADEM moves forward with development of methods and nutrient criteria for this waterbody type.

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Appendix A. List of ecoregional reference reaches and sampling dates used to evaluate the use of Hatchet Creek as a reference watershed for Cahaba River. The six stations used to establish the 2004 numeric nutrient target for the Cahba River are shown in bold.

Station	Basin	Location Desc	Latitude	Longitude	County	Drainage Area (mi2)	Avg Stream Width (ft)	Dominant Substrate	Visit Date	Season	Sampling Year
Piedmont Ecoregion: Southern Inner Piedmont (45a)											
CRHR-9	TALLAPOOSA R	Cornhouse Cr at Randolph Co Rd. 33	33.21195	-85.51806	Randolph	29.6	36	CobGrav	5/30/2000	Spring	2000
									5/10/2005	Spring	2005
HAT-2	TALLAPOOSA R	Hatchet Creek at Dunham Property	32.99980	-86.14250	Coosa	132.0	84	CobGrav	10/11/2005	Fall	2005
HAT-3	TALLAPOOSA R	Hatchet Creek at Co Rd 4	33.13050	-86.05500	Clay	60.0	38	CobGrav	10/11/2005	Fall	2005
HATC-2	TALLAPOOSA R	Hatchet Cr. at US Hwy 280	33.03639	-86.12333	Coosa	96.0	64	CobGrav	10/11/2005	Fall	2005
HATC-3	TALLAPOOSA R	Hatchet Cr. at Tyler Ford	32.91330	-86.28442	Coosa	268.0	174	CobGrav	6/30/2004	Spring	2004
	TALLAPOOSA R								10/12/2005	Fall	2005
HATC-4	TALLAPOOSA R	Hatchet Cr approx. 4 mi us of Coosa Co. Rd. 18	32.94392	-86.23579	Coosa	237.0	175	Bedrock	6/30/2004	Spring	2004
									10/12/2005	Fall	2005
HCR-1	TALLAPOOSA R	Hurricane Creek upstream of Randolph Co. Rd. 26	33.17546	-85.59829	Randolph	13.7	28	CobGrav	7/9/1992	Spring	1992
									6/15/1993	Spring	1993
									6/14/1994	Spring	1994
									5/18/1995	Spring	1995
									10/17/1997	Fall	1997
									5/12/1998	Spring	1998
									6/1/1999	Spring	1999
									5/17/2000	Spring	2000
									5/10/2005	Spring	2005
JCKC-1	COOSA R	Jack's Creek at Coosa Co Rd. 40 nr Rockford	32.91720	-86.13375	Coosa	11.3	27	Sand	5/2/2005	Spring	2005
JNSC-16	COOSA R	Jones Cr at Coosa Co. Rd. 18	32.90492	-86.29758	Coosa	5.3	15	Sand	5/24/2000	Spring	2000
									6/25/2004	Spring	2004
									6/23/2005	Spring	2005
PNTC-11	COOSA R	Paint Cr at unnamed Co Rd. off of Coosa Co Rd. 56 nr Marble	33.01838	-86.44741	Coosa	16.8	21	Sand	5/24/2000	Spring	2000
									6/23/2005	Spring	2005
Piedmont Ecoregion: Talladega Upland (45d)											
TCT-5	COOSA R	Talladega Cr at AL Hwy 77	33.37839	-86.03025	Talladega	74.0	50	CobGrav	4/17/1990	Spring	1990
									6/16/1993	Spring	1993
									5/16/1995	Spring	1995
									5/12/1998	Spring	1998
									7/6/1999	Summer	1999
									6/1/2000	Spring	2000
									6/9/2003	Spring	2003
									6/29/2004	Spring	2004
									6/29/2005	Spring	2005

Appendix A. List of ecoregional reference reaches and sampling dates used to evaluate the use of Hatchet Creek as a reference watershed for Cahaba River. The six stations used to establish the 2004 numeric nutrient target for the Cahba River are shown in bold.

Station	Basin	Location Desc	Latitude	Longitude	County	Drainage Area (mi2)	Avg Stream Width (ft)	Dominant Substrate	Visit Date	Season	Sampling Year
Ridge and Valley Ecoregion: Southern Limestone / Dolomite Valleys and Low Rolling Hills (67f)											
DRYT-9	COOSA R	Dry Cr at Talladega Co. Rd. 234	33.36568	-86.08963	Talladega	9.0	35	Sand	6/1/2000	Spring	2000
									6/20/2002	Spring	2002
FRMB-8	CAHABA R	Fourmile Cr at Bibb Co. Rd. 10	33.07702	-86.97035	Bibb	8.0	25	Sand	5/16/2002	Spring	2002
									6/5/2003	Spring	2003
HNMB-4	BLACK WARRIOR R	Hendrick Mill Br at Blount Co. Rd. 15	33.87612	-86.56885	Blount	3.0	12	CobGrav	6/13/2000	Spring	2000
									5/29/2002	Spring	2002
									6/10/2003	Spring	2003
									6/23/2004	Spring	2004
									5/30/2007	Spring	2007
Ridge and Valley Ecoregion: Southern Sandstone Ridges (67h)											
DRYC-2	COOSA R	Dry Cr at Calhoun Co. Rd 55 (Rabbittown Rd.)	33.84240	-85.59422	Calhoun	5.1	12	CobGrav	6/14/2000	Spring	2000
									6/25/2002	Spring	2002
									5/3/2005	Spring	2005
MAYB-1	CAHABA R	Mayberry Creek @ unnamed Bibb County Rd (May be 24) off of Bibb Co. Rd. 10.	33.07125	-86.93853	Bibb	11.6	24	Sand	6/9/1993	Spring	1993
									6/8/1994	Spring	1994
									6/7/1995	Spring	1995
									6/15/1999	Spring	1999
									5/16/2002	Spring	2002
									6/5/2003	Spring	2003
									5/15/2007	Spring	2007

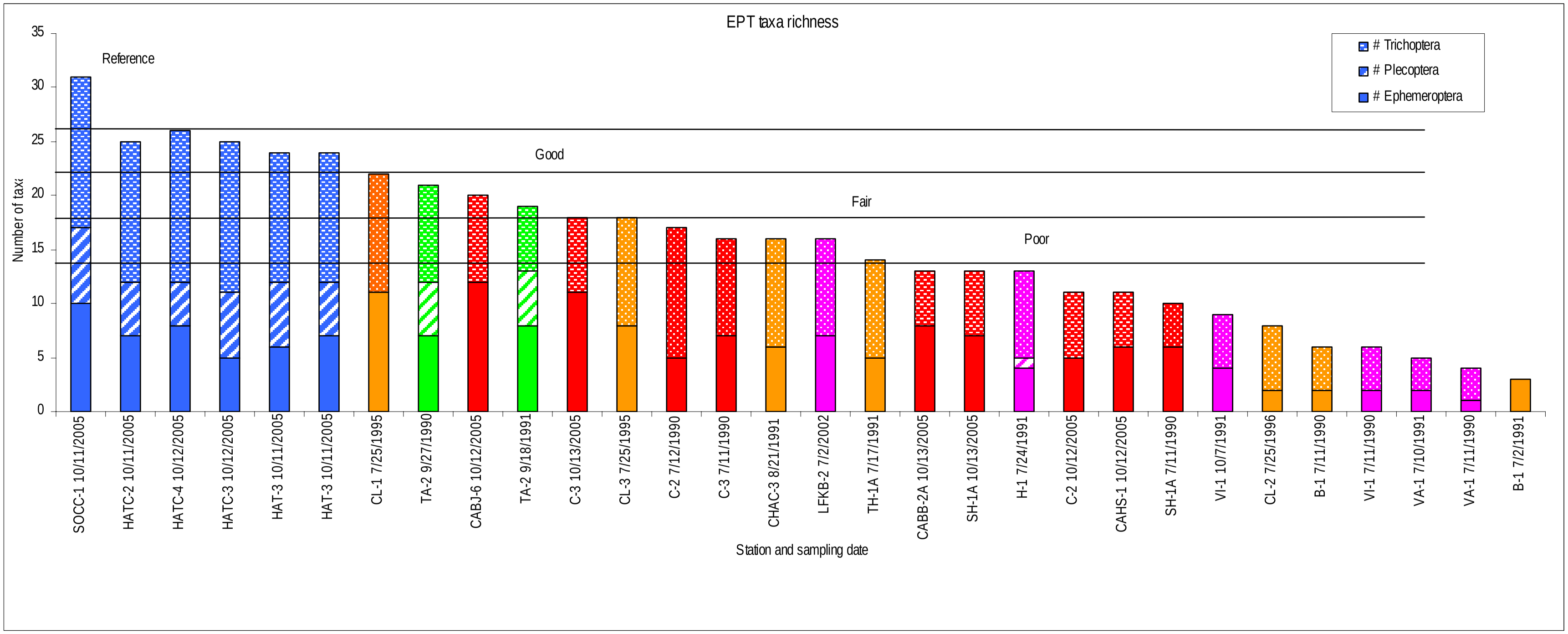
Appendix A. List of ecoregional reference reaches and sampling dates used to evaluate the use of Hatchet Creek as a reference watershed for Cahaba River. The six stations used to establish the 2004 numeric nutrient target for the Cahba River are shown in bold.

Station	Basin	Location Desc	Latitude	Longitude	County	Drainage Area (mi2)	Avg Stream Width (ft)	Dominant Substrate	Visit Date	Season	Sampling Year
Southwestern Appalachians Ecoregion: Dissected Plateau sub-region (68e)											
BRSL-3	BLACK WARRIOR R	Brushy Cr Upstream of North Loop of Lawrence Co. Rd. 73 (east of Co. Rd 70) in Bankhead National Forest	34.33070	-87.28620	Lawrence	8.9	27	CobGrav	7/16/1997	Summer	1997
									6/12/2002	Spring	2002
									6/12/2003	Spring	2003
INMW-1	BLACK WARRIOR R	Inman Creek @ unnamed Forest Service Rd in the Bankhead National Forest	34.21590	-87.22400	Winston	4.0	23	CobGrav	6/24/1993	Spring	1993
									6/16/1994	Spring	1994
									5/18/1995	Spring	1995
									7/15/1997	Summer	1997
									7/11/2001	Summer	2001
									6/13/2002	Spring	2002
									6/11/2003	Spring	2003
MRTC-1	BLACK WARRIOR R	Marriott Cr On unnamed rd south of Cullman Co Rd 18	34.04211	-86.86283	Cullman	7.5	16	Bedrock	6/22/1994	Spring	1994
									5/17/1995	Spring	1995
									6/20/2002	Spring	2002
									6/10/2003	Spring	2003
SF-1	BLACK WARRIOR R	Sipsey Fork at Winston Co Rd 60 (Cranal Road)	34.28558	-87.39906	Winston	89.2	50	CobGrav	6/16/1992	Spring	1992
									6/6/2007	Spring	2007
SF-2	BLACK WARRIOR R	Sipsey Fork @ AL Hwy 33 north of Double Springs	34.21810	-87.36891	Winston	125.9	69	Bedrock	6/17/1992	Spring	1992
									6/12/2002	Spring	2002
TPSL-1	BLACK WARRIOR R	Thompson Creek @ US Forest Service Rd. 208. in the Bankhead National Forest	34.34100	-87.47120	Lawrence	15.4	29	CobGrav	6/23/1993	Spring	1993
									6/14/1994	Spring	1994
									5/17/1995	Spring	1995
									7/15/1997	Spring	1997
									6/12/2002	Spring	2002
									6/11/2003	Spring	2003

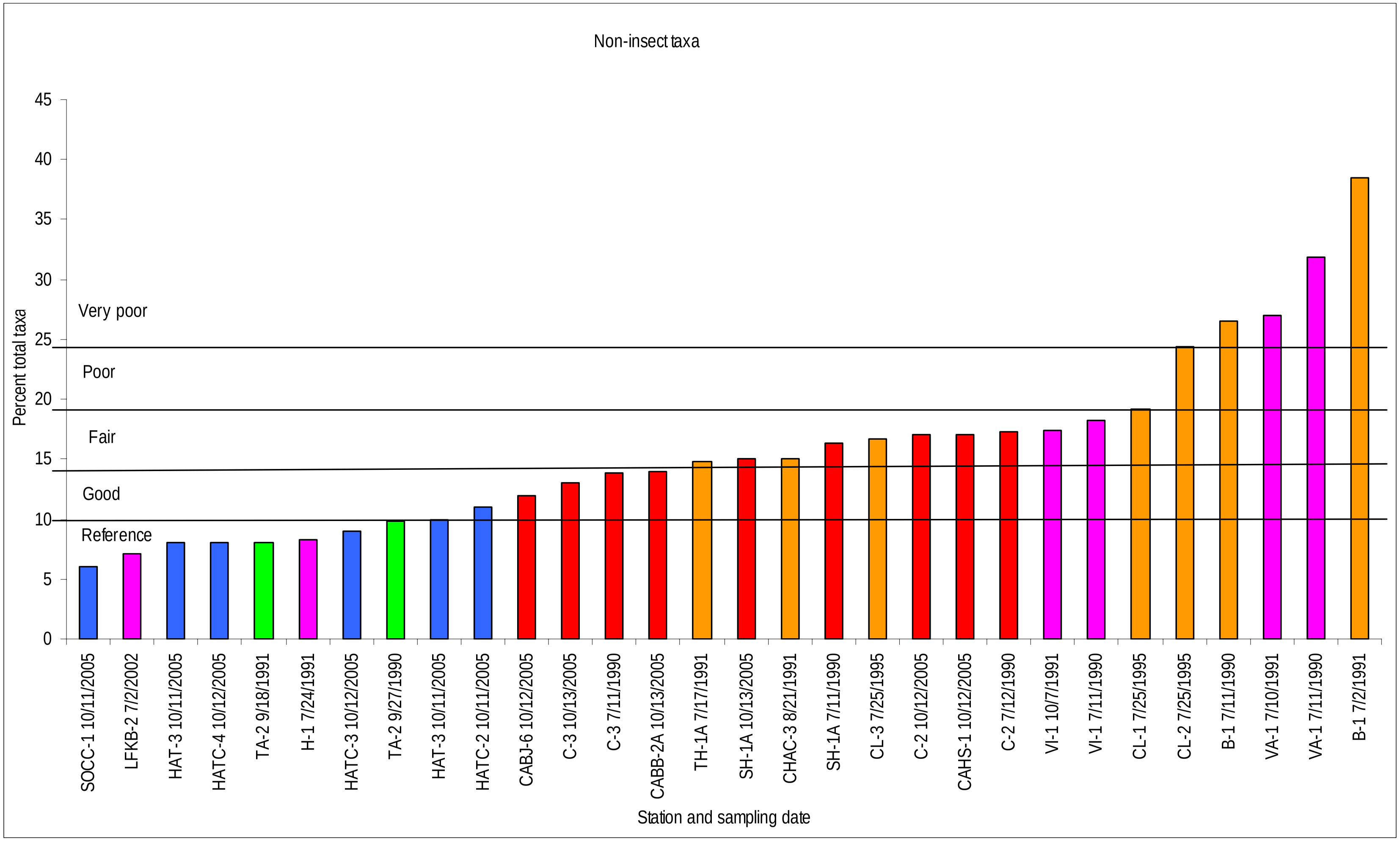
Appendix B. Location description of historical bioassessment stations located in the Piedmont (45), Ridge and Valley (67), and Southwestern Appalachian (68 ecoregions). The date(s) that bioassessments were conducted is also listed.

Station ID	Locale Name	Ecoregion	Subecoregion	Drainage Area (mi^2)	Stream Width (Ft.)[a]	Basin	County	Location Desc	Latitude	Longitude	Bioassessment Date(s)
B-1	Buck Ck	Ridge and Valley (67)	Southern Limestone / Dolomite Valleys and Low Rolling Hills (67f)	70	64	Cahaba R	Shelby	Buck Creek below dam in Helena off Hwy 261 (RM2.4)	33.29694	-86.84264	7/11/1990; 7/2/1991
CHAC-3	Chattooga R	Ridge and Valley (67)	Southern Limestone / Dolomite Valleys and Low Rolling Hills (67f)	286	80	Coosa R	Cherokee	Chattooga R @ 0.11 miles from Cherokee CR 140	34.31440	-85.47137	8/21/1991
CL-1	Choccolocco Ck	Ridge and Valley (67)	Southern Limestone / Dolomite Valleys and Low Rolling Hills (67f)	496	90	Coosa R	Talladega	Choccolocco Ck in the vicinity of AL Hwy 77 bridge north of	33.56192	-86.12631	7/25/1995
CL-2	Choccolocco Ck	Ridge and Valley (67)	Southern Limestone / Dolomite Valleys and Low Rolling Hills (67f)	251	60	Coosa R	Talladega	Choccolocco Ck at Talldega CR 58 near Coldwater, Al	33.58194	-85.90556	7/25/1995
CL-3	Choccolocco Ck	Ridge and Valley (67)	Southern Limestone / Dolomite Valleys and Low Rolling Hills (67f)	323	50	Coosa R	Talladega	Choccolocco Ck at Talladega Co. Rd. 399 crossing.	33.55139	-86.00528	7/25/1995
H-1	Hurricane Ck	Southwestern Appalachians (68)	Shale Hills (68f)	108	45	Black Warrior R	Tuscaloosa	Hurricane Creek @ Co. Rd. 88 (old Co Rd 116) near Peterson (CM	33.22983	-87.46181	7/24/1991
LFKB-2	Locust Fk	Southwestern Appalachians (68)	Dissected Plateau (68e)	578	110	Black Warrior R	Blount	Locust Fork at Armston Loop/Center Springs Rd (Vaughns	33.88849	-86.69532	7/2/2002
TA-2	Tallapoosa R	Piedmont (45)	Talladega Upland (45d)	351	108	Tallapoosa R	Cleburne	Tallapoosa River @ bridge crossing east of Muscadine	33.73272	-85.37217	9/27/1990; 9/18/1991
TH-1A	Tallaseehatchee Ck	Ridge and Valley (67)	Southern Limestone / Dolomite Valleys and Low Rolling Hills (67f)	123	60	Tallapoosa R	Talladega	Tallaseehatchee Ck @ Talladega Co Rd 178	33.27009	-86.27468	7/17/1991
VA-1	Valley Ck	Southwestern Appalachians (68)	Shale Hills (68f)	93	65	Black Warrior R	Jefferson	Valley Creek @ Jefferson Co Rd 36 (CM 32.3)	33.38775	-87.05874	7/11/1990; 7/10/1991
VI-1	Village Ck	Southwestern Appalachians (68)	Shale Hills (68f)	70	60	Black Warrior R	Jefferson	Village Creek @ on FAS-12 Rd. west of Mulga (CM 19.2)	33.57417	-86.98667	7/11/1990; 10/7/1991

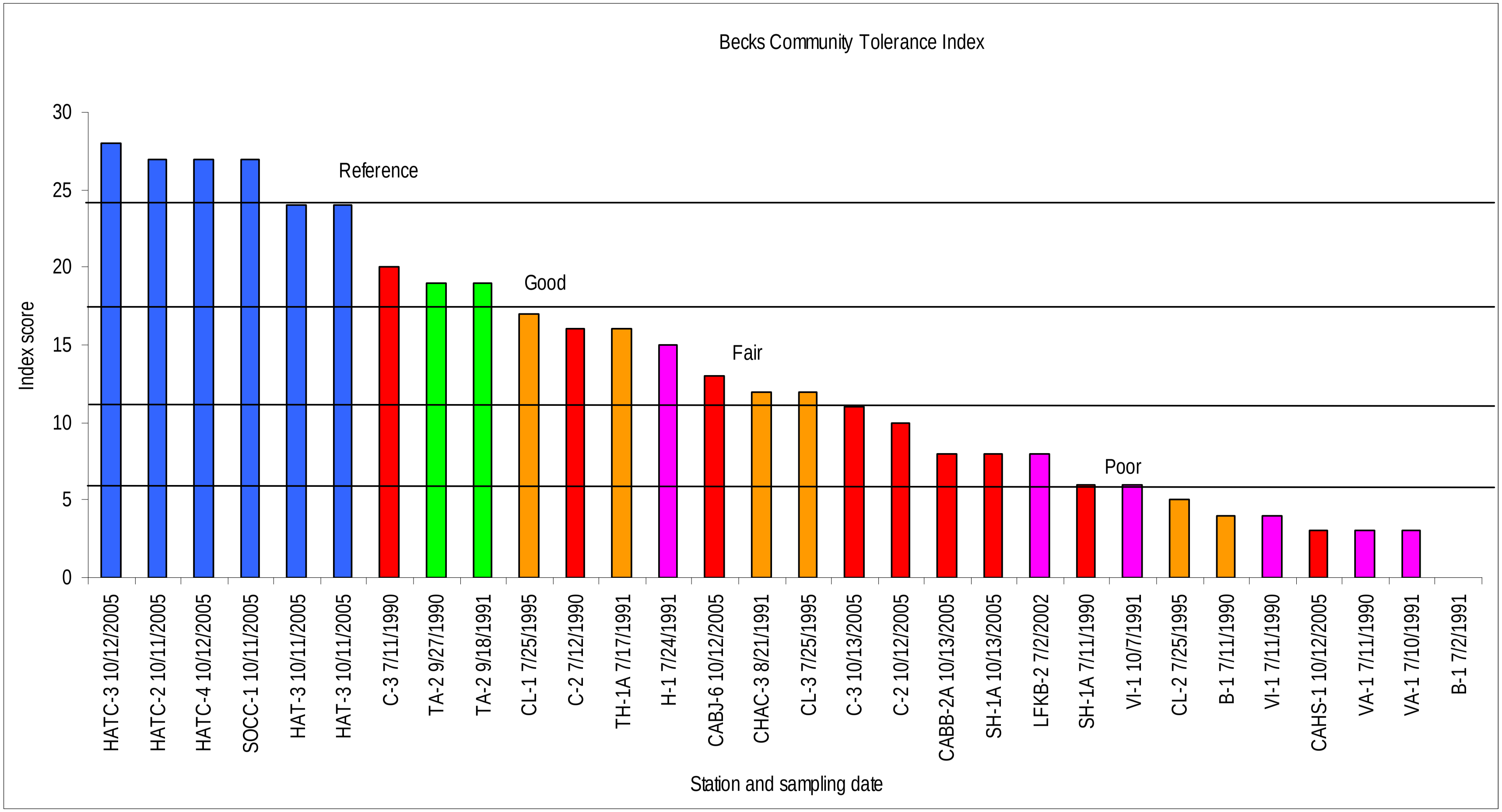
Appendix C. Comparison of the Cahaba River (red) and Hatchet Creek (blue) EPT taxa richness metric results with seventeen historical bioassessments conducted July through October at riffle-run stream locations with large drainage areas located in the Ridge and Valley (orange), Piedmont (green), or Southwestern Appalachian (purple) ecoregions. Results are arranged in descending order.



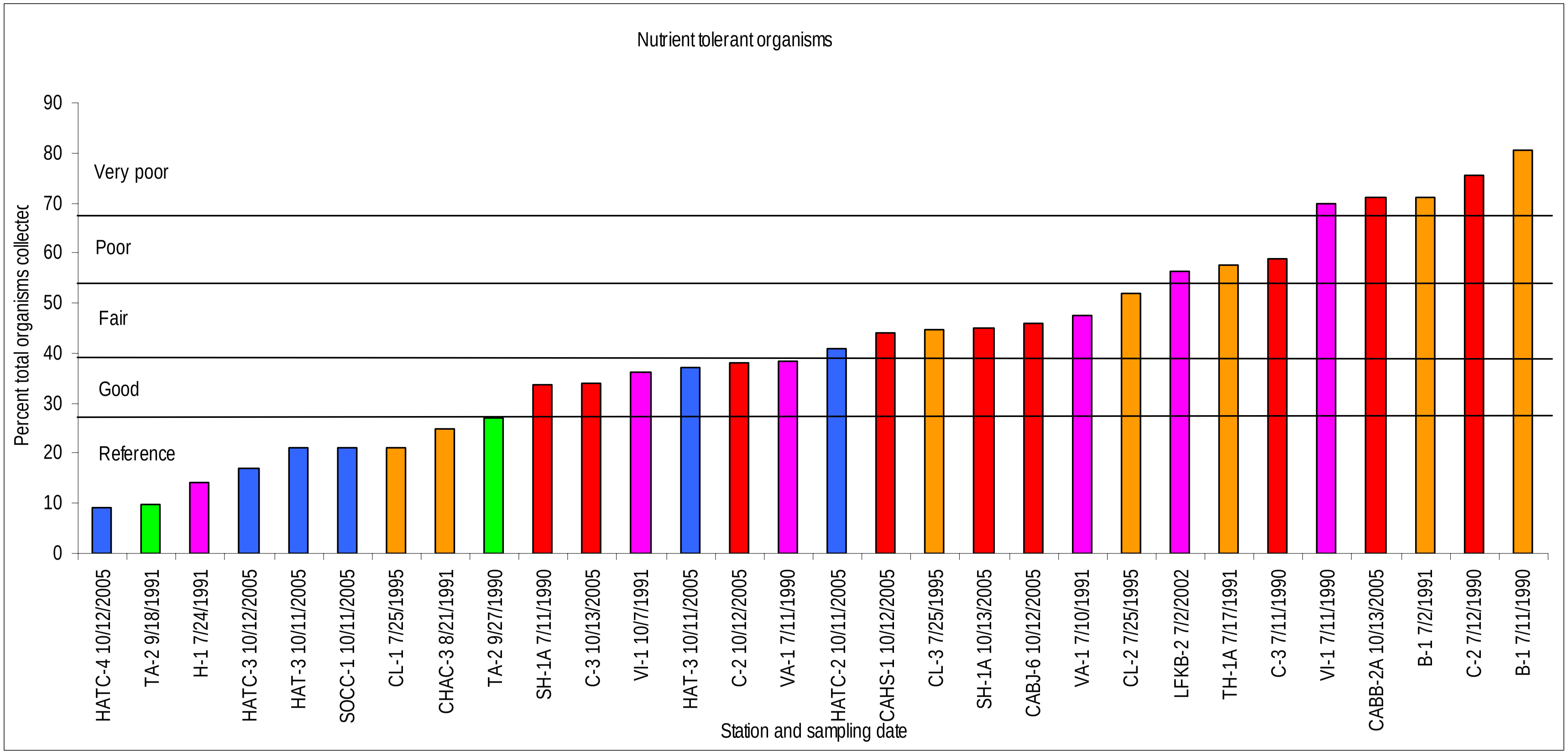
Appendix D. Comparison of the Cahaba River (red) and Hatchet Creek (blue) percent non-insect taxa metric results with seventeen historical bioassessments conducted July through October at riffle-run stream locations with large drainage areas located in the Ridge and Valley (orange), Piedmont (green), or Southwestern Appalachian (purple) ecoregions. Results are arranged in ascending order.



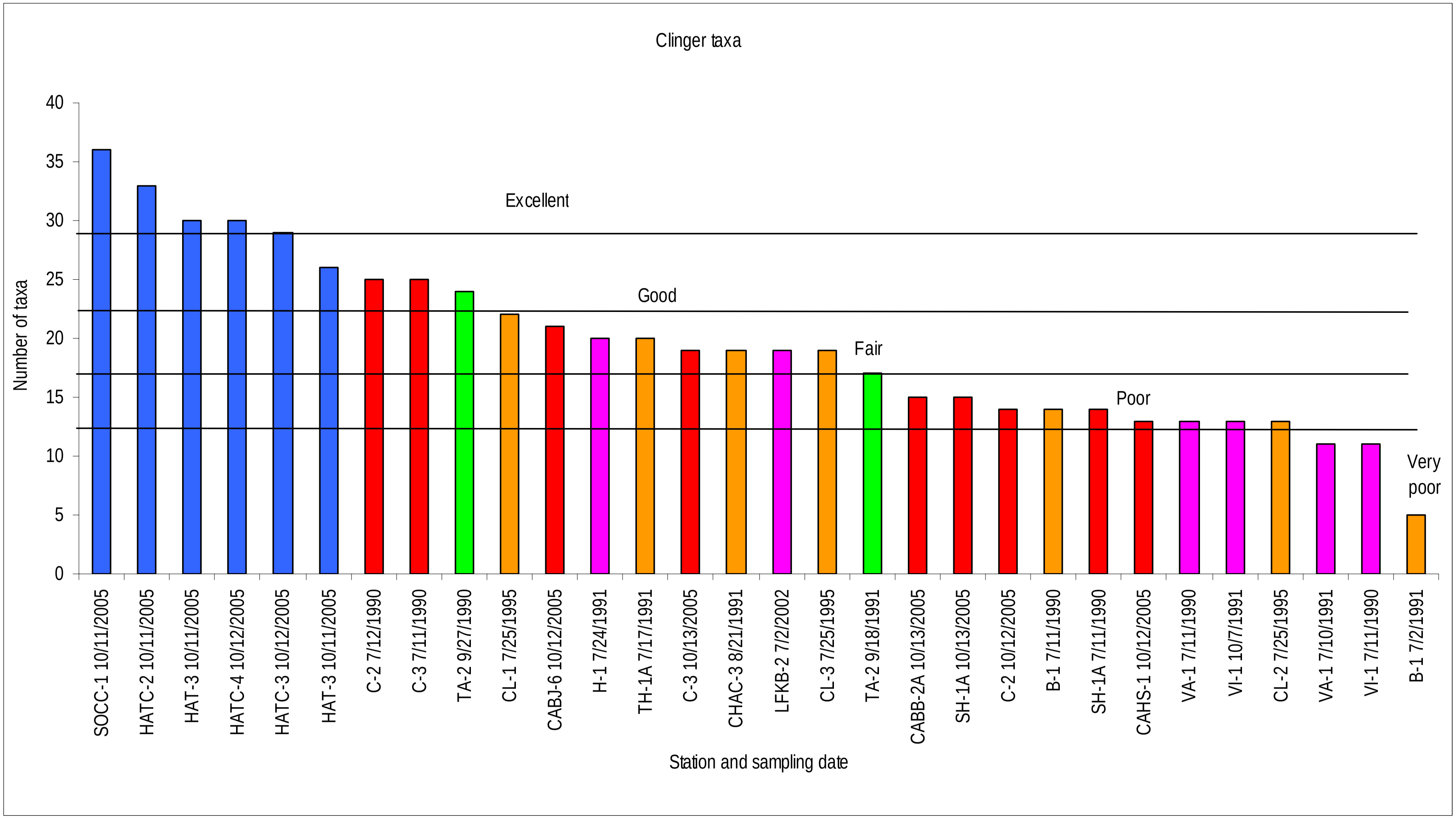
Appendix E. Comparison of the Cahaba River (red) and Hatchet Creek (blue) Becks community tolerance index results with seventeen historical bioassessments (yellow) conducted July through October at riffle-run stream locations with large drainage areas located in the Ridge and Valley (orange), Piedmont (green), or Southwestern Appalachian (purple) ecoregions. Results are arranged in descending order.



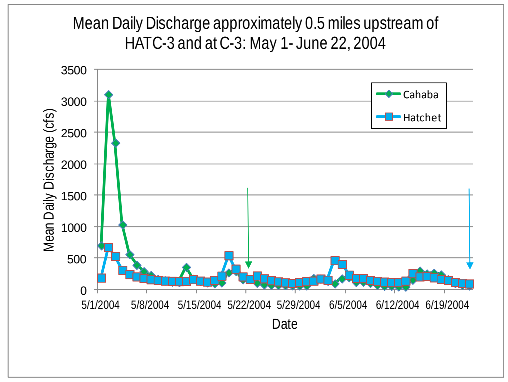
Appendix F. Comparison of the Cahaba River (red) and Hatchet Creek (blue) percent nutrient tolerant metric results with seventeen historical bioassessments conducted July through October at riffle-run stream locations with large drainage areas located in the Ridge and Valley (orange), Piedmont (green), or Southwestern Appalachian (purple) ecoregions. Results are arranged in ascending order.

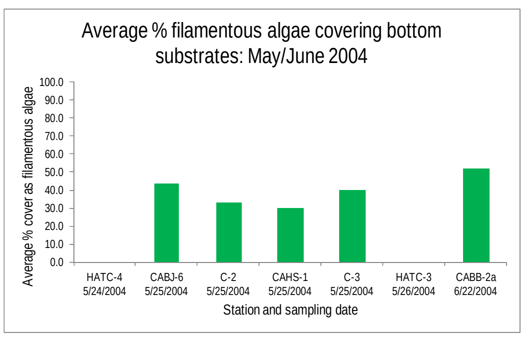


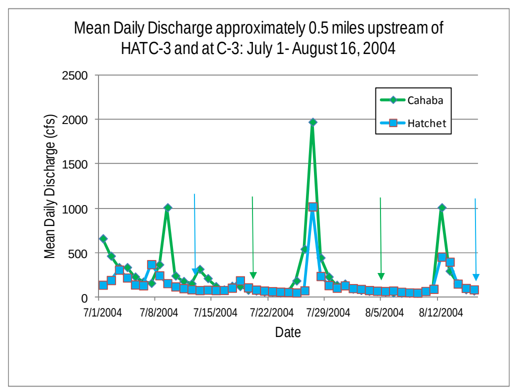
Appendix G. Comparison of number of clinger taxa collected from Cahaba River (red) and Hatchet Creek (blue) with seventeen historical bioassessments conducted July through October at riffle-run stream locations with large drainage areas located in the Ridge and Valley (orange), Piedmont (green), or Southwestern Appalachian (purple) ecoregions. Results are arranged in descending order.

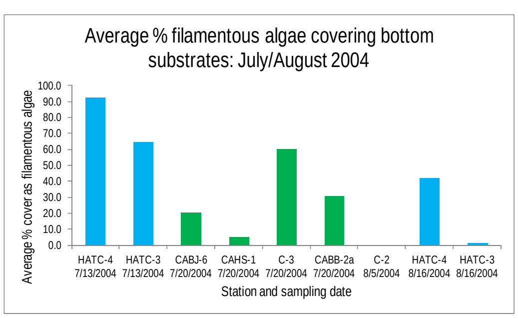


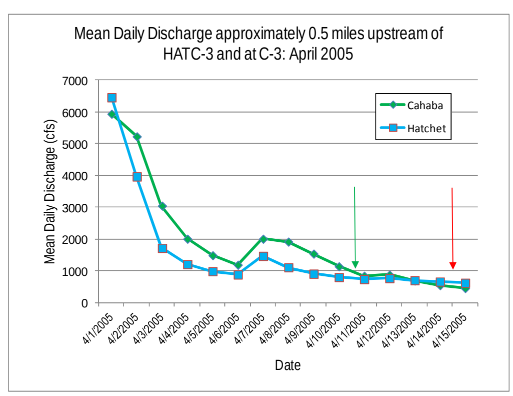
Appendix H. Comparison of average percent bottom substrates covered by filamentous algae estimated at the Cahaba River (green) and Hatchet Creek stations (blue), July 2004-August 2008. USGS gage flows measured at C-3 (green) and approximately 0.5 miles upstream of HATC-3 (blue) are also provided for each sampling event. Results are arranged in chronological order. Sampling events are indicated with colored arrows (Cahaba=green; Hatchet=blue; Cahaba and Hatchet=red). The scale varies among graphs as needed.

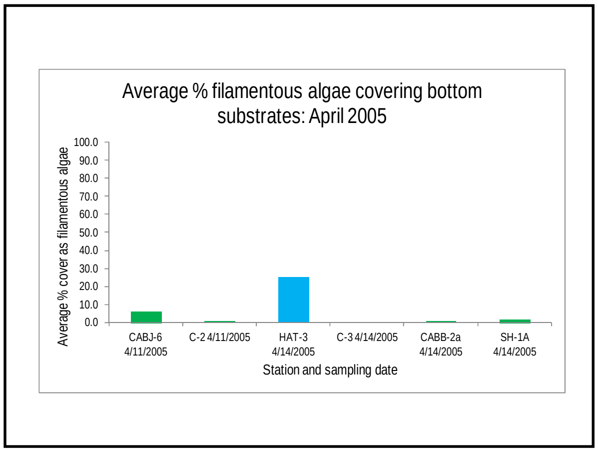


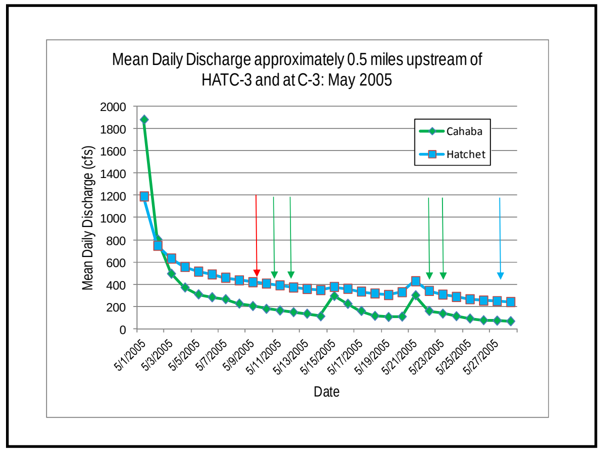


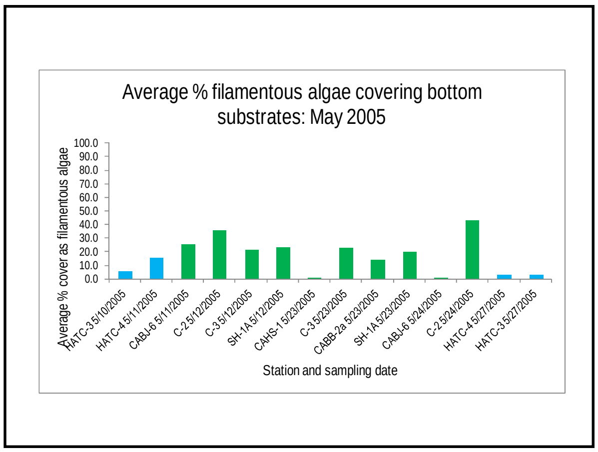


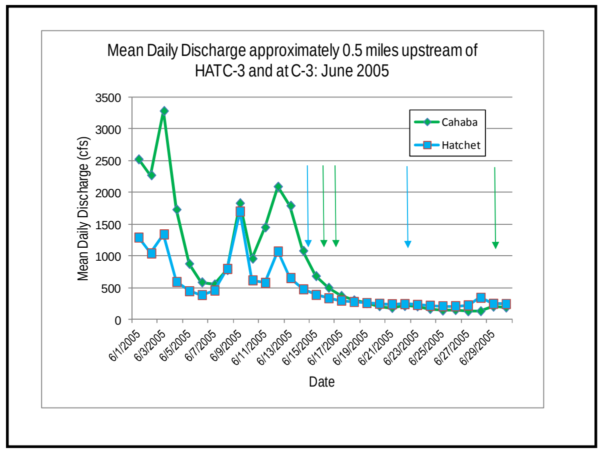


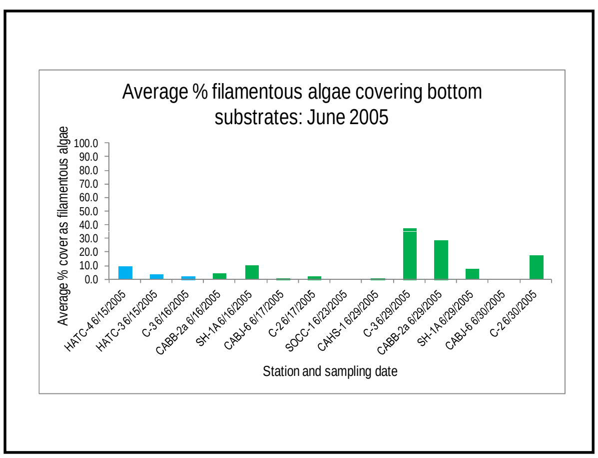


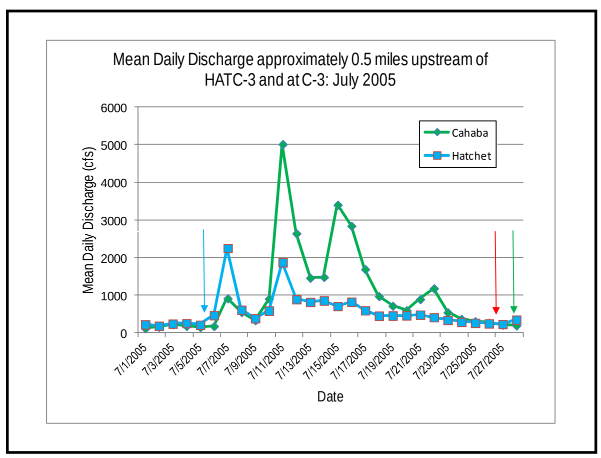

Average % filamentous algae covering bottom substrates: April 2005
Average % cover as filamentous algae
Station and sampling date
CABJ-6 4/11/2005
C-2 4/11/2005
HAT-3 4/14/2005
C-3 4/14/2005
CABB-2a 4/14/2005
SH-1A 4/14/2005

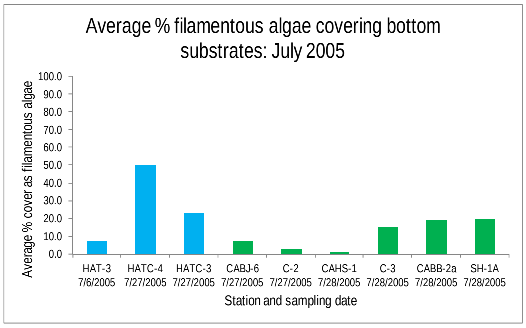

Mean Daily Discharge approximately 0.5 miles upstream of HATC-3 and at C-3: May 2005
Mean Daily Discharge (cfs)
Cahaba
Hatchet
Date

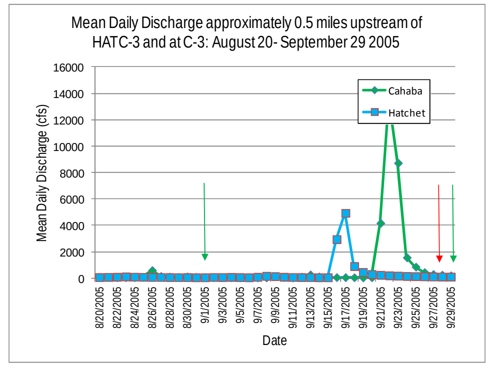

Average % filamentous algae covering bottom substrates: May 2005
Average % cover as filamentous algae
Station and sampling date
HATC-3 5/10/2005
HATC-4 5/11/2005
CABJ-6 5/11/2005
C-2 5/12/2005
C-3 5/12/2005
SH-1A 5/12/2005
CAHS-1 5/23/2005
C-3 5/23/2005
CABB-2a 5/23/2005
SH-1A 5/23/2005
CABJ-6 5/24/2005
C-2 5/24/2005
HATC-4 5/27/2005
HATC-3 5/27/2005

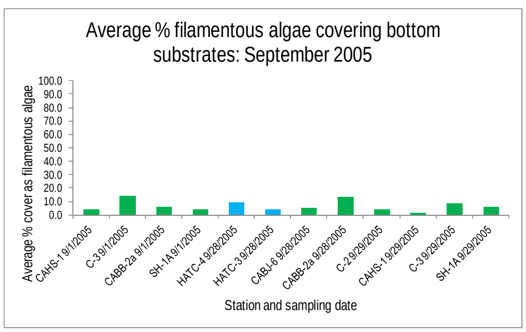

Mean Daily Discharge approximately 0.5 miles upstream of HATC-3 and at C-3: June 2005
Mean Daily Discharge (cfs)
Cahaba
Hatchet
Date

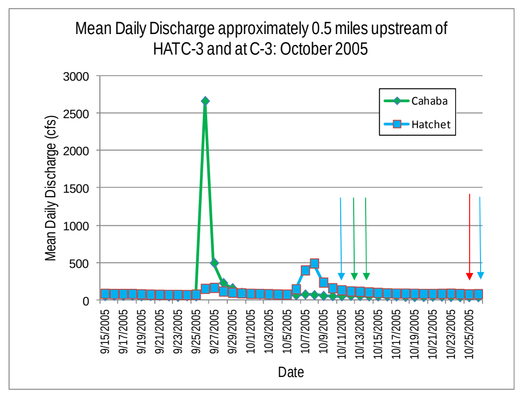

Average % filamentous algae covering bottom substrates: June 2005
Average % cover as filamentous algae
Station and sampling date
HATC-4 6/15/2005
HATC-3 6/15/2005
C-3 6/16/2005
CABB-2a 6/16/2005
SH-1A 6/16/2005
CABJ-6 6/17/2005
C-2 6/17/2005
SOCC-1 6/23/2005
CAHS-1 6/29/2005
C-3 6/29/2005
CABB-2a 6/29/2005
SH-1A 6/29/2005
CABJ-6 6/30/2005
C-2 6/30/2005

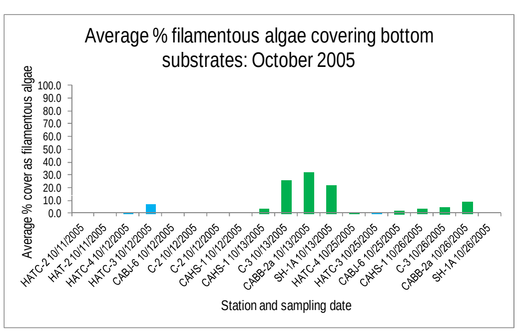

Mean Daily Discharge approximately 0.5 miles upstream of HATC-3 and at C-3: July 2005
Mean Daily Discharge (cfs)
Cahaba
Hatchet
Date

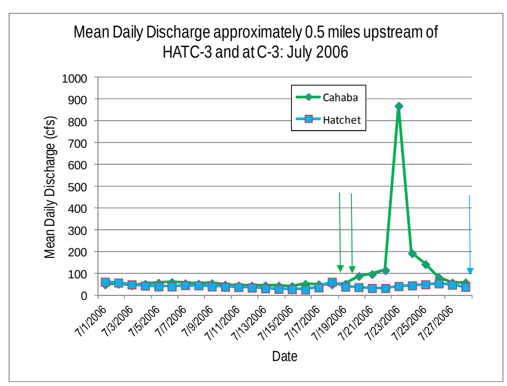

Average % filamentous algae covering bottom substrates: July 2005
Average % cover as filamentous algae
Station and sampling date
HAT-3 7/6/2005
HATC-4 7/27/2005
HATC-3 7/27/2005
CABJ-6 7/27/2005
C-2 7/27/2005
CAHS-1 7/28/2005
C-3 7/28/2005
CABB-2a 7/28/2005
SH-1A 7/28/2005

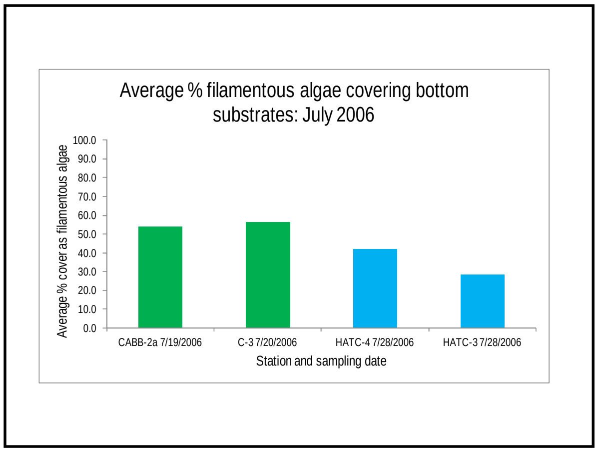

Mean Daily Discharge approximately 0.5 miles upstream of HATC-3 and at C-3: August 20- September 29 2005
Mean Daily Discharge (cfs)
Date
Cahaba
Hatchet

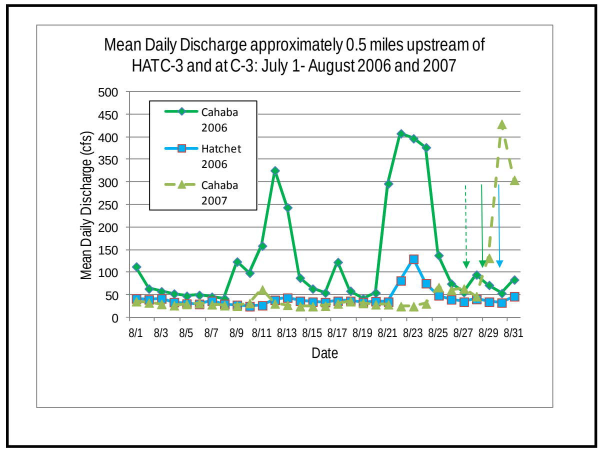

Average % filamentous algae covering bottom substrates: September 2005
Average % cover as filamentous algae
Station and sampling date
CAHS-1 9/1/2005
C-3 9/1/2005
CABB-2a 9/1/2005
SH-1A 9/1/2005
HATC-4 9/28/2005
HATC-3 9/28/2005
CABJ-6 9/28/2005
CABB-2a 9/28/2005
C-2 9/29/2005
CAHS-1 9/29/2005
C-3 9/29/2005
SH-1A 9/29/2005

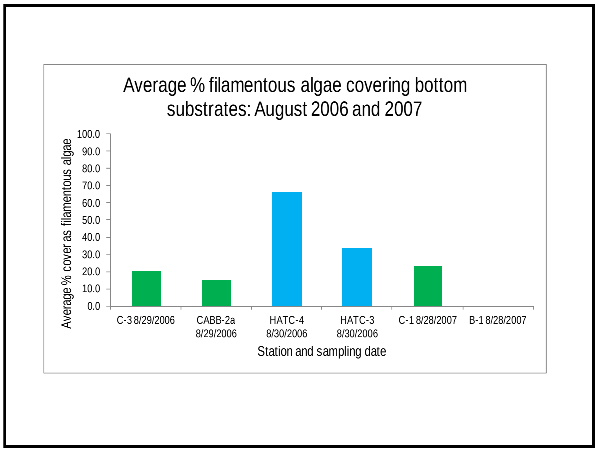

Mean Daily Discharge approximately 0.5 miles upstream of HATC-3 and at C-3: October 2005
Mean Daily Discharge (cfs)
Date
Cahaba
Hatchet


Average % filamentous algae covering bottom substrates: October 2005
Average % cover as filamentous algae
Station and sampling date


Mean Daily Discharge approximately 0.5 miles upstream of HATC-3 and at C-3: July 2006
Mean Daily Discharge (cfs)
Date
Cahaba
Hatchet


Average % filamentous algae covering bottom substrates: July 2006
Average % cover as filamentous algae
Station and sampling date
CABB-2a 7/19/2006
C-3 7/20/2006
HATC-4 7/28/2006
HATC-3 7/28/2006


Mean Daily Discharge approximately 0.5 miles upstream of HATC-3 and at C-3: July 1- August 2006 and 2007
Mean Daily Discharge (cfs)
Cahaba 2006
Hatchet 2006
Cahaba 2007
Date


Average % filamentous algae covering bottom substrates: August 2006 and 2007
Average % cover as filamentous algae
Station and sampling date
C-3 8/29/2006
CABB-2a 8/29/2006
HATC-4 8/30/2006
HATC-3 8/30/2006
C-1 8/28/2007
B-1 8/28/2007

Appendix I. List of taxa collected at the Cahaba River and Hatchet Creek sites, October 11-13, 2005.

Taxon	CABJ-6	C-2	CAHS-1	C-3	CABB-2a	SH-1A	HAT-3	HATC-2	HAT-2	HATC-4	HATC-3	SOCC-1
Ephemeroptera												
Baetidae												
Acentrella	3											
Baetis	54			250	72	528			14	14	224	165
Heterocloeon					378							106
Plauditus	144			36					2	12		
Procloeon				3								
Baetidae UNID dif	162		144	278	18	1784	2	560				132
Baetidae UNID						1104				48	138	
Baetiscidae												
Baetisca										4	2	
Caenidae												
Brachycercus										2		3
Caenis								4		4		24
Cercobrachys												2
Ephemerellidae												
Attenella	54											
Ephemerella					144							
Eurylophella							2					5
Serratella									12			75
Ephemerellidae UNID dif	108										40	
Ephemeridae												
Hexagenia							10					
Ephemeridae UNID dif	3							160				
Heptageniidae												
Heptagenia				39								10
Leucrocuta									2			
Maccaffertium	441	362	582	300		364	897	337	841	70	360	640
Stenacron	18	72	123	358	54	284	6					3
Stenonema				39	504	16			2			
Heptageniidae UNID dif	396	83	546	477		480		105		12		80
Heptageniidae UNID							29		6		86	
Isonychidae												
Isonychia	993	144	255	1537	204		585	246	72			196
Trichorythidae												
Tricorythidae UNID dif	6	36	93	32	54	108		4		14	24	315

Appendix I. List of taxa collected at the Cahaba River and Hatchet Creek sites, October 11-13, 2005.

Taxon	CABJ-6	C-2	CAHS-1	C-3	CABB-2a	SH-1A	HAT-3	HATC-2	HAT-2	HATC-4	HATC-3	SOCC-1
Plecoptera												
Leuctridae												
Leuctra							9					
Leuctridae UNID dif												4
Peltoperlidae												
Tallaperla								4				
Perlidae												
Acroneuria							9	2	110	2	56	3
Agnetina							135	249	36	2		255
Attaneuria							2				2	
Neoperla							135	84	2	6	118	55
Paragnetina							69	93	47	24	162	66
Perlesta											4	53
Perlidae UNID dif												104
Pteronarcyidae												
Pteronarcys									2		4	210
Unidentifiable Plecoptera												12
Trichoptera												
Brachycentridae												
Brachycentrus							41	22	14		4	31
Micrasema							139	400	60	26	100	243
Brachycentridae UNID dif				18								
Calamoceratidae												
Anisocentropus							8	6	2			
Dipseudopsidae												
Phylocentropus							10	20			2	
Glossosomatidae												
Agapetus	48		18									
Helicopsychidae												
Helicopsyche									12			
Hydropsychidae												
Ceratopsyche/Symphitopsyche	873	123		18	687	72		82		24	2	527
Cheumatopsyche	2061	2044	1551	976	57	2312	649	1541	847	218	1282	752
Hydropsyche	216	152	471	390	12	148		320	66	124	1212	180
Hydropsychidae UNID dif	690		684	90		2212		400		12		627
Hydropsychidae UNID		183										
Hydroptilidae												
Hydroptila					18					24		
Neotrichia											26	

Appendix I. List of taxa collected at the Cahaba River and Hatchet Creek sites, October 11-13, 2005.

Taxon	CABJ-6	C-2	CAHS-1	C-3	CABB-2a	SH-1A	HAT-3	HATC-2	HAT-2	HATC-4	HATC-3	SOCC-1
Leptoceridae												
Ceraclea											48	
Mystacides											24	21
Nectopsyche	3					76	16	176	24	16	4	138
Oecetis				11			2	6	2	50	6	46
Setodes									40	2		
Triaenodes				108			8	2	18		108	32
Leptoceridae UNID dif		60										4
Philopotamidae												
Chimarra	3177	3102	342		6	8	349	752	3228	338	2900	7
Philopotamidae UNID dif	60	240										
Polycentropodidae												
Cernotina										4		
Cyrnellus												30
Nyctiophylax							4			2		
Polycentropus							2	4		110	2	14
Polycentropodidae UNID dif									2	24		3
Psychomyiidae												
Lype							2					
Coleoptera												
Hydrophilidae												
Helocombus	3											
Dryopidae												
Helichus	9						24	91	4	4	24	31
Dytiscidae												
Uvarus							2					
Elmidae												
Ancyronyx	3			27		16	94	12	6			70
Dubiraphia	39		6	3			10	2	4	44	4	5
Gonielmis												12
Macronychus	183	11	81	180	54		82	88	230	58	148	261
Microcylloepus	183	63		9	162	8	45	574	61	62	522	63
Optioservus							90	2			72	60
Oulimnius							45					
Stenelmis	216	300	93	158	291	3684	810	2320	278	52	1202	320
Gyrinidae												
Dineutus								4				
Gyrinus												14

Appendix I. List of taxa collected at the Cahaba River and Hatchet Creek sites, October 11-13, 2005.

Taxon	CABJ-6	C-2	CAHS-1	C-3	CABB-2a	SH-1A	HAT-3	HATC-2	HAT-2	HATC-4	HATC-3	SOCC-1
Haliplidae												
Peltodytes								2				
Hydrophilidae												
Berosus		18				44						
Helobata								6				
Helochares				9								
Sperchopsis			3									
Lampyridae												
Lampyridae UNID dif											2	
Psephenidae												
Ectopria				11			2	8		6	2	2
Psephenus	102	6		18			53	2	40	4	2	74
Ptilodactylidae												
Anchytarsus							49	2		24	26	7
Scirtidae												
Cyphon		120										
Unidentifiable Coleoptera	3											
Diptera												
Athericidae												
Atherix								80			24	
Ceratopogonidae												
Bezzia										12		
Probezzia									4			
Sphaeromias										2	4	
Ceratopogonidae UNID dif										2		
Chaoboridae												
Chaoborus				3								
Empididae												
Hemerdromia							9		16	2	40	3
Empididae UNID dif												3
Simuliidae												
Prosimulium	36						43	13				240
Simulium	3627			2819		52	263	564	426	64	1102	2570
Simulidae UNID dif	108			39	31866							
Tabanidae												
Tabanus											24	

Appendix I. List of taxa collected at the Cahaba River and Hatchet Creek sites, October 11-13, 2005.

Taxon	CABJ-6	C-2	CAHS-1	C-3	CABB-2a	SH-1A	HAT-3	HATC-2	HAT-2	HATC-4	HATC-3	SOCC-1
Tipulidae												
Antocha									12			
Dicranota	36											
Hexatoma							45			24		
Hexatoma								2				
Limnophila												63
Tipula	36						34		2	4		60
Tipulidae UNID dif												3
Chironomidae												
Ablabesmyia	83		21	4	18	22	4	11	2	15	8	175
Cardiocladius	19			23			13					25
Cladopelma						5						
Cladotanytarsus	3			21		8						
Clinotanypus										15		
Corynoneura			38	174		54			40			
Cricotopus/Orthocladius				26		109	13	109	207	2412	334	9
Cryptochironomus				11		50	4			2		6
Dicrotendipes			78	32	90	84		2				
Labrundinia									2			
Lopescladius									20			
Microspectra										18		
Microtendipes							27	108	22			33
Nanocladius	19								20			
Natarsia										13		
Nilotanypus			38			40						
Orthocladinae Genus C							2					
Orthocladinae UNID												15
Orthocladinae UNID dif						40				2		
Paracladopelma				7								
Parametriocnemus							14	4				29
Paratendipes	3											
Pentaneura				44		100				151		
Phaenopsectra						4	2	4		70		280
Polypedilum	5222	1725	717	2218	3903	1483	313	323	180	77	52	778
Procladius				4				2		2	2	
Psectrocladius							13	24				
Pseudochironomus						17						
Rheocricotopus			75	23		488	43	24	60	62	366	33
Rheotanytarsus	19	54	134	87	226	159	50	98	357	2	28	132

Appendix I. List of taxa collected at the Cahaba River and Hatchet Creek sites, October 11-13, 2005.

Taxon	CABJ-6	C-2	CAHS-1	C-3	CABB-2a	SH-1A	HAT-3	HATC-2	HAT-2	HATC-4	HATC-3	SOCC-1
Chironomidae, cont.												
Robackia											2	
Stelechomyia												3
Stempellinella							25	9	2			3
Stenochironomus		8				40	92	97	466	64	20	18
Stictochironomus							8			25		
Synorthocladius												15
Tanypodinae UNID dif											24	
Tanytarsini UNID dif						48					2	7
Tanytarsus				61	18	165	53	45	46	400	71	18
Thienemanniella	86			87	144	90	86				40	36
Thienemannimyia Grp						407	14		20	82		
Tribelos	3		56				19	4				23
Tvetnia	83			44	82		2	72	203	38	187	76
Xestochironomus										73	2	18
Xylotopus							8					9
Chironomini				4			13			79	4	18
Unidentifiable Diptera	18					48						
Hemiptera												
Gerridae												
Metrobates		14										
Rheumatobates			3									
Trepobates		3										
Veliidae												
Rhagovelia												3
Lepidoptera												
Pyralidae												
Parapoynx										12		
Petrophila								2		4		
Megaloptera												
Corydalidae												
Corydalus	162	6			3	56	135	12	46	4	68	64
Nigronia								2				8
Sialidae												
Sialis							10					
Odonata												
Aeshnidae												
Basiaeschna				3	18							
Boyeria	3		3		36	12	4	8	6	2	8	17
Nasiaeschna			3									

Appendix I. List of taxa collected at the Cahaba River and Hatchet Creek sites, October 11-13, 2005.

Taxon	CABJ-6	C-2	CAHS-1	C-3	CABB-2a	SH-1A	HAT-3	HATC-2	HAT-2	HATC-4	HATC-3	SOCC-1
Calopterygidae												
Calopteryx					18		4	92	6		8	3
Hetaerina					72						4	113
Coenagrionidae												
Argia	15	3	87	206	54	224	10	26	6	40	24	6
Enallagma				42		28					6	
Coenagrionidae UNID dif		6						4				
Corduliidae												
Epitheca										12		
Neurocordulia				11			2			2		
Somatochlora											2	
Gomphidae												
Arigomphus											4	
Dromogomphus	3						2		8		6	
Gomphus	3			3			2		8	14	4	
Hagenius							9					
Lanthus									12			
Ophiogomphus												10
Progomphus	84		3			8	4		2	4	20	15
Stylurus	6		9									
Gomphidae UNID dif				6		4		4		4		
Libellulidae												
Libellula			3									
Macromiidae												
Macromia	3				18		24	24	154	28	58	15
Unidentifiable Odonata										12		
Amphipoda												
Crangonyctidae												
Gammarus						4						
Talitridae												
Hyalella	3				18							
Decapoda												
Cambaridae												
Cambarus												17
Cambaridae UNID dif							9					

Appendix I. List of taxa collected at the Cahaba River and Hatchet Creek sites, October 11-13, 2005.

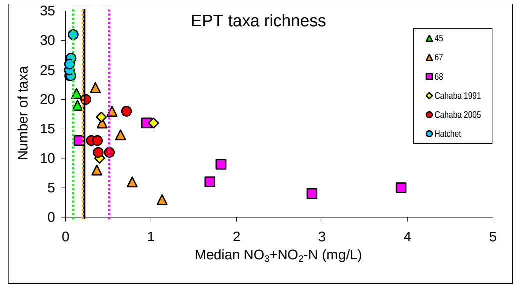
Taxon	CABJ-6	C-2	CAHS-1	C-3	CABB-2a	SH-1A	HAT-3	HATC-2	HAT-2	HATC-4	HATC-3	SOCC-1
Isopoda												
Asellidae												
Caecidotea									6			
Lirceus					540	4	4				6	26
Hydracarina												
HYDRACHNELLAE (HYDRACARINA)							2	2				
Annelida												
Planariidae	36	3										
Hirudinea UNID dif			3	9						2		
Oligochaeta UNID dif	96		54	11		200	51	12	97	38	12	
Gastropoda												
Ancylidae												
Ferrissia						4		73				15
Laevapex								2				
Hydrobiidae												
Amnicola					12051							
Somatogyrus	270	5309	1074	606					112	6	5328	
Physidae												
Physella		18		3		8	4	2			8	
Planorbidae												
Planorbella			3									12
Planorbula						4						
Pleuroceridae												
Elimia	2931	1928	1185	429	399		508	128	64	144	394	571
Leptoxis				79								
Viviparidae												
Campeloma	18			3			4					
Pelecypoda												
Corbiculidae												
Corbicula	117	114	99	33	57	792	116	6	28	664	172	170
Sphaeriidae												
Sphaeriidae UNID dif						8		2		6	28	

Appendix J. Relationship between untransformed water quality data and metric results from the twelve 2005 Cahaba River (Cahaba 2005) and Hatchet Creek (Hatchet) bioassessments and fifteen historical bioassessments conducted at eleven large, riffle-run streams. All macroinvertebrate bioassessments were conducted between July and October within the Piedmont (45), Ridge and Valley (67), and Southwestern Appalachians (68) ecoregions. Bioassessments conducted at three of the 2005 Cahaba River stations in 1991 (Cahaba 1991) were also included in the analyses. The 2006 Cahaba River total phosphorus target and the 2010 ecoregional reference guidelines for each parameter are also shown.

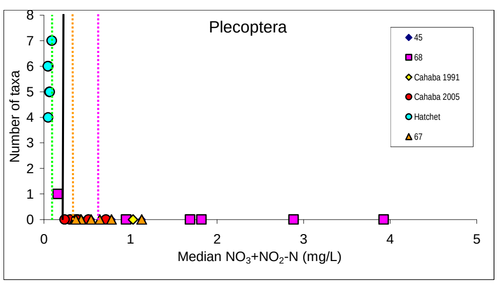
- 45
- 67
- 68
- Cahaba 1991
- Cahaba 2005
- Hatchet

- Piedmont (45) Ecoregional Guideline
- Ridge and Valley (67) Ecoregional Guideline
- Southwestern Appalachin (68) Ecoregional Guideline
- Visually-estimated concentration at which metric results indicate a decline in biological conditions.
- 2006 Cahaba River Total Phosphorus target

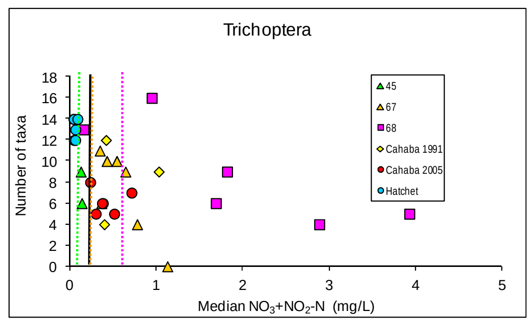
Annual median NO_3+NO_2-N (mg/L)



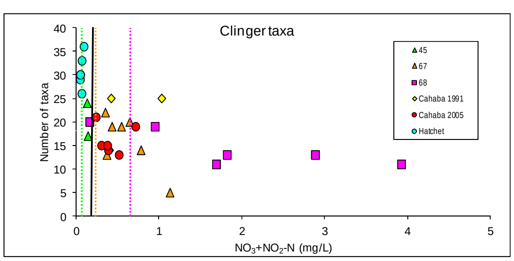
Annual median NO_3+NO_2-N (mg/L)



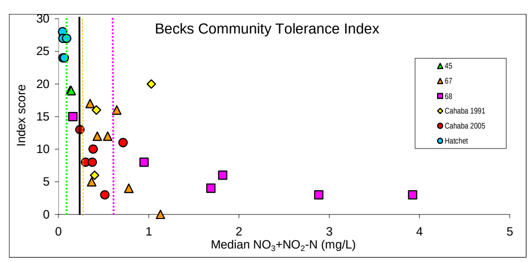
Annual median NO_3+NO_2-N (mg/L)



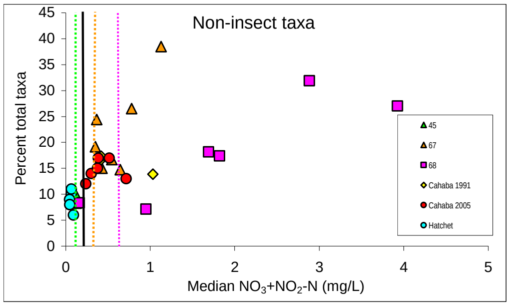
Annual median NO_3+NO_2-N (mg/L)



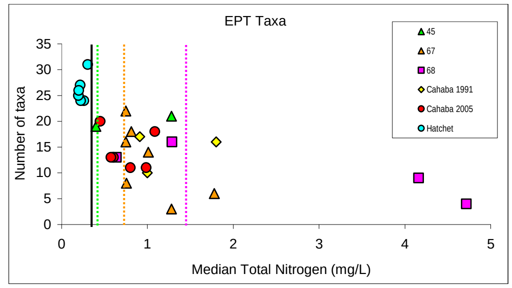
Annual median NO_3+NO_2-N (mg/L)



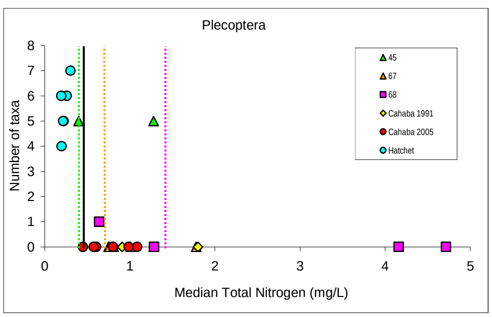
Annual median NO_3+NO_2-N (mg/L)



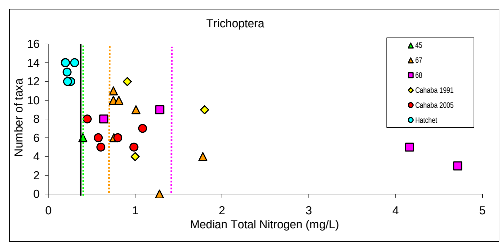
Annual median Total Nitrogen (mg/L)



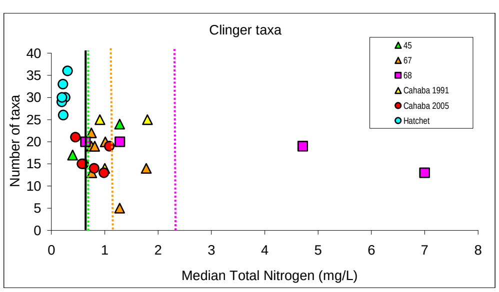
Annual median Total Nitrogen (mg/L)



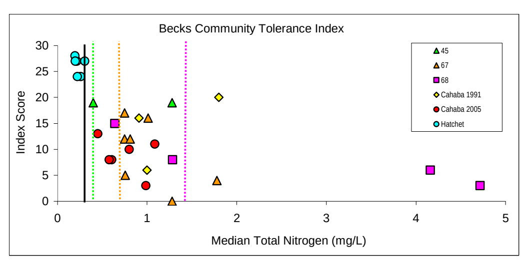
Annual median Total Nitrogen (mg/L)



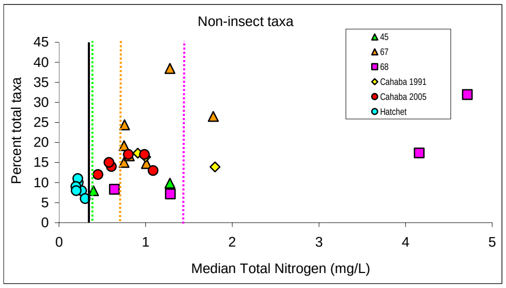
Annual median Total Nitrogen (mg/L)



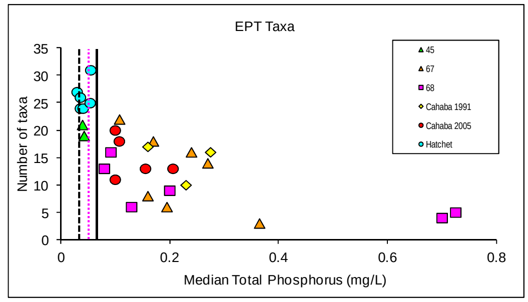
Annual median Total Nitrogen (mg/L)



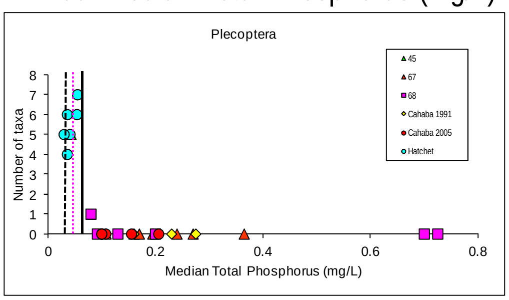
Annual median Total Nitrogen (mg/L)



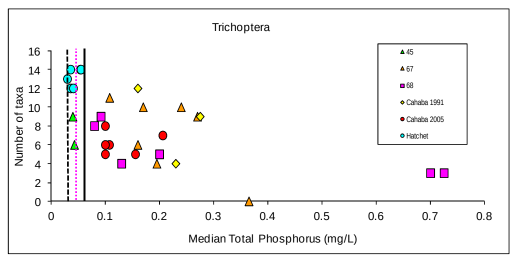
Annual median Total Phosphorus (mg/L)



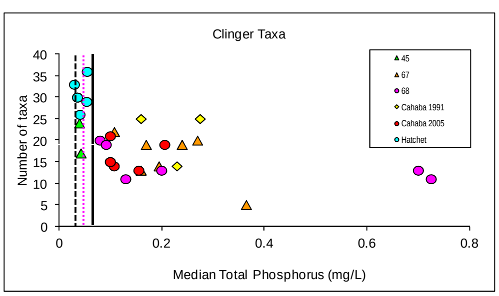
Annual median Total Phosphorus (mg/L)



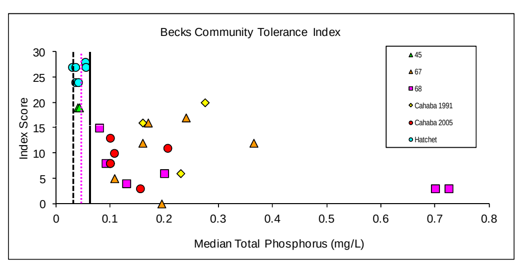
Annual median Total Phosphorus (mg/L)



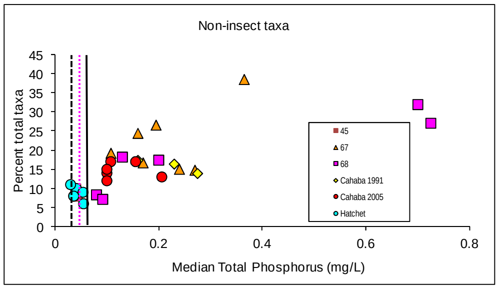
Annual median Total Phosphorus (mg/L)



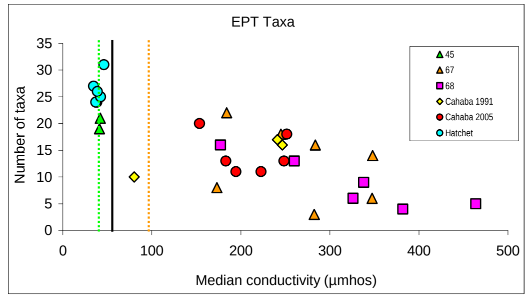
Annual median Total Phosphorus (mg/L)



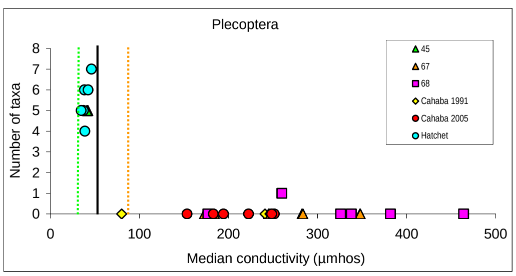
Annual median Total Phosphorus (mg/L)



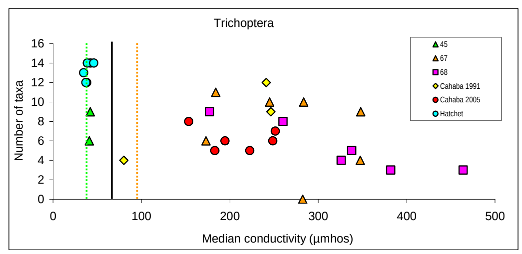
Annual median Conductivity (µmhos)



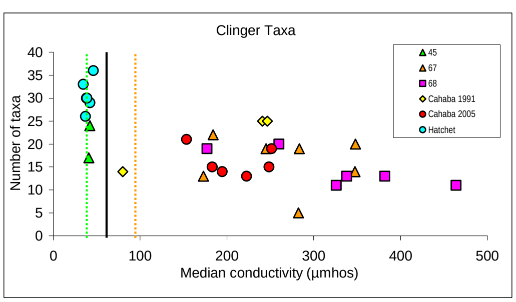
Annual median Conductivity (µmhos)



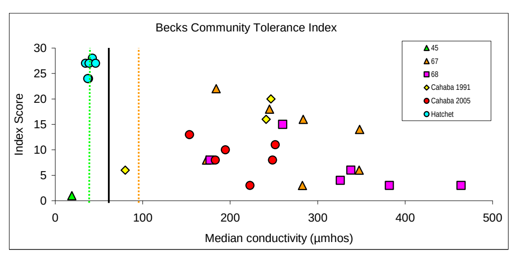
Annual median Conductivity (µmhos)



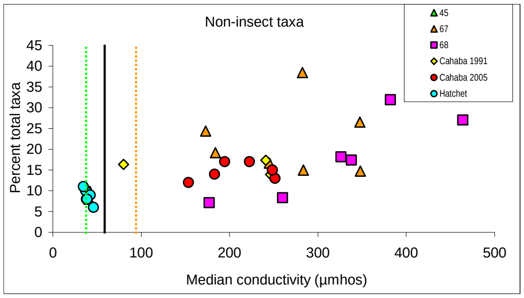
Annual median Conductivity (µmhos)



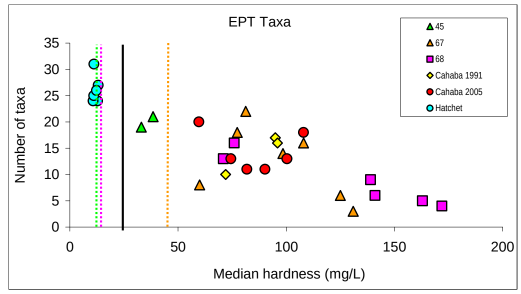
Annual median Conductivity (µmhos)



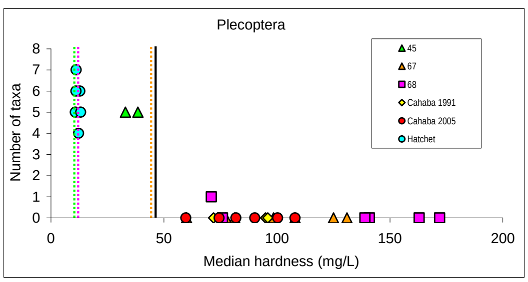
Annual median Conductivity (µmhos)



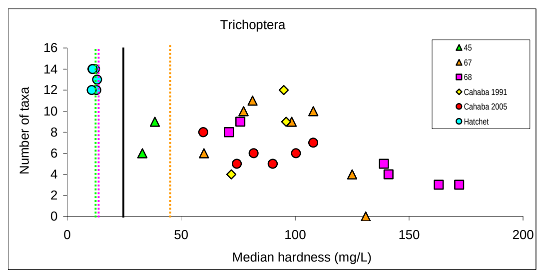
Annual median hardness (mg/L)



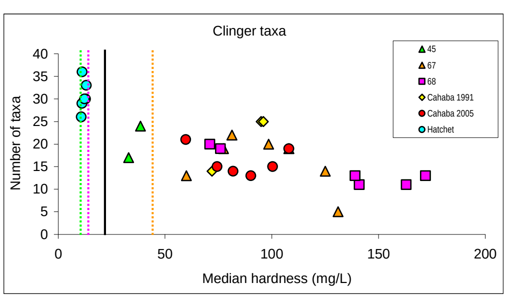
Annual median hardness (mg/L)



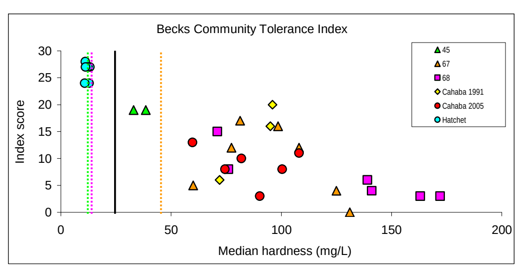
Annual median hardness (mg/L)



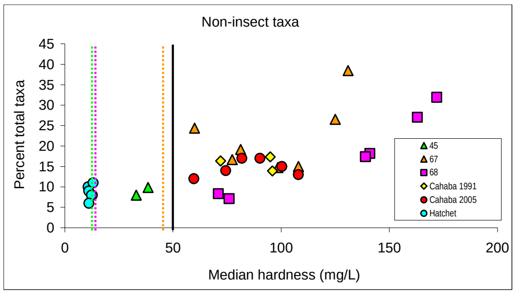
Annual median hardness (mg/L)



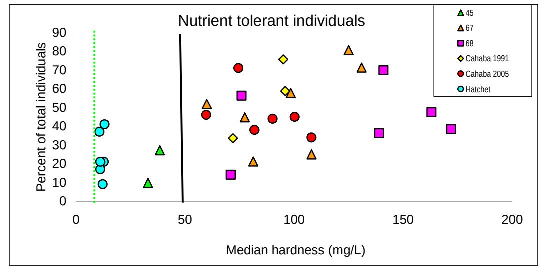
Annual median hardness (mg/L)



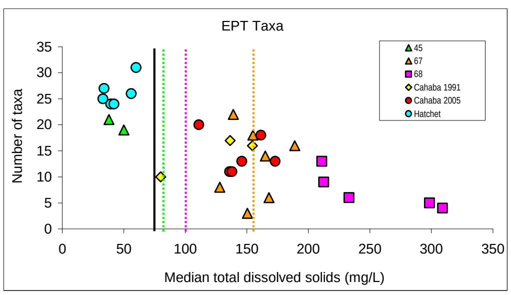
Annual median hardness (mg/L)



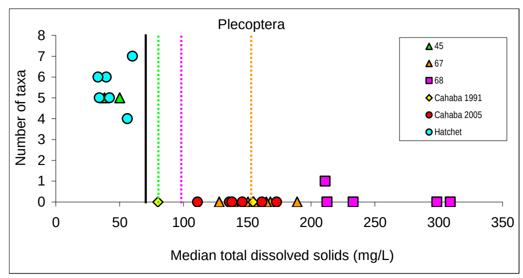
Annual median hardness (mg/L)



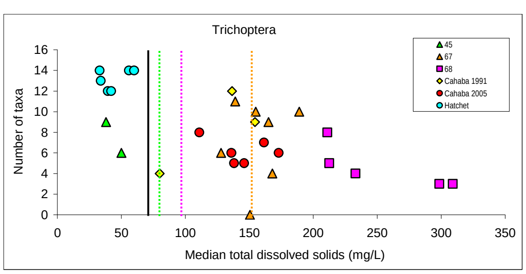
Annual median Total Dissolved Solids (mg/L)



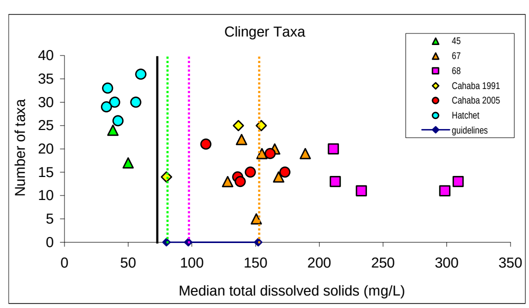
Annual median Total Dissolved Solids (mg/L)



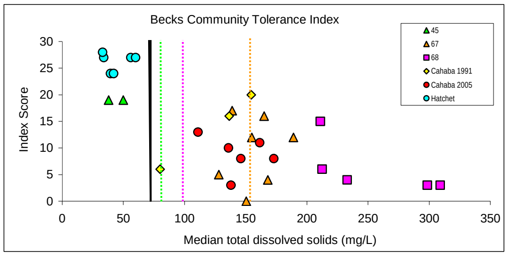
Annual median Total Dissolved Solids (mg/L)



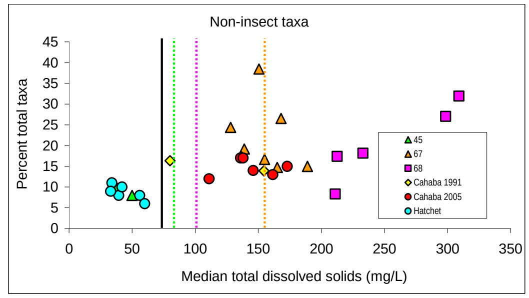
Annual median Total Dissolved Solids (mg/L)



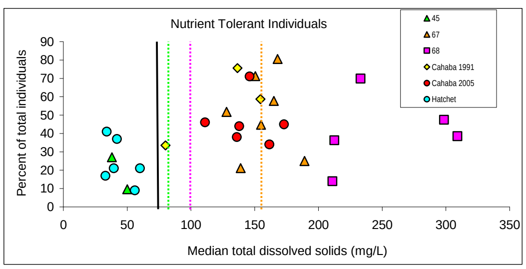
Annual median Total Dissolved Solids (mg/L)



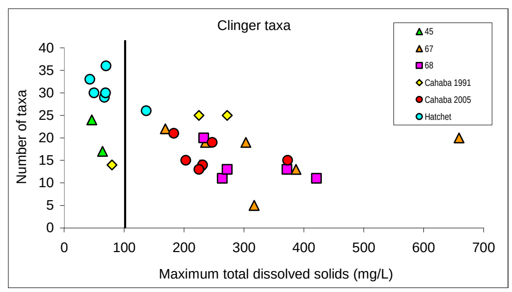
Annual median Total Dissolved Solids (mg/L)



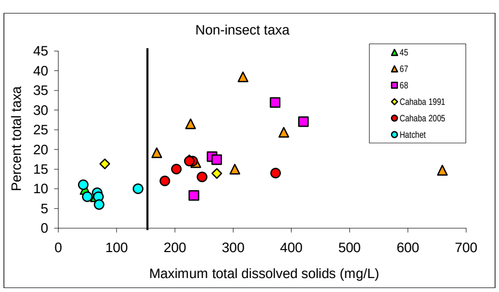
Annual median Total Dissolved Solids (mg/L)



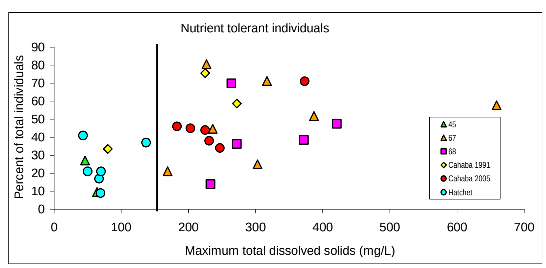
Annual maximum Total Dissolved Solids (mg/L)



Annual maximum Total Dissolved Solids (mg/L)

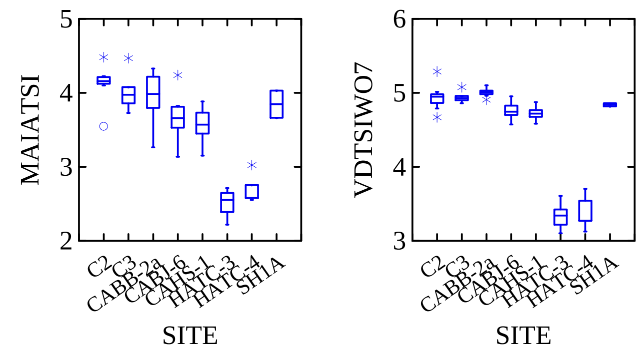


Annual maximum Total Dissolved Solids (mg/L)

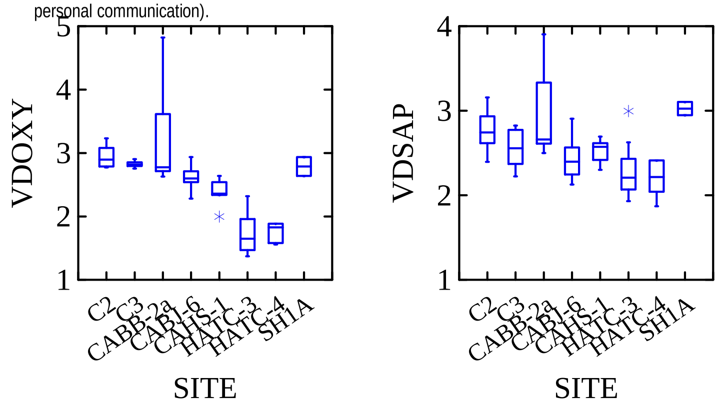


Appendix K. Selected metric results from the 2004 and 2005 diatom community assessments

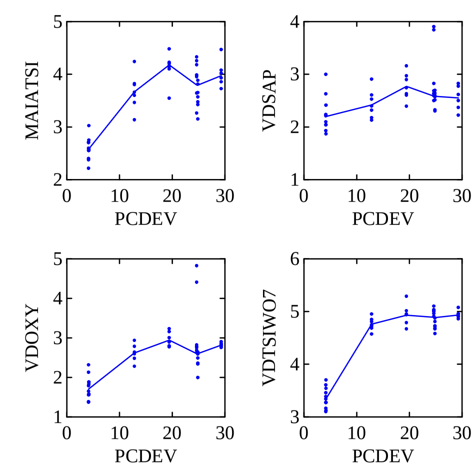
Mid-Atlantic Status Index (MAIATSI): Developed using data from a large probabilistic monitoring study in the mid-Atlantic Highlands. It uses species abundance and total phosphorus optima categories to place each site into one of six categories, with category one being most sensitive to enriched conditions and category six being more tolerant of enriched conditions.
Van Dam Trophic Status Index (VDTSIW07): Similar to the MAIATSI, but less sensitive to differences among sites at higher concentrations (J. Stevenson, personal communication).



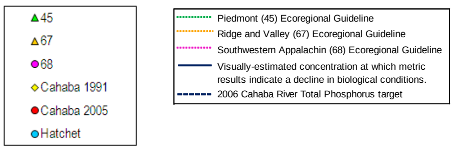
Van Dam Oxygen Tolerance Index (VDOXY): Many diatom species have been assigned to an oxygen requirement category. The index has five categories, with Category 1 species requiring close to 100% DO saturation and Category 5 requiring 10% saturation or less.
Van Dam Saprobic Index (VDSAP): The Van Dam Saprobic Index has 5 categories describing a species' ability to live in an organic rich environment lacking O2 (high BOD, low O2), with 1 being high o2 saturation and relatively low BOD and 5 being low O2 saturation and high BOD. (J. Stevenson, personal communication).



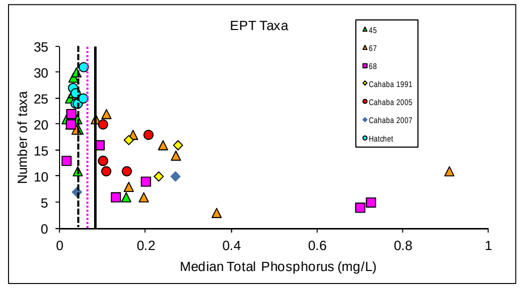
Diatom Response To Development (PCDEV=% Developed Land): Results from Cahaba and Hatchet sites versus percent developed land (PDDEV)



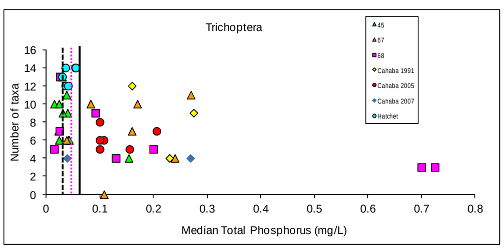
Appendix L-2. Relationship between untransformed water quality data and metric results from the twelve 2005 Cahaba River (Cahaba 2005) and Hatchet Creek (Hatchet) bioassessments and fifteen historical bioassessments conducted at eleven large, riffle-run streams. All macroinvertebrate bioassessments were conducted between July and October within the Piedmont (45), Ridge and Valley (67), and Southwestern Appalachians (68) ecoregions. Sixteen additional bioassessments conducted during 2005, 2007, and 2010 at eleven addition stations are also included. The 2004 Cahaba River total phosphorus target and the 2010 ecoregional reference guidelines for each parameter are also shown.



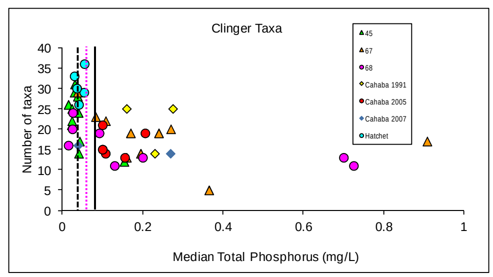
Annual median Total Phosphorus (mg/L)



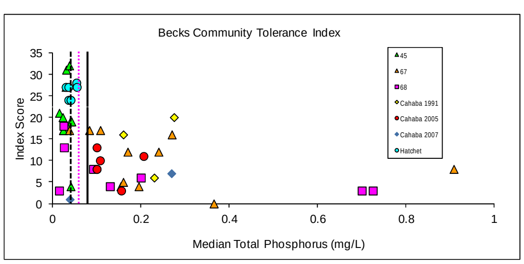
Annual median Total Phosphorus (mg/L)



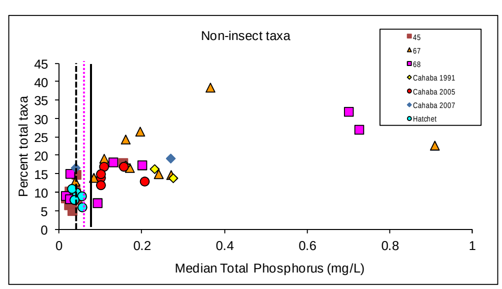
Annual median Total Phosphorus (mg/L)



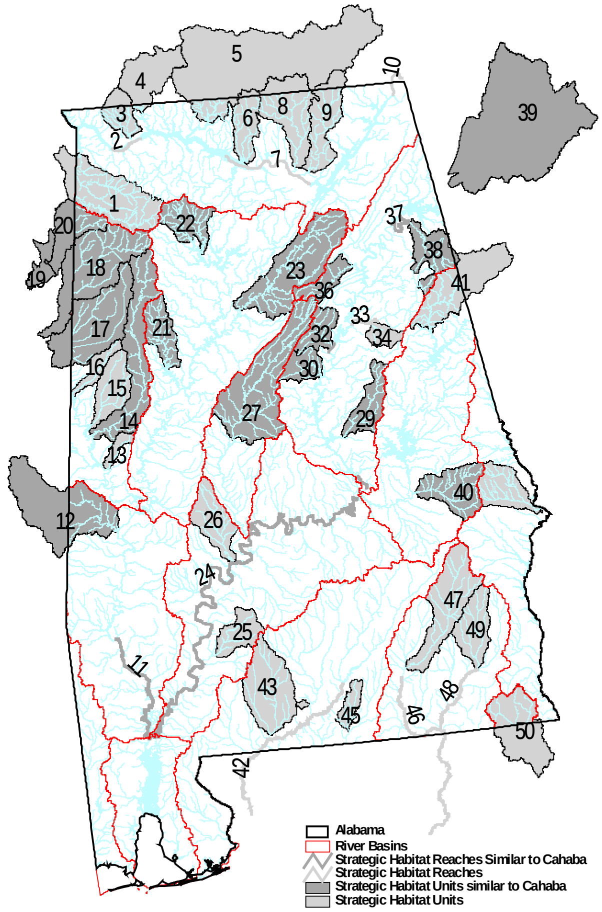
Annual median Total Phosphorus (mg/L)



Annual median Total Phosphorus (mg/L)



Appendix M-1. Strategic habitat units and river reaches identified as critical habitat for endangered, threatened of priority species (Wynn et al. 2012)



Unit #	Waterbody Name
Middle Tennessee-Elk (0603) subregion	
1	Bear Creek
2	Tennessee River-Wilson dan tailwater
3	Cypress Creek
4	Shoal Creek
5	Elk River
6	Limestone, Piney, Beaverdam Creeks
7	Tennessee River-Guntersville dam tailwater
8	Flint River
9	Paint Rock River
10	Tennessee River-Nickajack dam tailwater
Mobile-Tombigbee (0316) subregion	
11	Lower Tombigbee River
12	Sucarnoochee River
13	Trussels Creek
14	Sipsey River
15	Lubbub Creek
16	Coalfire Creek
17	Luxapalila Cfreek
18	Buttahatchee River
19	East Fork Tombigbee River
20	Bull Mountain Creek
21	North River
22	Sipsey Fork
23	Locust Fork

Unit #	Waterbody Name
Alabama River (0315) subregion	
24	Alabama River
25	Big Flat Creek
26	Bogue Chitto Creek
27	Upper Cahaba River
28	Coosa River downstream Jordan dam
29	Hatchet Creek
30	Yellowleaf Creek
31	Coosa River downstream Logan Martin dam
32	Kelly Creek
33	Lower Choccolocco Creek
34	Cheaha Creek
35	Shoal Creek
36	Big Canoe Creek
37	Weiss Lake bypass (Dead River)
38	Terrapin Creek
39	Upper Coosa tributaries
40	Uphapee, Choctafaula, Chewacla Cr.s
41	Tallapoosa River
42	Conecuh River
Choctawhatchee-Escambia (0314)/ Apalachicola (0313) subregions	
43	Murder Creek
44	Amos Mills Creek
45	Five Runs Creek
46	Pea River
47	Upper Pea River
48	Choctawhatchee River
49	West Fork Choctawhatchee River
50	Chipola River
51	Uchee Creek

Appendix M-2. Strategic habitat units and river reaches identified as critical habitat for ≥5 of the same endangered, threatened or priority species as the Upper Cahaba River (Wynn et al. 2012)

Species		Conservation status		Mobile-Tombigbee (0316) subregion										Alabama River (0315) subregion													
Scientific name	Common name	USFWS	Alabama	11	12	14	17	18	19	20	21	22	23	24	26	27	28	29	30	31	32	33	36	37	38	39	40
Mussels																											
Elliptio arca	Alabama Spike		P1	H	H	X	X	X		X		H	H	H		H			X	H				H	X	X	
Elliptio arctata	Delicate Spike		P1	H	H	X		X		H	X	H	H	X		X							X		X	H	
Epioblasma metastriata	Upland Combshell	E	Ex										H			H				H		H	H	H		H	
Epioblasma othcaloogensis	Southern Acornshell	E	Ex													H			H	H	H	H	H		H	H	
Epioblasma penita	Southern Combshell	E	P1	H				X	H					H		X	H			H			H			H	
Hamiota altilis	Finelined Pocketbook	T	P2											H	X	X	X	X	X	H	X	X	X	X	X	X	X
Hamiota perovalis	Orangenacre Mucket	T	P2		X	X	X	X	X	X	X	X	X		X	X											
Lasmigona etowaensis	Etowah Heelsplitter		P2													X			X						X	X	
Ligumia recta	Black Sandshell		P2			X			X					H		H											
Medionidus acutissimus	Alabama Moccasinshell	T	P2	H		X	X	X	H	H	X	X	H	H		H	X	X		H		H	H	H		X	H
Pleurobema decisum	Southern Clubshell	E	P2	H		X	X	X	X	X	H	H		X	X	X	X	H	X	X	X	X	X	X	X	X	X
Pleurobema perovatum	Ovate Clubshell	E	P1	H	X	X	X	H	H	X	H			H	X	X											X
Potamilus inflatus	Inflated Heelsplitter	T	P2	X					X					X		H											
Ptychobranchus foremanianus	Rayed Kidneyshell	E	P1													X	H		X		X	H	X	H	X	X	
Snails																											
Clappia cahabensis	Cahaba Pebblesnail		P1													X											
Elimia ampla	Ample Elimia		P2													X											
Elimia annettae	Lilyshoals Elimia		P2													X											
Elimia bellacrenata	Princess Elimia		P1													X											
Elimia cochliaris	Cockle Elimia		P1													X											
Elimia compacta	Oblong Elimia		P1													X											
Elimia showalteri	Compact Elimia		P2													X											
Elimia varians	Puzzle Elimia		P2													X											
Elimia variata	Squat Elimia		P2													X											
Leptoxis ampla	Round Rocksnail	T	P2													X											
Lepyrium showalteri	Flat Pebblesnail	E	P1													X											
Lioplax cyclostomaformis	Cylindrical Lioplax	E	P1													X											
Marstonia sp.	Cahaba Pyrg		P1													X											
Rhodacmea cahabensis	Cahaba Ancylid		P1													X											
Fishes																											
Acipenser oxyrinchus desotoi	Gulf Sturgeon	T	P2	X										X		H	H			H							
Cyprinella caerulea	Blue Shiner	T	P2													H						X				X	
Notropis cahabae	Cahaba Shiner	E	P1										X			X											
Noturus munitus	Frecklebelly madtom		P2			X	X	X		X				X		X										X	
Percina aurolineata	Goldline Darter	T	P1													X										X	
Percina brevicauda	Coal Darter		P2										X			X		X									
Reptiles and Amphibians																											
Macrochelys temminckii	Alligator Snapping Turtle		P2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Farancia erytrogramma	Rainbow Snake		P2													X											
# of SHU/SHR targeted spp in common with the Cahaba R.				9	5	9	7	9	8	8	6	6	8	12	5	36	7	5	7	9	5	8	9	7	8	14	5

Ex-Extirpated, E-Endangered, T-Threatened, H-Historic, I-Introduced, P1-Highest Conservation Concern, P2-High Conservation Concern