GEOLOGICAL SURVEY OF ALABAMA

Berry H. (Nick) Tew, Jr.
State Geologist

WATER INVESTIGATIONS PROGRAM

HABITAT AND BIOLOGICAL ASSESSMENT OF THE TERRAPIN CREEK WATERSHED AND DEVELOPMENT OF THE INDEX OF BIOTIC INTEGRITY FOR THE COOSA AND TALLAPOOSA RIVER SYSTEMS

OPEN-FILE REPORT 0601

by

Patrick E. O’Neil, Thomas E. Shepard, and Marlon R. Cook

This report was prepared in cooperation with the
Alabama Department of Conservation and Natural Resources
Wildlife and Freshwater Fisheries Division

Tuscaloosa, Alabama
2006

TABLE OF CONTENTS

PART 2a: BIOLOGICAL AND HABITAT ASSESSMENT OF THE TERRAPIN CREEK WATERSHED

PART 2b: SURFACE WATER-QUALITY ASSESSMENT OF THE TERRAPIN CREEK WATERSHED

TABLES

ILLUSTRATIONS

ABSTRACT

The Geological Survey of Alabama in conjunction with the Alabama Department of Conservation and Natural Resources, Wildlife and Freshwater Fisheries Division, conducted a study from 2003 through 2005 with three objectives: 1) Determine optimum fish community sampling effort needed for consistent, representative, and cost-effective results applicable to the Index of Biotic integrity (IBI); 2) Develop IBI metrics and scoring criteria calibrated to conditions in the Coosa and Tallapoosa River systems in Alabama; and 3) Conduct a biological, habitat, and water-quality study in the Terrapin Creek watershed to demonstrate the newly calibrated IBI and evaluate water-quality conditions of lower Terrapin Creek as it enters the Dead River (Weiss Bypass). Sampling for the project initiated in the Terrapin Creek watershed in 2003 and expanded to other Coosa River and Tallapoosa River tributaries in 2004-05.

Results of the sampling study showed that collecting effort should be stratified over four habitat types (riffles, runs, pools, and shorelines). A minimum of 10 sampling efforts, devoted to each of riffles, runs, and pools plus two shoreline efforts for a total of “30+2" sampling efforts, were determined sufficient to yield a sample compatible for use with the IBI.

Thirty-eight candidate metrics were evaluated for use in the Coosa-Tallapoosa IBI and 12 metrics were selected for use, consistent with the original intent and formulation of the IBI for midwestern streams. Six metrics were in the species richness and composition category: number of native fish species, number of darter species, number of native minnow species, number of sucker species, number of intolerant species, and proportion as tolerant species. Three metrics were in the trophic composition category: proportion as omnivores and herbivores, proportion as invertivores, and proportion as top carnivores. Three metrics were in the reproduction, abundance, and fish condition category: proportion as non-lithophilic spawners, average catch per unit of effort, and proportion with deformities, lesions, tumors + proportion as hybrids.

An assessment of biological and habitat conditions in the Terrapin Creek system was conducted as part of this project to demonstrate applicability of the IBI in a watershed investigation. Terrapin Creek was chosen for the assessment because it is

important as a source of stream flow, and potential recolonization source of aquatic organisms, for the Dead River section of the Coosa River. The assessment was conducted employing the sampling methodology and IBI metrics and scoring criteria developed in this study. Fish samples were collected at 19 stations and habitat condition was visually evaluated at each station using standard U.S. EPA habitat forms. The water-quality parameters of temperature, dissolved oxygen, specific conductance, and pH were measured at each station. Four of the nineteen stations were selected for long-term study and were sampled once in each of the three years of this study.

Fish sampling in the Terrapin Creek system produced 45 species and two hybrids. Biological condition was rated as good at only two stations, fair at 13 stations, and poor at four stations. Both stations with good condition were located in mostly forested watersheds and had high habitat scores. Agricultural activities in the northern (downstream) part of the watershed have degraded habitat condition and biological communities at stations in the main channel and some tributaries. Poor biological condition at one tributary station in the southeastern part of the watershed was likely related to sedimentation from a nearby clear cut area.

Contaminants that are causing water-quality impairments in lower Terrapin Creek are sediment, nutrients, and bacteria. Sediment loads were primarily composed of suspended material with the annual sediment load near the mouth of 72 tons per square mile of drainage area per year. Nitrate concentrations near the mouth were less than 0.5 mg/L for all nine samples collected. The nitrate load estimated for the downstream station was 0.54 tons per square mile of drainage area per year. Total phosphorus concentrations exceeded a critical limit of 0.05 mg/L in four of nine samples collected from the downstream station and the orthophosphate load was 0.07 tons per square mile of drainage area per year. The single sample fecal coliform limit of 2,000 colonies per 100 mL was exceeded in 3 of 6 samples collected at the downstream station. Water samples were also analyzed for a suite of metallic, inorganic nonmetallic, and organic constituents, and none of these constituents were detected in significantly high concentrations.

INTRODUCTION

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

The concept of "rapid biological assessment" requires the time-efficient analysis of stream conditions at a relatively low cost. Assessments must characterize the existence and severity of impairment to water-use classifications, help identify the sources and causes of water-use impairment, evaluate the effectiveness of actions to control water pollution, support water-use attainability studies, and characterize regional biotic components (Plafkin and others, 1989). In conjunction with chemical/physical water-quality measurements and analysis of habitat quality and condition, the biological assessment is an effective tool for assessing and managing water quality within the ecoregion concept. The most widely used approach for biological assessment is sampling and analysis of the macroinvertebrate community using the RBP-III methodology (Plafkin and others, 1989; Barbour and others, 1999) or some variation thereof. Assessment of the fish community is another water-quality tool that is rapidly becoming available in many states as more and more questions are being asked of biological data to screen, assess, regulate, and manage water resources.

Assessing the biological condition of streams using the fish community has distinct advantages over the use of other aquatic groups.

- ♦ Fishes occupy the range of positions throughout the food chain such as herbivores, carnivores, piscivores, omnivores, insectivores, and planktivores, thereby integrating a variety of watershed functions and conditions into their community trophic structure.

- ♦ Fishes are generally present in all but the most polluted waters.

- ♦ Because fishes are relatively long-lived compared to macroinvertebrates and generally spawn for a confined period in a year, their population numbers and fluctuations are more stable over longer periods of time.

- ♦ Compared to diatoms and macroinvertebrates, fishes are relatively easy to identify. Species identification for all individuals collected is possible and, if desired, individuals can be identified by a trained fisheries biologist and released at the field station. If samples are returned to the laboratory they can be sorted, identified, and data sheets prepared relatively quickly allowing several samples to be processed in a day.

- ♦ Technician training is easier with fishes than with macroinvertebrates because fish are larger and easier to see and can be identified more readily than macroinvertebrates. Alabama has around 300 freshwater fish species compared to several thousand macroinvertebrate species.

- ♦ Environmental requirements of fishes are relatively well known for a majority of species. Life history information is extensive for many species and detailed distributional information is becoming more available with time.

- ♦ Water-quality standards, legislative mandates, and public opinion are more directly related to the status of a lake or stream as a fishery resource. One goal of the Clean Water Act is to make waters “fishable and swimmable,” a directly measurable and attainable concept. Public perception of streams, pollution, and water quality monitoring is linked closely with fish because of their value as a food source and as a recreational resource.

The Index of Biotic Integrity (IBI) was proposed by Karr (1981) as a method to rapidly, efficiently, and directly assess the quality of water resources based on the condition of the fish community. Karr and Dudley (1981) defined biological integrity as the ability of an aquatic ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitats within a region. As originally conceived by Karr, the IBI compared 12 measured characteristics of a stream’s fish community with values of these characteristics that would be expected in a similar-sized stream in the same geographic area with minimal human impacts (Angermeier and Karr, 1986). The 12 characteristics, or metrics as they are termed in the IBI, were divided between three broad ecological categories of species richness and composition, trophic composition, and fish abundance and condition. Karr and others (1987) demonstrated that the IBI performed more consistently than the Shannon-Weiner diversity index or individual community metrics at ranking stations and identifying impaired stations and that the IBI reliably reflected known habitat and water quality perturbations.

Many modifications of the original metrics have been developed by applying the IBI in areas outside the Midwest. In reviewing many of these studies, Miller and others (1988) found that the IBI was applicable to a range of stream sizes with varying levels of habitat and water quality degradation. They also noted that the addition or deletion of metrics or modification of scoring criteria for individual metrics did not compromise the responsiveness of the IBI to environmental perturbations when careful consideration was given to maintaining the basic ecological foundation of the technique. The IBI has successfully been adapted to many warmwater stream systems in North America (Karr and others, 1986; Miller and others, 1988; Georgia Department of Natural Resources, 2005) as well as varied habitats such as cold-water streams (Leonard and Orth, 1986; Lyons and others, 1996), reservoirs (Hickman and McDonough, 1996), and large rivers (Ohio EPA 1987a). Hughes and Oberdorff (1999) reviewed 10 applications of the IBI on six continents outside of the U.S. and Canada and found that IBI concepts based on assemblage and community ecology could successfully be applied to all six continents inhabited by freshwater fish.

In Alabama, the IBI has been used by the Tennessee Valley Authority (TVA) in fixed station sampling in the Tennessee River basin since 1986 (Saylor and Ahlstedt, 1990). The IBI has also been used by the Geological Survey of Alabama (GSA) to help interpret conditions in the upper Cahaba River system (Shepard and others, 1997), lower Cahaba River system (O'Neil and Shepard, 2000a), the upper Black Warrior River system (O'Neil and Shepard, 2000b; Shepard and others, 2002; Shepard and others 2004), Hatchet Creek (O'Neil and Shepard, 2004), Choccolocco Creek (O'Neil and Chandler, 2005), and the Choctawhatchee-Pea River system (Cook and O'Neil, 2000). The IBI was also applied by Davenport and others (2005) in the upper Cahaba River system. The Alabama Department of Environmental Management (ADEM) uses the IBI for stream screening assessments in their water-quality monitoring activities (ADEM, 1999a).

Although the IBI has been successfully applied in selected drainages in Alabama, several obstacles remain if a biomonitoring method based on the fish community is to be applied statewide for assessing streams and stream habitat.

- ♦ A standardized wadeable stream sampling protocol must be created and adopted for use. Future research will be needed to explore lake, reservoir, and nonwadeable river sampling protocols.

- ♦ The IBI has not been calibrated statewide to Alabama's high fish biodiversity and variable ecological and physiographic regions.

Ecoregional and(or) drainage-specific scoring criteria will need to be determined for most of Alabama's waters.

- ♦ Application of the IBI requires accurate species identifications by well-trained individuals. Any organization applying the IBI in Alabama should consider the benefits of "green" sampling (i.e. non-destructive sampling) with identifications made on site and collected fishes returned to the stream.

- ♦ A standardized list of ecological, reproductive guild, and tolerance guild designations for all species of fishes in the state needs to be adopted.

- ♦ Ecoregional and (or) drainage reference sites should be established and sampled systematically over time. The Alabama Department of Environmental Management (ADEM) has already established ecoregional reference sites for their macroinvertebrate program, and these sites need to be sampled for fishes on a prescribed basis.

In 2002 the GSA began a cooperative study with the Alabama Department of Conservation (ADCNR) Wildlife and Freshwater Fisheries Division (WFFD) to explore some of these issues of IBI implementation. Three objectives of this study were to (1) determine optimum fish community sampling effort needed for consistent, representative, and cost-effective results applicable to the Index of Biotic integrity (IBI); (2) develop IBI metrics and scoring criteria calibrated to conditions in the Coosa and Tallapoosa River systems in Alabama; and (3) conduct a biological, habitat, and water-quality study in the Terrapin Creek watershed to demonstrate the newly calibrated IBI and evaluate water-quality conditions of lower Terrapin Creek as it enters the Dead River (Weiss Bypass). Teels and Danielson (2001) published a paper outlining an application of the IBI to a Virginia watershed which was a succinct outline for the IBI development process. We have followed some of their approach in preparation of this report.

ACKNOWLEDGMENTS

Many individuals assisted with project design, field sampling, and data analysis throughout this project. Nick Nichols of WFFD was instrumental in design of the project and coordinated funding through the Wildlife Conservation and Restoration Program. Steve Rider, also of WFFD, has consistently provided encouragement of IBI development, promoted biomonitoring concepts, and assisted with field sampling. Many individuals have assisted with field sampling and we appreciate their contributions. These individuals included Travis Powell, Phillip Jessie, Dan Catchings, Rob Andress, and Kevin Baswell of WFFD; and Brett Smith, Eric Mullins, Stuart McGregor, Neil Moss, John Koster, Blakeney Gillett, and Phillip Henderson of GSA; David Thompson, Chris Johnson, Lee Davis, Michael Len, and Rick Dowling of ADEM assisted with sampling in Hatchet Creek. David Thompson also provided ADEM data and results of his analysis of the human disturbance gradient for the Coosa and Tallapoosa River systems. Phillip Henderson of GSA assisted with GIS analyses and map preparation. Jeff Gardner of the U.S. Forest Service provided permission to sample streams in the Talladega National Forest, Shoal Creek Ranger District, and Mary Shew of the National Park Service facilitated our sampling at a station in the Little River Canyon National Preserve. We also wish to acknowledge the contributions of Charlie Saylor, Amy Wales, Bob Wallus, and all other Tennessee Valley Authority sampling crews, to stream biomonitoring in the southeast, in particular the Tennessee River Valley. Our work with these individuals over the years has been instrumental in forging our ideas about sampling and the effectiveness of the IBI is as a water-quality monitoring tool.

The IBI concepts and sampling methods that originated out of this study were presented at a stream sampling workshop held on May 25, 2005. Several biologists from ADCNR, ADEM, and GSA attended with the common goal of initiating standardized stream sampling methods, compatible for use with the IBI, for state government fish biomonitoring programs. Many thanks to Steve Rider for help organizing the workshop and to Chris Greene, Damon Abernathy, and all in the WFFD District 4 office for local arrangements.

STUDY AREA

The Coosa River is the largest tributary of the Alabama River and extends from the headwaters in southeastern Tennessee to its junction with the Tallapoosa River at Fort Toulouse near Montgomery. In spite of the high degree of habitat alteration in the main stem of the Coosa, the system as a whole still supports a high diversity of aquatic organisms. Mettee and others (1996) report 147 fish species from the Coosa River system, highest of any tributary system in the Mobile Basin.

The Coosa and Tallapoosa Rivers drain approximately 14,836 square miles (mi^2) in Alabama and Georgia (fig. 1). About 64 percent of these two watersheds are in Alabama and 36 percent in Georgia (table 1). Slightly less than half of the Coosa's watershed is in Georgia with only about 14 percent of the Tallapoosa's headwaters originating in Georgia. The Coosa main channel flows for about 255 miles from the Georgia state line to its confluence with the Tallapoosa while the Tallapoosa flows for about 214 miles from the Georgia line before it joins the Coosa.

Table 1. Drainage areas for the Coosa and Tallapoosa River systems.

River system	Drainage areas (mi^2) and (percent)		
	Alabama	Georgia	Total
Coosa	5,400 (53)	4,761 (47)	10,161
Tallapoosa	4,024 (86)	651 (14)	4,675
Total	9,424 (64)	5,412 (36)	14,836

The main channel and lower portions of many tributaries to the Coosa have been extensively modified by dams which impound and alter the flow of nearly the entire length of the river for hydroelectric power generation, flood control, irrigation, recreation, and navigation (Alabama Water Watch Program, 2002). Over 70 percent of the main stem of the Coosa River is now impounded (Irwin and others, 2001) and the remainder

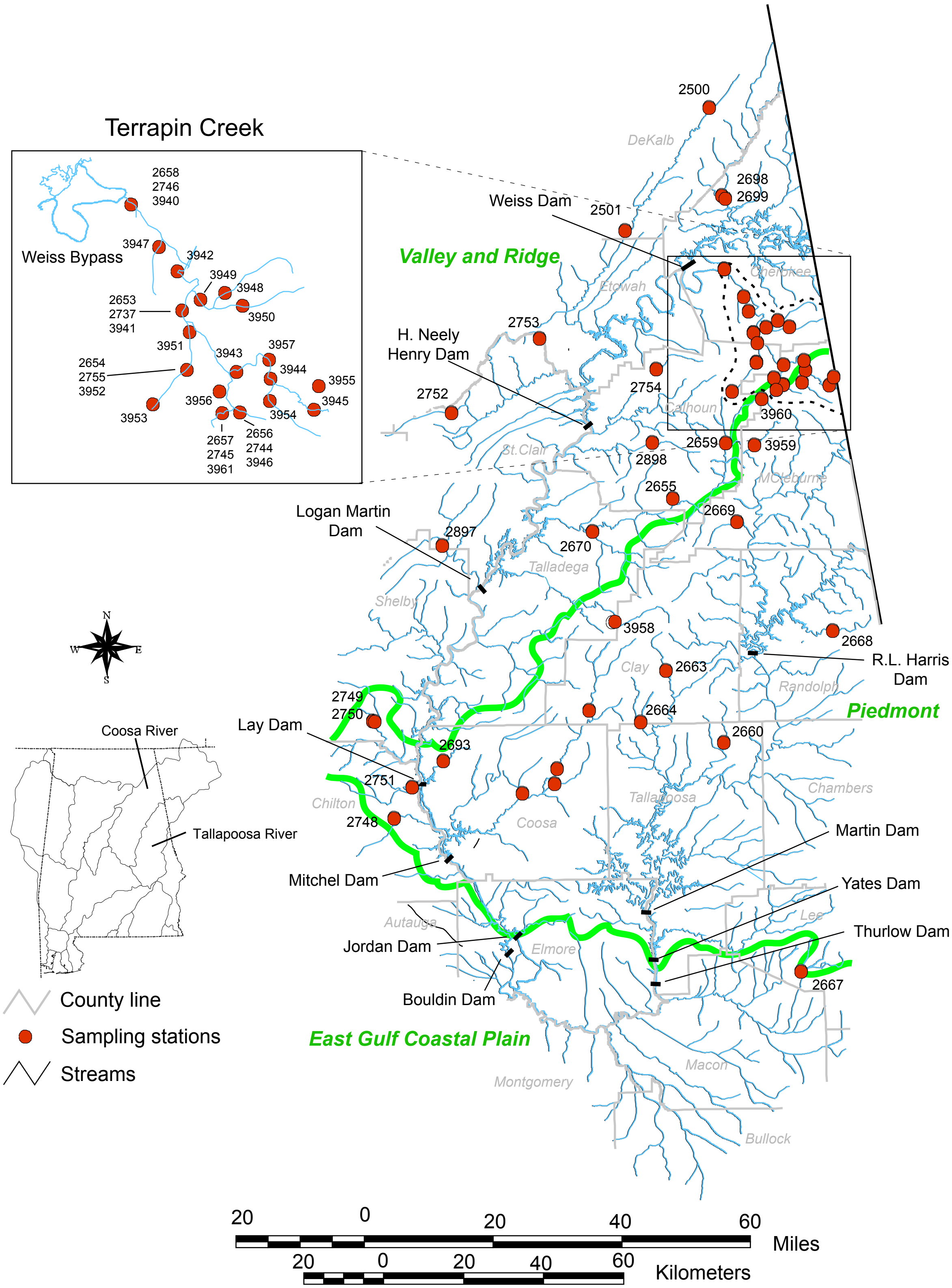


Figure 1. Study area in the Coosa and Tallapoosa River systems.

is affected by erratic peaking flows due to power generation. The Coosa River has for decades held the promise of river navigation and in the late 1800s the Federal Government appropriated funds for work on such a project and three locks were completed before the project was later abandoned. As the realities of hydroelectric power came to light, the Alabama Power Company capitalized on the Coosa's potential to provide hydroelectric power to Alabama and a series of dams were constructed. Lay Dam was constructed in 1914 followed by Mitchell Dam in 1923 and Jordan Dam in 1929. Construction activities were delayed during World War II, but later the Power Company completed Weiss Dam in 1962, Logan Martin Dam in 1964, and H. Neely Henry Dam in 1966.The Coosa River is not a navigable waterway for commercial traffic but it does support a viable recreation and lake cottage industry. Major tributaries to the Coosa moving downstream from north to south are Little River, Terrapin Creek, Big Wills Creek, Big Canoe Creek, Ohatchee Creek, Choccolocco Creek, Kelly Creek, Talladega Creek, Tallaseehatchee Creek, Waxahatchee Creek, Yellowleaf Creek, Hatchet Creek, and Weogufka Creek.

Like its sister the Coosa, the Tallapoosa River is not a navigable waterway but provides significant hydroelectric generating capacity and recreational opportunities. When Martin Dam was completed in 1926 it created one of the largest impoundments in Alabama. Further downstream, Yates Dam was completed in 1928 and Thurlow Dam in 1930. The last of the great hydroelectric dams on the Tallapoosa River was Harris, completed in 1982. Major tributaries to the Tallapoosa include Wedowee Creek, Chickasonoxee Creek, Emuckfaw Creek, Enitachopco Creek, Hillabee Creek, Sougahatchee Creek, and south of the Fall Line flow Uphapee Creek, Cubahatchee Creek, Line Creek, and Chubbehatchee Creek.

The upstream three-fourths of the Coosa River in Alabama flows through the limestone-rich Alabama Valley and Ridge physiographic section (equivalent to ecoregions 67g-Southern Shale Valleys, and 67f-Southern Limestone/Dolomite Valleys and Low Rolling Hills; Griffith and others, 2001) with a few streams along its northeast course originating in the Weisner Mountains and the metamorphic Northern Piedmont Upland physiographic districts (equivalent to ecoregions 67h-Southern Sandstone

Ridges, and 45d-Talladega Upland). Tributaries in the lower one-fourth of the system originate in the Northern Piedmont Uplands district to the east and in the Fall Line Hills district and the East Gulf Coastal Plain section and alluvial sediments to the south and west (equivalent to ecoregions 45a-Southern Inner Piedmont, and ecoregion 65i-Fall Line Hills). The Tallapoosa flows almost exclusively through the Piedmont (ecoregion 45) until it passes over the Fall Line and enters the alluvial sediments before joining with the Coosa to form the Alabama River.

ALABAMA VALLEY AND RIDGE

The Alabama Valley and Ridge consists of a series of folded and faulted parallel ridges and valleys that trend northeast-southwest with elevations generally ranging from 600 to 2,000 feet. Ridges are made of sandstone and chert while valleys are generally developed on limestone and shale. Seven districts are delineated in the Alabama Valley and Ridge including the Coosa Valley, Coosa Ridges, Weisner Ridges, Cahaba Valley, Cahaba Ridges, Birmingham-Big Canoe Valley and Armuchee Ridges. Over half of the area within the Valley and Ridge is occupied by the Coosa Valley. The Coosa Ridges district consists of a folded parallel ridge belt about 5 miles wide and 50 miles long extending across St. Clair and Shelby Counties. The district is characterized by parallel, linear sandstone ridges separated by shale valleys. The most prominent mountain ridges are Oak, Double Oak, and Backbone. Streams originating in the Coosa Ridges district drain to either the Coosa or Cahaba rivers and demonstrate a typical "trellised" drainage pattern where tributaries follow the strike of a formation as closely as possible, keeping on beds of softest rock and crossing the harder belts only occasionally. This pattern can be seen in streams such as Kelley Creek, Beaver Creek, and Shoal Creek.

The Coosa Valley district extends for about 100 miles from Cherokee to Chilton County averaging about 20 miles wide. The Coosa Valley is a plain underlain by shale and limestone with ridges of low relief. The primary drainage feature of the Coosa Valley is the Coosa River which is impounded along most of its length in Alabama. The common occurrence of the flame chub, mountain shiner, and blacknose dace in the Coosa and Tennessee Rivers suggests a past stream connection. The Weisner Ridges district consists of a series of dissected mountains of extreme relief rising above the

Coosa Valley some 900 feet. The Weisner Ridges extend for 40 miles from the Alabama-Georgia state line to Coldwater Mountain at Anniston.

PIEDMONT UPLAND

The Piedmont Upland section is a section of the "older Appalachians" as described by Fenneman (1938). This undulating plain is the result of long-term degradation of the surface rocks while the underlying rocks are severely deformed and angled to the surface. The Piedmont Upland section in Alabama is a wedge-shaped feature bounded on the south by coastal plain sediments and to the northwest by the Alabama Valley and Ridge. Piedmont geology is complex consisting of high- and low-grade metamorphic and igneous rocks including quartzite, phyllite, slate, schist, amphibolite, and gneiss. The Piedmont Upland section is divided into two districts, the Northern Piedmont Upland and the Southern Piedmont Upland. Elevations in the Northern Piedmont Upland generally range from 1,000 to 1,200 feet in the northeast and from 500 to 600 feet in the southwest part. The Talladega and Rebecca Mountains form a prominent northeast trending ridge system in the north part of the district with Cheaha Mountain the highest point in the state at 2,407 feet. The Tallapoosa River is the major system draining the Northern Piedmont Upland and is impounded extensively along its length for hydroelectric power generation. The lower reaches of the Coosa River, including Mitchell and Jordan Lakes, flows through the southern end and joins with the Coosa to form the Alabama River. Numerous small springs and clear upland streams occur throughout the Northern Piedmont Upland.

SAMPLING STATIONS

Data for evaluating the IBI sampling methodology, development of a Coosa and Tallapoosa IBI, and for evaluating the Terrapin Creek watershed were collected under a common sampling strategy. Forty-nine stations were sampled in the Coosa and Tallapoosa systems from 2003-05, with 59 total collections from these stations (table 2, fig. 1, appendix A). Nineteen stations were sampled in the Terrapin Creek system, 20 additional stations in the Coosa River system, and six stations in the Tallapoosa River system all upland of the Fall Line.

Table 2. Station location information for fish collections in the Coosa and Tallapoosa River systems, 2003-05

GSA No.	Station	Section, Township, Range	Latitude	Longitude	County	Date	Time	Area (sq mi)
2736	Hatchet Cr. @ McConnell Property	sec. 26, T. 23 N., R. 18 E.	32.9439	-86.2358	Coosa	5-Oct-04	1015-1330	238
2739	Socapatoy Cr. @ Co. Hwy. 69	sec. 22 T. 23 N., R. 19 E.	32.9656	-86.1496	Coosa	5-Oct-04	1500-1730	46
2737	Hatchet Cr. @ Dunham Property	sec. 11, T. 23 N., R. 19 E.	32.9998	-86.1425	Coosa	6-Oct-04	0920-1150	125
2738	Hatchet Cr. @ East Mill	sec. 7, T. 22 S., R. 6 E.	33.1305	-86.055	Clay	6-Oct-04	1325-1530	59.2
2748	Walnut Cr. @ Co. Hwy. 455	sec. 16, T. 22 S., R. 15 E.	32.89028	-86.57911	Chilton	9-Sep-04	0935-1220	35.0
2751	Yellow Leaf Cr. @ Co. Hwy. 55	sec. 14, T. 22N, R. 15 E.	32.95958	-86.53092	Chilton	10-Sep-04	1340-1525	77.9
2693	Paint Cr. @ Little Tom's Road	sec. 35, T. 24N, R. 16 E.	33.018333	-86.44731	Coosa	20-Jul-05	1605-1715	16.7
2750	Waxahatchee Cr. @ Co. Hwy. 42	sec. 22, T. 22 S., R. 1 E.	33.10869	-86.63039	Shelby	10-Sep-04	0930-1210	46.6
2749	Camp Branch @ Co. Hwy. 42	sec. 22, T. 22 S., R. 1 W.	33.10897	-86.63594	Shelby	9-Sep-04	1400-1600	30.3
3958	Talladega Cr. NE of Chandler Springs	sec. 36, T. 19 S., R. 6 E.	33.32803	-85.9904	Clay	19-Sep-03	0940-1115	53.7
2897	Kelly Cr. @ Lawley	sec. 33, T. 17 S., R. 2 E.	33.50486	-86.44722	St. Clair	14-Sep-04	0920-1120	85.8
2670	Cheaha Cr. @ Co. Hwy. 005	sec. 20, T. 17 S., R. 6 E.	33.53419	-86.04158	Talladega	5-Aug-05	0925-1100	109
2655	Snow Cr. @ Oxford Lake Park	sec. 29, T. 17 S., R. 8 E.	33.6075	-85.82481	Calhoun	28-Jul-05	1045-1230	18.7
2659	Choccolocco Cr. @ Ala. Hwy. 9	sec. 10, T. 15 N., R. 9 E.	33.73111	-85.6800	Calhoun	28-Jul-05	0815-0930	94.4
3959	Shoal Cr. @ Pine Glen Camp Ground	sec. 16, T. 15 S., R. 10 E.	33.72491	-85.60199	Cleburne	13-Aug-03	1310-1510	17.9
3960	Choccolocco Cr. @ Forest Road 540	sec. 10, T. 14 S., R. 10 E.	33.82975	-85.58167	Cleburne	7-Aug-03	1430-1635	5.53
2898	Cane Cr. upstream of U.S. Hwy. 431	sec. 11, T. 15 S., R. 7 E.	33.73408	-85.8783	Calhoun	1-Sep-04	0755-1100	30.6
2752	Big Canoe Cr. @ Co. Hwy. 31	sec. 22, T. 14 S., R. 2 E.	33.80456	-86.41961	St. Clair	29-Sep-04	1005-1220	37.3
2753	Little Canoe Cr. near U.S. Hwy. 11	sec. 24, T. 12 S., R. 4 E.	33.97097	-86.1805	Etowah/ St. Clair	29-Sep-04	1350-1600	22.3
2754	Ohatchee Cr. @ Mt. Gilead Road	sec. 13, T. 13 S., R. 7 E.	33.8988	-85.86497	Calhoun	30-Sep-04	0840-1125	21.5
2501	Big Wills Cr. @ Co. Hwy. 39	sec. 31, T. 9 N., R. 7 E.	34.213139	-85.945778	Dekalb	19-Aug-05	0920-1050	156
2500	Big Wills Cr. @ U.S. Hwy 11 in Fort Payne	sec. 29, T. 6 N., R. 9 E.	34.49267	-85.71419	DeKalb	18-Aug-05	1445-1615	35.6
2658	Terrapin Cr. @ Co. Hwy. 71	sec. 34, T. 10 S., R. 9 E.	34.12333	-85.67819	Cherokee	27-Jul-05	0750-0935	283

Table 2. Station location information for fish collections in the Coosa and Tallapoosa River systems, 2003-05--Continued

GSA No.	Station	Section, Township, Range	Latitude	Longitude	County	Date	Time	Area (sq mi)
2746	Terrapin Cr. @ Co. Hwy. 71	sec. 34, T. 10 S., R. 9 E.	34.12333	-85.67819	Cherokee	31-Aug-04	0900-1135	283
3940	Terrapin Cr. @ Co. Hwy. 71	sec. 34, T. 10 S., R. 9 E.	34.1234	-85.6782	Cherokee	18-Sep-03	1420-1630	283
3947	Little Cr. @ Co. Hwy. 14	sec. 19, T. 10E, R. 11 S.	34.0599	-85.6259	Cherokee	19-Aug-03	0940-1210	5.31
3942	Terrapin Cr. @ Co. Hwy. 175	sec.5, T. 12 S., R. 10 E.	34.02769	-85.61386	Cherokee	17-Sep-03	1545-1810	245
3948	Frog Cr. @ Co. Hwy. 12	sec. 12, T. 12 S., R. 10 E.	34.00494	-85.53433	Cherokee	28-Aug-03	0850-1035	19.2
3949	Hurricane Cr. @ Co. Hwy. 4	sec. 15, T. 12 S., R. 10 E.	33.99032	-85.56699	Cherokee	12-Jun-03	1020-1235	32.6
3950	Hurricane Cr. @ Co. Hwy. 8	sec. 17, T. 12 S., R. 11 E.	33.99069	-85.50361	Cherokee	19-Aug-03	1400-1555	22.9
2653	Terrapin Cr. @ Co. Hwy. 8	sec. 20, T. 12 S., R. 10 E.	33.97922	-85.60171	Cherokee	27-Jul-05	1040-1215	172
2747	Terrapin Cr. @ Co. Hwy. 8	sec. 20, T. 12 S., R. 10 E.	33.97922	-85.60171	Cherokee	31-Aug-04	1325-1600	172
3941	Terrapin Cr. @ Co. Hwy. 8	sec. 20, T. 12 S., R. 10 E.	33.97922	-85.60171	Cherokee	12-Aug-03	1410-1610	172
3951	Nances Cr. NE of Piedmont	sec.28, T. 12 S., R. 10 E.	33.9556	-85.59064	Calhoun	7-Aug-03	0950-1215	27.4
2654	Nances Cr. @ Babbling Brook Road	sec. 9, T. 13 S., R. 10 E.	33.91133	-85.59486	Calhoun	27-Jul-05	1315-1440	20.5
2755	Nances Cr. @ Babbling Brook Road	sec. 9, T. 13 S., R. 10 E.	33.91133	-85.59486	Calhoun	3-Sep-04	1255-1440	21.0
3952	Nances Cr. @ Babbling Brook Road	sec. 9, T. 13 S., R. 10 E.	33.91133	-85.59486	Calhoun	27-Aug-03	1545-1725	20.5
3953	Nances Cr. near Victory Baptist	sec. 2, T. 14 S., R. 9 E.	33.84675	-85.66125	Calhoun	28-Aug-03	1120-1330	7.69
3956	Tributary to South Fork Terrapin Cr.	sec. 24, T. 13 S., R. 10 E.	33.87636	-85.54781	Cleburne	18-Aug-03	1600-1755	1.68
2656	South Fork Terrapin Cr. @ Rabbittown Road	sec.30, T. 13 S., R. 11 E.	33.86053	-85.52238	Cleburne	26-Jul-05	1000-1205	18.3
2744	South Fork Terrapin Cr. @ Rabbittown Road	sec.30, T. 13 S., R. 11 E.	33.86053	-85.52238	Cleburne	30-Aug-04	1030-1253	18.3
3946	South Fork Terrapin Cr. @ Rabbittown Road	sec.30, T. 13 S., R. 11 E.	33.86053	-85.52238	Cleburne	6-Aug-03	1050-1400	18.3
2657	Marys Cr. @ Forest Road 500	sec. 36, T. 13 S., R. 10 E.	33.84986	-85.54169	Cleburne	26-Jul-05	1320-1515	2.78
2745	Marys Cr. @ Forest Road 500	sec. 36, T. 13 S., R. 10 E.	33.84986	-85.54169	Cleburne	30-Aug-04	1345-1530	2.78
3961	Marys Cr. @ Forest Road 500	sec. 36, T. 13 S., R. 10 E.	33.84986	-85.54169	Cleburne	8-Aug-03	0850-1115	2.75
3943	Terrapin Cr. @ unnumbered Co. Hwy.	sec. 7, T. 13 S., R. 11 E.	33.90597	-85.52061	Cleburne	18-Sep-03	1050-1210	72.9

Table 2. Station location information for fish collections in the Coosa and Tallapoosa River systems, 2003-05--Continued

GSA No.	Station	Section, Township, Range	Latitude	Longitude	County	Date	Time	Area (sq mi)
3957	Little Terrapin Cr. @ Co. Hwy. 49	sec. 10, T. 13 S., R. 11 E.	33.91489	-85.46581	Cleburne	27-Aug-03	1220-1420	15.8
3944	Terrapin Cr. @ Co. Hwy. 202	sec. 14, T. 13 S., R. 11 E.	33.89281	-85.4612	Cleburne	18-Aug-03	1155-1310	41.3
3954	Camp Cr. @ Co. Hwy. 283	sec. 27, T. 13 S., R. 11 E.	33.86553	-85.47194	Cleburne	20-Aug-03	1035-1230	5.87
3955	Mountain Cr. @ Co. Hwy. 123	sec. 21, T. 13 S., R. 12 E.	33.87619	-85.38587	Calhoun	13-Aug-03	0845-1020	4.11
3945	Terrapin Cr. @ Co. Hwy. 123	sec. 32, T. 13 S., R. 12 E.	33.85767	-85.39783	Cleburne	20-Aug-03	0745-0935	5.88
2698	Little River @ Canyon Mouth Park	sec. 3, T. 9 S., R. 9 E.	34.288611	-85.681583	Cherokee	18-Aug-05	0845-1040	199
2699	Little River @ Ala. Hwy. 273	sec. 3, T. 9 S., R. 9 E.	34.26806	-85.67306	Cherokee	18-Aug-05	1230-1335	202
2667	Chewacla Cr. @ Co. Hwy. 10	sec. 24, T. 18 S., R. 25 E.	32.53575	-85.49669	Lee	4-Aug-05	0820-0950	52.7
2664	Little Hillabee Cr. @ Co. Hwy. 5	sec. 1, T. 24 .N, R. 21 E.	33.102778	-85.917083	Tallapoosa	20-Jul-05	0920-1055	57.9
2663	Enitachopco Cr. @ Owens Road	sec. 7, T. 21 S., R. 8 E.	33.21842	-85.84778	Clay	20-Jul-05	1210-1335	26.2
2660	Emuckfaw Cr. 2.5 E. of Daviston	sec. 19, T. 24 N., R. 24 E.	33.055	-85.69472	Tallapoosa	19-Jul-05	1420-1610	29.0
2669	Chulafinne Cr. @ U.S. Hwy 431	sec. 13, T. 17 S., R. 9 E.	33.55306	-85.65275	Cleburne	4-Aug-05	1610-1720	20.5
2668	Wedowee Cr.	sec. 4, T. 20 S., R. 12 E.	33.30397	-85.39933	Randolph	4-Aug-05	1315-1430	19.9

PART 1: SAMPLING METHODOLOGY DEVELOPMENT AND IBI DEVELOPMENT

SAMPLING METHODOLOGY

For biological assessment methods to be successfully integrated into water resource management, the sample collection technique must be standardized to ensure that equal and representative effort is applied to all samples; must be efficient in use relative to personnel, funds, and time; and the sampling method must have known statistical characteristics for sampling the targeted organisms and biological communities. The GSA wadeable stream sampling methodology was first described by O'Neil and Shepard (2000b). Use of this method in Alabama streams since then has revealed the need to refine some of its elements such as improving the definition of sampling effort, determining the amount of effort needed to achieve statistically reliable results, and further description of habitat strata for sampling. Incorporation of these improvements has resulted in a better-defined and standardized sampling protocol that can be used by different agencies and groups to collect fish samples for IBI analyses. Effectively applying the protocol still requires knowledgeable use of stream sampling gear such as seines, dip nets, and electrofishing equipment, and a basic understanding of stream hydrology, geomorphology, and stream ecology.

STREAM HABITATS

Perhaps the single most basic requirement of any stream sampling program is to have field personnel who understand the basic ecology, hydrology, and physical structure of stream environments. The sampling skill and knowledge of the field crew is important for collecting a representative and valid fish sample. Good sampling technique is also critical, and the only way to acquire good technique is through experience. The use of intuitive natural history instinct, or in other words "thinking like a fish," cannot be overstated. Emphasis should be placed on sampling areas where fish are likely to occur–shoals, riffles, microhabitats with structure, and plunge pools below riffles–keeping in mind that the goal of biological assessment is to collect a sample that represents the diversity and abundance patterns of the resident fish community and is adequate for assessing biological condition, not a census of the entire community. Understanding how fishes live and where the most productive areas for fishes are located is crucial. An inexperienced sampling crew can spend too much time sampling areas that appear to be acceptable habitat but in reality do not support fishes to any degree.

Stream habitat is a reflection of channel bed topography consisting of riffles and pools created by the interaction of stream flow and downstream bedload sediment transport (Petts and Foster, 1985). Riffles are topographic high areas created by accumulated coarse sediment material, and a pool is a topographic low usually characterized by accumulated finer sediment material. Runs are transitional areas where, as one moves downstream from a pool to a riffle, depth decreases and velocity increases, and when exiting a riffle depth increases and velocity decreases. Shoreline habitat is found where the water surface interacts with the landscape resulting in a diverse array of microhabitats such as shallow shoals, deep holes, riparian cover (or lack of cover), log snags, weed beds, and undercut banks. The shoreline can be the most species-rich area in a stream and is a mandatory area to sample. Stratifying stream habitat into four basic habitat zones (riffles, runs, pools, shorelines) provides an efficient way to partition sampling effort to ensure adequate sampling.

Fishes are generally clumped together in groups, or may be solitary, in areas of preferred habitat which generally correspond to the riffle-run-pool-shoreline zones. Some fishes are distributed across all habitat zones, others may occur in two or three zones, while others may be confined to one habitat zone and may even prefer small microhabitats within a habitat zone or use different habitat zones during different seasons. As an example, consider the fish collection made in South Fork Terrapin Creek on July 26, 2005 (fig. 2). This figure is a graphical representation of the distribution of fish species in this stream. Two species were confined to the riffle zone while two different species were found in both the riffle and run zones. Three species were widely distributed at this station and were found in three zones (riffle, run, pool). Five species were found in the run and pool zones, three species were found only in pools, six species were found in the pool and shoreline zones, and five species were found exclusively in the shoreline zone. If sampling was confined only to the riffle-run complex, or consisted of electrofishing only the pools, then a substantial part of the

Figure 2. Habitat use by fishes collected in South Fork Terrapin Creek, July 26, 2005.

Species	Riffle	Run	Pool	Shore
Etheostoma jordani	■			
Percina palmaris	■			
Cottus carolinae	■	■		
Cyprinella callistia	■	■		
Campostoma oligolepis	■	■	■	
Cyprinella trichroistia	■	■	■	
Phenacobius catostomus	■	■	■	
Notropis stilbius		■	■	
Hypentelium etowanum		■	■	
Etheostoma coosae		■	■	
Notropis xaenocephalus		■	■	
Notropis asperifrons		■	■	
Lythrurus lirus			■	
Etheostoma stigmaeum			■	
Percina kathae			■	
Luxilus chrysocephalus			■	■
Moxostoma erythrurum			■	■
Lepomis auritus			■	■
Lepomis macrochirus			■	■
Lepomis megalotis			■	■
Micropterus coosae			■	■
Ameiurus natalis				■
Fundulus stellifer				■
Gambusia affinis				■
Ambloplites ariommus				■
Lepomis cyanellus				■

shading indicates presence

resident biodiversity would not be sampled and relative abundances would be unrepresentative of the natural setting.

COLLECTING THE SAMPLE

The effectiveness of sampling fishes depends on many factors such as stream size, substrate conditions, flow regime, amount of cover in the stream channel, type of sampling gear, and the expertise and knowledge of the collectors. Karr (1981) indicated that one of the basic foundations of the IBI is that the entire fish community should be adequately sampled relative to their true abundances in nature with minimal bias towards certain species or size classes of fishes. This can be difficult to accomplish unless a standardized sampling method has been adopted that assures a representative and valid fish sample will be collected.

The use of fish samples collected for purposes other than IBI can be problematical when used in the IBI process because samples collected for such purposes are usually biased to the intended use of the data. For example, samples collected for taxonomic purposes target species of research interest and are generally restricted to narrowly defined habitat types while sampling gear for fisheries investigations typically select for large, commercially important species or sport fishes.

SAMPLING GEAR

The shortest possible sampling time yielding representative, valid samples is a significant factor driving the sampling programs of regulatory and management agencies. The reality of today’s work environment is that more stations have to be sampled with less field personnel and fewer dollars, making efficient sampling methods highly desirable. Efficient sampling methods as described in this report encompass two fundamental ideas: (1) the least amount of time is devoted to collecting the sample, and (2) the samples are representative of the biological community and statistically valid relative to the amount of sampling effort per site needed to reach a defined endpoint. Large watershed and basin areas often must be assessed within a prescribed time period making an efficient sampling method a necessity.

Sampling methods vary between researchers and agencies but they all use three basic types of sampling gear; some type of electrofishing unit, dip nets, and minnow seines (Barbour and others, 1999; Yoder and Smith, 1999). Electrofishing gear has become a standard for all types of IBI investigations with pulsed DC units generally the preferred mode of operation. Electrofishing gear comes in a variety of configurations; a towable barge unit with electrode poles, backpack units with long rat tails and one electrode pole, backpack units with two electrode poles, and a stream-side generator that charges a steel grid placed in the sampling area. Many workers prefer using two electrodes while others prefer one electrode and the rat tail trailing behind the shocker. The methods outlined herein are based on two electrodes that are held in front of the shocker.

Seines serve as a complement to the electroshocker and are used to catch, scoop, or dip stunned fishes and to trap fishes in sloughs and backwaters. At other times, seines are used as the primary device for capturing fishes in pools, runs, and along shoals. Each sampling team should have a variety of seine lengths for different size streams. The standard nylon minnow seine used by GSA biologists is 10 to 15 feet wide, 6 feet deep, and has a delta weave of 3/16 inch. Some agencies, such as TVA, standardize on 15-foot and 20-foot nylon seines (Saylor and Ahlstedt, 1990). An 8-foot-wide seine is sometimes necessary for very narrow streams while a 15-foot or 20-foot-wide seine is used in larger streams and rivers.

TECHNIQUE

An effective sampling combination is to use the backpack shocker in combination with the seine. In riffles and runs, the net is set in shallow, rocky areas or deeper, swifter chutes; the backpacker then walks upstream for 15 to 20 feet outside of the area to be sampled and proceeds to shock downstream through the riffle into the seine while disturbing the bottom. Stunned fishes in the water column will wash into the net, while benthic fishes can be dislodged from the bottom by kicking the substrate. Another variation is to have a crew member behind the backpacker skating their feet from side to side disturbing the bottom and dislodging stunned benthic fishes. Because riffles and runs are quite often very productive areas, all microhabitats should be sampled: the head, foot, middle, and sides. Vegetated shorelines along riffle margins are usually very productive areas as are head areas where riffles start to break. Plunge pools where runs transition to pools often yield a diverse catch of minnow species.

Stream runs between riffles and pools are also productive habitats and are sampled by either seining downstream or by moving with the seine from bank to bank across the stream in a downstream direction either alone or following the backpacker. Pools may be less productive than runs and riffles but generally support species not found in either habitat zone. Lower velocity in pools requires more effort to pull the seine through the water column causing collecting efficiency to generally decline. Following the electroshocker can be effective in pools, and trapping fishes against the shore or in a slough at the end of a pull can also be effective. Deep pools with structure can be sampled by blocking the downstream end with the seine and working the upstream area with a shocker and dip nets for a few minutes. Wider seines are more advantageous in pools for trapping fishes.

Shorelines along pools and runs can have complex habitat structure and yield game species and sucker species not normally found in the basic riffle-run-pool sequence. The shoreline sampling technique was created by TVA biologists and consists of a crew member working the electroshocker upstream along a shoreline for a length of 150 feet shocking around the habitat structures. One or two of the field crew follows closely scooping the stunned individuals with dip nets. Distance can be measured accurately with a forestry-type hip chain. A minimum of two 150-foot shoreline samples are collected per station.

SAMPLING EFFORT

Sampling effort is a critical part of the sampling methodology because it determines, in large part, the success of acquiring a representative sample and the resulting value of the data for the IBI process, and the number of field samples that can be acquired in a timely fashion. Too little effort in a stream will yield results incompatible for use in the IBI and too much effort will yield redundant data and consume valuable field time. An efficient sampling methodology is a trade-off between these two competing outcomes and sampling effort is the determinant of both. Two questions determine the amount of sampling effort needed to satisfy both of the desired outcomes: (1) What is the endpoint for sampling?, and (2) How much sampling effort is needed to reach that defined endpoint?

SAMPLING ENDPOINTS

Three of the most commonly used sampling endpoints are time, area, and species depletion. Time is perhaps the easiest endpoint to implement and consists of sampling a stream for a set amount of time, or sampling habitat zones for a set amount of time, or operating a shocking unit for a set amount of time. Time is easily quantified and can be consistently applied by crews with different sampling skill levels. However, all streams are different and each one requires a different amount of time to collect a similar amount or type of sample. Structurally complex and large streams will require more time to sample compared to simple sand and gravel-bottomed streams. Although time is an easily standardized endpoint, failure to allow for stream-specific conditions can lead to invalid and unrepresentative samples.

Area is a widely accepted endpoint for defining sampling effort. One area method is a fixed-distance designation. Yoder and Smith (1999) and Ohio EPA (1987b) specify a standard stream reach length of 150-200 meters for Ohio streams, while Massachusetts DEP (1995) has determined that a 100-meter reach is sufficient. Angermeier and Karr (1986) showed that IBI values approached an asymptote at reach distances of 140 to 280 meters. Another area approach is the proportional-distance designation where a standard number of stream channel widths is used to designate the length of stream sampled, for instance a length equal to 40 times the average stream width (Barbour and others, 1999). Simonson and Lyons (1995) reported that a sampled reach equal to 35 times average stream width was suitable for generating fish bioassessment data for Wisconsin streams.

Angermeier and Smogor (1994) proposed that interactive sampling approaches, like species depletion, may be useful for determining sampling endpoint. The interactive sampling approach evaluates some aspects of the fish community, such as total number of species, at regular intervals during a sample and is used to gauge the adequacy of sampling effort. Because the IBI relies heavily on the biodiversity component of the fish community, species richness and species depletion measures may have more ecological justification as a sample endpoint. Species depletion is determined by accumulating a species list with increasing sampling effort much the same way that species-area relationships are derived by accumulating species by sampling larger and larger areas. As in the species-area relationship, as more and more species are added to the list with additional sampling effort, the cumulative species curve will begin to become asymptotic as the total number of species are discovered at a sampling site. The point at which the curve flattens can be designated as the point of species depletion, i.e. the point where additional sampling effort will result in little gain in biodiversity, which in turn can be used to determine the total amount of sampling effort to reach the endpoint. One or two additional species may be collected by expending additional sampling effort, but they usually do not result in any additional gain in biological information.

The TVA (Saylor and Ahlstedt, 1990) has adopted a species depletion sampling methodology for its stream sampling program. A basic amount of effort is applied to each habitat zone, and if new species are not collected after a set amount of effort beyond the basic sampling effort requirement, then sampling is stopped; if new species are collected, then additional sampling effort is applied. This process is repeated within each habitat zone until a point when new species are no longer collected in a habitat zone after a defined amount of sampling effort has been applied, at which time sampling stops for that habitat zone. Species depletion, as applied by TVA, is an excellent way for defining sampling effort because by the end of the sample you can be very assured that biodiversity was almost completely sampled and that relative abundances likely represent proportions found in nature. The only disadvantage to the TVA approach is that samples in watersheds of high biodiversity or samples in larger stream and river reaches may take several hours to complete.

HOW MUCH SAMPLING EFFORT

If the sampling endpoint is determined by total time spent sampling or total area or length of stream sampled, then total sampling effort is defined by the endpoint itself. If interactive measures, such as species depletion, are used as the endpoint, then a critical question becomes, “How will sampling effort be measured?” Total effort in this case has to be measured in smaller, quantifiable efforts so that depletion can be evaluated against sampling effort accumulated to that point. The TVA (Saylor and Ahlstedt, 1990) has rigorously defined a smaller sampling effort as 300 ft^2 of substrate based principally upon their preference for longer seines to accommodate the larger flowing streams and rivers in the TVA region, a 20-foot seine with an effective width of 15 feet is set and 20 feet of stream is sampled upstream of the net (15 ft x 20 ft = 300 ft^2). The TVA applies the 300 ft^2 sampling effort standard in each habitat zone. The GSA sampling effort is smaller than the TVA effort because 10-foot and 15-foot seines are used to collect samples equal to about 160 to 200 ft^2 in riffles and runs, 150-300 ft^2 in pools, and 300 ft^2 along a shoreline (150 feet in length x 2 feet wide). For the purposes of this study one effort was defined as a seine haul (10- or 15-foot seine) through a pool for at least 20 feet, or a seine set in a riffle or run and sampled for at least 20 feet where fishes are shocked into the net, or a set length of shoreline (150 feet x 2 feet) shocked for fishes.

The objective of the experimental sampling investigation was to answer the question “How many smaller sampling efforts are needed to reach a defined endpoint?” The concept of species depletion and the interactive evaluation approach were applied to answer this question using individual IBI metrics and other quantitative measures of the fish community. The biodiversity and trophic components of the IBI were evaluated using the interactive approach.

EXPERIMENTAL SAMPLING PROTOCOL

Thirty-one stream stations were sampled in the Coosa River drainage that represented a variety of watershed sizes (1.68 mi^2 to 283 mi^2 in area) with varying levels of human disturbance. Stations were collected such that 15 sampling efforts were completed in each habitat zone (15 riffle efforts, 15 run efforts, and 15 pool efforts) and two shoreline efforts for a total of 47 efforts. This number of efforts (15 per habitat zone) was selected based on our sampling experiences over 25 years and our recent experience with the TVA sampling method to ensure that each station was over sampled. Species data were hand recorded on paper and later transferred to spreadsheets in the office. The basic data file for each station consisted of abundance counts for each species collected in each effort for each habitat zone. For analytical purposes, the first sampling unit was created by combining two shoreline efforts with one pool, one riffle, and one run effort randomly selected from the basic data file. Another pool, riffle, and run effort were then selected randomly and added to sampling unit 1 to create sampling unit 2. Each sequential sampling unit represented the cumulative total of all previous units plus the addition of one randomly selected pool, run, and riffle effort. This procedure was repeated until 15 sampling units had been created, depleting all sampling efforts in the basic data file. This random resampling process without replacement was replicated 15 times to create a data set sufficient in size to evaluate sampling effort statistically (fig. 3).

The resulting data were graphed to determine the number of sampling units required for the metric value versus sampling unit curves to reach a critical asymptote. Metric values at 15 sampling units were assumed to be representative of the true population condition in the sampled stream reach. This population value was graphically represented on each curve as the metric value at 15 sampling units +/- 5 percent of this value. For example, if the cumulative number of species equaled 30 at 15 sampling units, then the population value for the metric falls in the range 28.5 to 31.5 (30 +/- [.05x30]). These two end points are the critical asymptotes for a metric at a particular station. The required number of sampling units needed for two standard errors (SE) of the metric mean value to reach this critical asymptote determined the sampling endpoint. For example, two SE's for the metric number of species crosses into this range at 9 sampling units for Terrapin Creek at Co. Hwy. 71 whereas for the tributary to South Fork Terrapin Creek the distribution crosses into the range at 11 sampling units (fig. 4). These relationships are termed sampling depletion curves and are unique for each metric at each stream station.

Figure 5 illustrates sampling depletion curves for eight metrics calculated for a sample from South Fork Terrapin Creek on August 30, 2004. Sampling depletion curves calculated in like manner for all the stream sites and metrics listed in table 3 generally took the form of one to three different shapes. Type "A" curves always increased to the asymptote as sampling effort was depleted, type "B" curves decreased

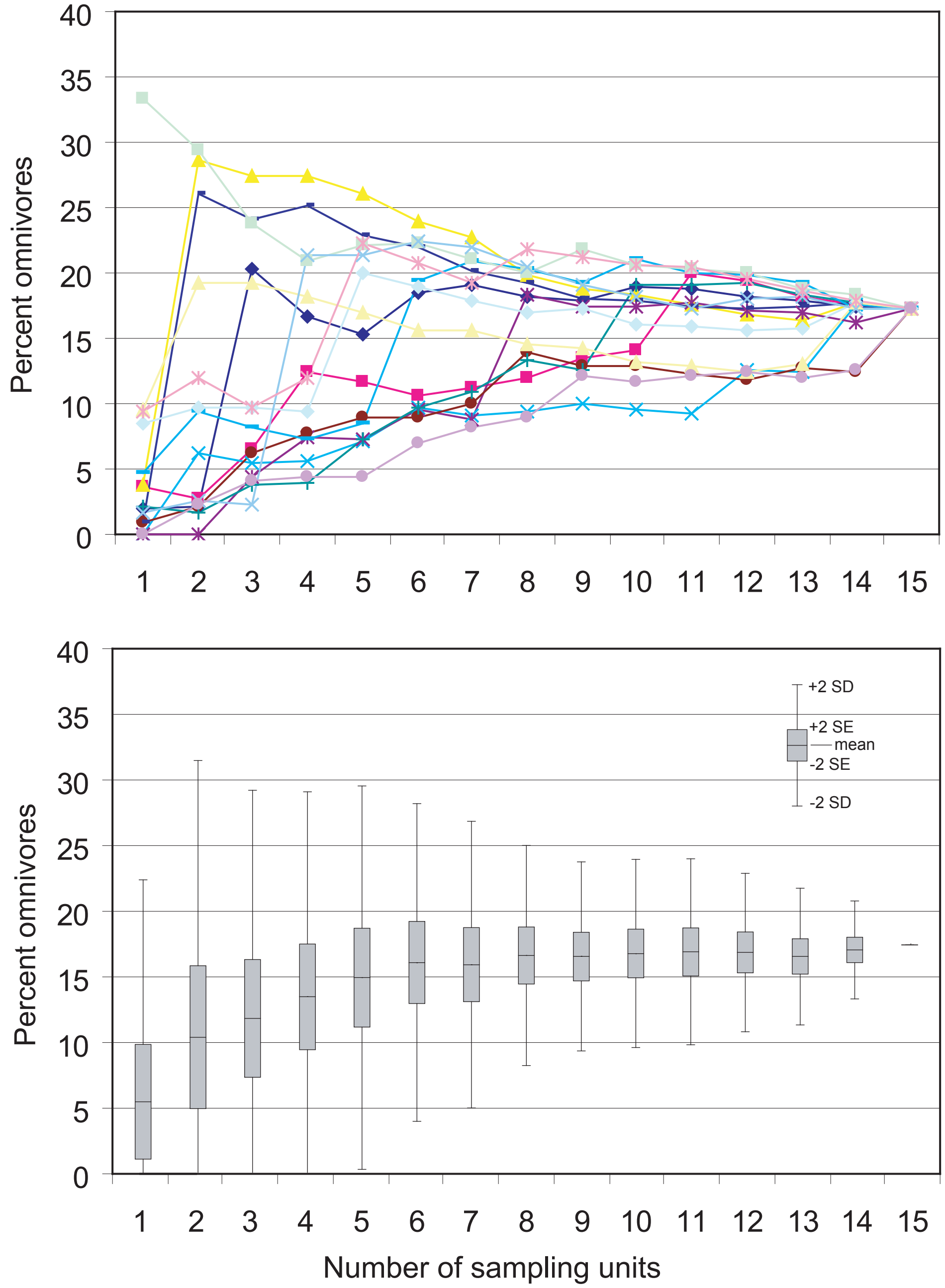
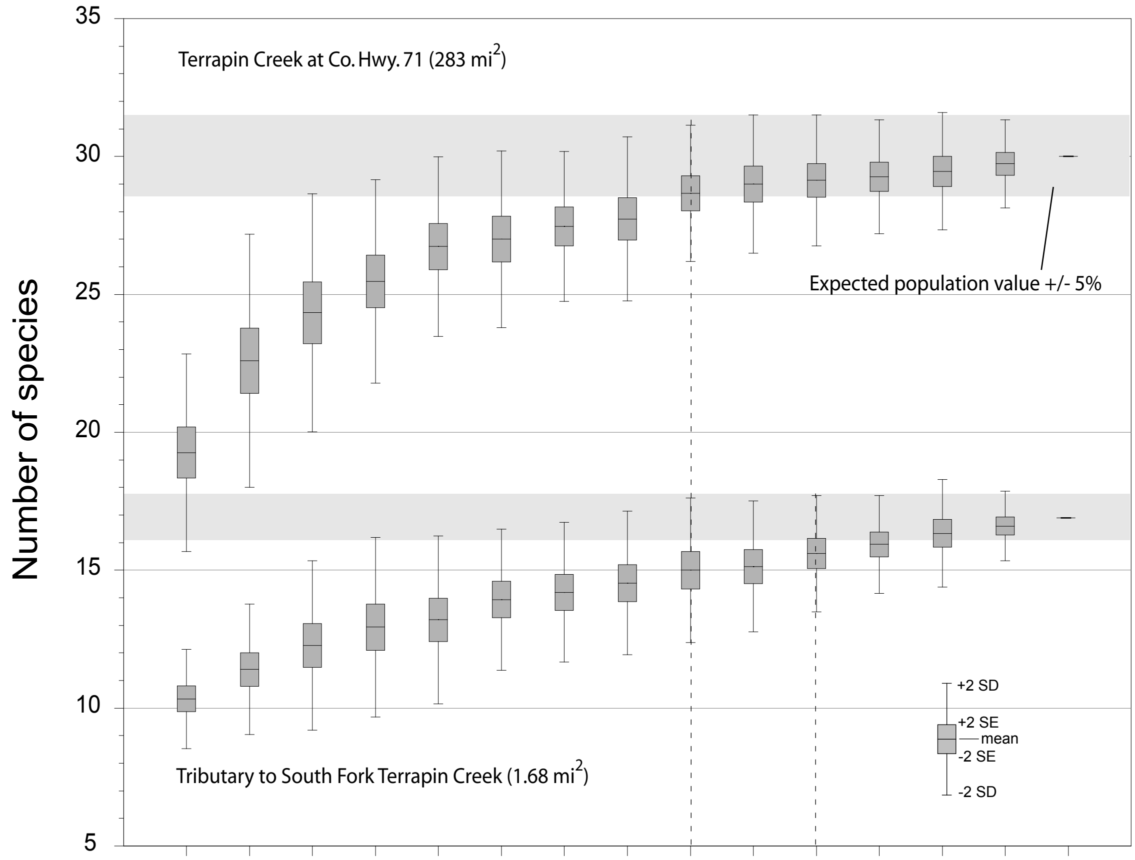


Figure 3. Random resampling example for South Fork Terrapin Creek, August 30, 2004.



	Sampling unit	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Habitat zone	Shoreline	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	Riffle	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Run	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Pool	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Total sampling efforts		5	8	11	14	17	20	23	26	29	32	35	38	41	44	47

Figure 4. Sampling depletion curves for two sites in Terrapin Creek.

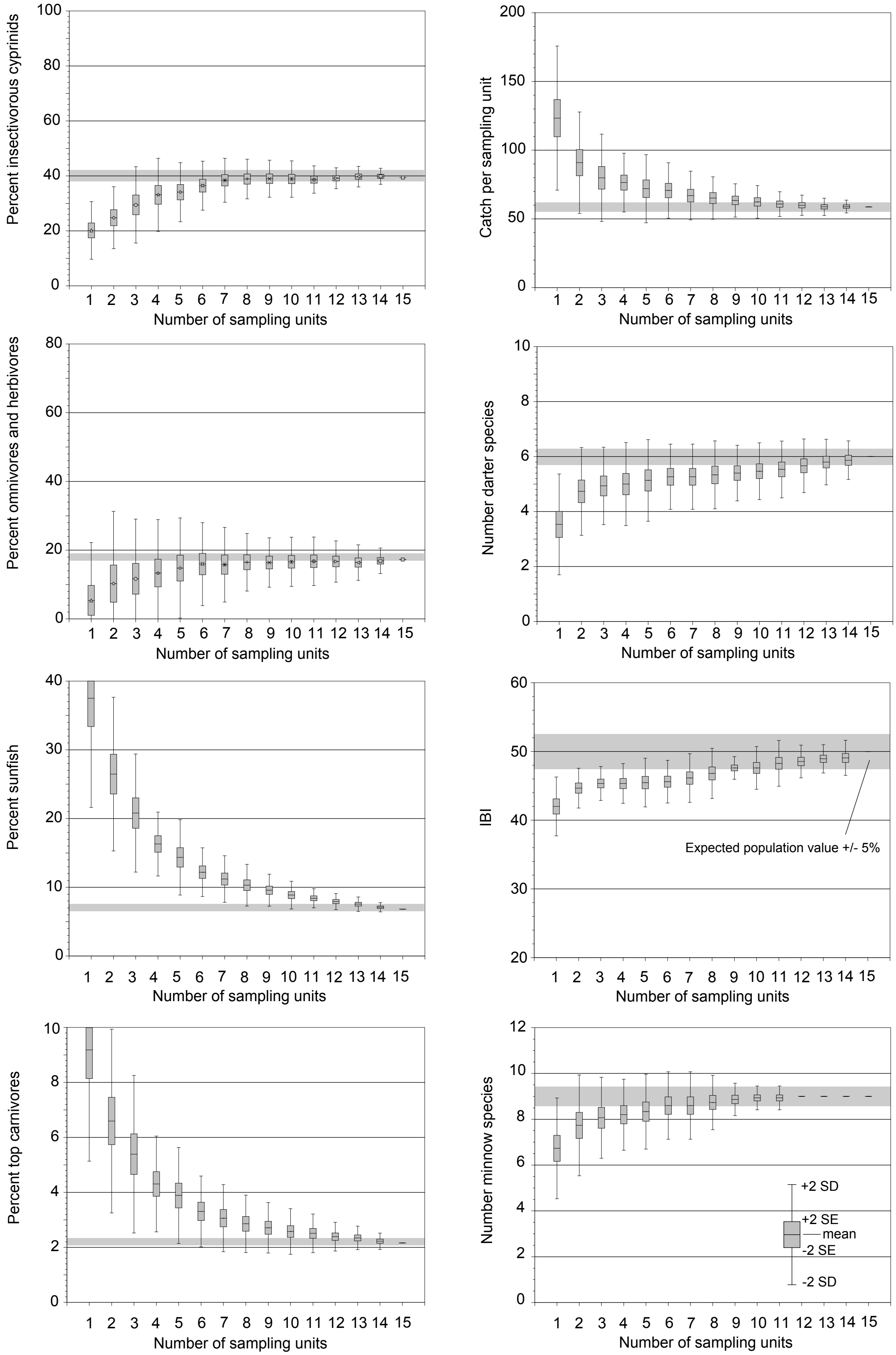


Figure 5. Sampling depletion curves for the IBI and selected metrics, South Fork Terrapin Creek, August 30, 2004.

Table 3. Number of sampling units required for metric value to reach asymptote

Station	Area (sq mi)	Sample Date	IBI metrics % InsCyp	% Omni	% TopCarn	% Sun	Num DarSp	Num MinSp	Num SukSp	Num SunSp	Total Species	Catch	IBI
Trib. To South Fork Terrapin Cr.	1.68	18-Aug-03	10	6	2	10	12	12	1	1	11	12	6
Marys Cr. @ FR 500	2.78	30-Aug-04	11	11	7	10	7	1	1	1	2	7	5
Marys Cr. @ FR 500	2.78	8-Aug-03	10	2	2	9	6	3	4	1	5	6	4
Mountain Cr. @ Co. Hwy. 123	4.11	13-Aug-03	13	6	9	14	7	4	1	8	8	11	3
Little Cr. @ Co. Hwy 14	5.31	19-Aug-03	14	1	15	14	10	10	1	1	7	6	2
Choccolocco Cr.	5.53	7-Aug-03	4	1	1	14	11	11	1	1	11	9	7
Camp Cr. @ Co. Hwy. 283	5.87	20-Aug-03	12	9	2	13	3	6	1	5	8	11	5
Terrapin Cr. @ Co. Hwy. 123	5.88	20-Aug-03	13	5	8	13	12	4	3	1	11	10	5
Nances Cr. @ Nances Cr. Comm.	7.71	28-Aug-03	12	8	14	11	1	4	11	10	10	8	5
Little Terrapin Cr.	15.8	27-Aug-03	10	8	11	11	5	3	1	1	10	12	5
Shoal Cr. @ Pine Glenn	17.9	13-Aug-03	8	1	12	14	4	8	1	1	9	9	3
SF Terrapin @ Rabbittown Rd	18.3	30-Aug-04	6	4	11	13	10	4	1	1	5	8	8
SF Terrapin @ Rabbittown Rd	18.3	6-Aug-03	5	6	5	13	8	5	1	1	8	12	4
Frog Cr @ Co. Hwy. 12	19.2	28-Aug-03	9	6	1	10	7	7	1	6	8	12	4
Nances Cr. @ Babbling Brook	20.5	27-Aug-03	12	5	2	15	4	7	11	1	8	11	12
Nances Cr. @ Babbling Brook	20.5	3-Sep-04	11	6	11	14	3	7	1	1	7	7	6
Ohatchee Cr.	21.5	30-Sep-04	12	1	9	11	5	10	11	11	11	9	6
Little Canoe Cr.	22.3	29-Sep-04	3	2	10	10	7	6	1	6	8	3	3
Hurricane Cr. @ Co. Hwy. 8	22.9	19-Aug-03	4	5	11	13	3	7	6	1	6	4	2
Nances Cr. NE of Piedmont	27.4	7-Aug-03	5	4	3	9	2	11	8	1	9	10	9
Camp Br.	30.3	9-Sep-04	8	2	3	11	5	7	6	1	9	7	6
Cane Cr.	30.6	1-Sep-04	9	5	10	14	3	7	1	1	8	4	6
Hurricane Cr. @ Co. Hwy. 4	32.6	12-Aug-03	7	6	12	13	5	4	11	1	8	10	3
Walnut Cr.	35.1	9-Sep-04	3	1	1	10	2	3	9	11	10	6	8
Big Canoe Cr.	37.3	29-Sep-04	4	1	10	13	3	6	7	1	7	2	5
Terrapin Cr. @ Co. Hwy. 202	41.3	18-Aug-03	7	4	8	12	7	8	7	1	7	9	3
Waxahatchee Cr.	46.6	10-Sep-04	10	2	11	11	6	7	2	1	7	8	5
Talladega Cr.	53.7	19-Sep-03	8	1	9	7	1	8	3	1	7	8	2
Terrapin Cr. nr Vigo Rd.	72.9	18-Sep-03	9	5	13	14	1	5	7	1	8	7	4
Yellowleaf Cr.	77.9	10-Sep-04	4	3	6	12	9	12	11	1	11	2	4
Kelly Cr.	85.8	14-Sep-04	7	4	2	14	11	9	12	1	10	7	8
Terrapin Cr. @ Co. Hwy 8	171	31-Aug-04	5	1	5	9	7	4	6	7	8	4	4
Terrapin Cr. @ Co. Hwy 8	171	12-Aug-03	4	3	9	13	3	8	2	6	10	7	3
Terrapin Cr. @. Co. Hwy. 175	245	17-Sep-03	2	1	11	13	8	6	1	7	11	5	3
Terrapin Cr. @ Co. Hwy 71	283	31-Aug-04	10	11	3	11	11	1	1	1	2	9	7
Terrapin Cr. @ Co. Hwy 71	283	18-Sep-03	8	5	11	13	5	8	9	5	9	11	10
Mean no. sampling units			8.03	4.22	7.50	11.97	5.94	6.47	4.50	2.97	8.17	7.86	5.14
Sample size			36	36	36	36	36	36	36	36	36	36	36
Standard deviation			3.3422	2.8396	4.2661	1.9196	3.2771	2.8534	3.9964	3.2469	2.2488	2.8701	2.3318
Standard error			0.557	0.4733	0.711	0.3199	0.5462	0.4756	0.6661	0.5411	0.3748	0.4783	0.3886
95% Confidence Interval		lower limit	6.8969	3.2614	6.0565	11.3227	4.8356	5.5068	3.1478	1.8736	7.4058	6.89	4.3499
		upper limit	9.1586	5.183	8.9435	12.6217	7.0533	7.4377	5.8522	4.0708	8.9276	8.8322	5.9279

InsCyp-insectivorous cyprinids, Omni-omnivores and herbivores, TopCarn-top carnivores, Sun-sunfish, DarSp-darter species, MinSp-minnow species, SukSp-sucker species, SunSp-sunfish species.

to the asymptote as sampling effort was depleted, and type “C” curves were essentially flat, neither increasing or decreasing, as sampling effort was depleted. All diversity metrics, percent insectivores, and the IBI curves were type A. Percent sunfish and catch per sampling unit curves were all type B. Percent omnivores was mixed with 64 percent of the sites having a type A curve, 23 percent a type C, and 13 percent a type B. Percent top carnivores was also mixed with 74 percent of sites having a type B curve, 15 percent a type A curve, and 11 percent a type C curve. The two metrics percent top carnivores and percent sunfish took more sampling effort to reach population values because most species that added abundance to these metrics were captured in the two shoreline efforts which were always added into the first sampling unit. The mathematical consequence of this is that a large, almost constant, number is sequentially reduced as sampling is depleted and abundance is added to the total and divided into the metric value. The resulting mean values and error estimates for these metrics at each sampling unit are reduced with additional sampling, thereby requiring more effort to reach the asymptote.

The sampling depletion data in table 3 were further evaluated by calculating the 95 percent confidence interval for each metric. These statistics incorporate the range of watershed sizes sampled and degree of human disturbance to better refine the amount of sampling effort required to meet expectations and requirements for calculation of individual metrics as well as for calculation of the IBI. The mean and 95 percent confidence intervals for 11 metrics are plotted in figure 6 illustrating how many sampling units would be required for calculating an IBI within the parameters of the sampling protocol and technique described. With the exception of the metric percent sunfish, it appears that 9 sampling units would be sufficient. We added one additional sampling unit to this and recommend that 30 efforts (consisting of 10 riffle, 10 run, and 10 pool efforts) and 2 shoreline efforts should be collected per site as the basic sampling protocol. Additional shoreline effort may be needed, particularly if the stream has a complex bank and shore structure, or perhaps additional riffle, run, or pool efforts, but as a minimum sampling effort the “30+2" recommendation should be followed. In our opinion, ten efforts per habitat slightly over samples and in all likelihood less than

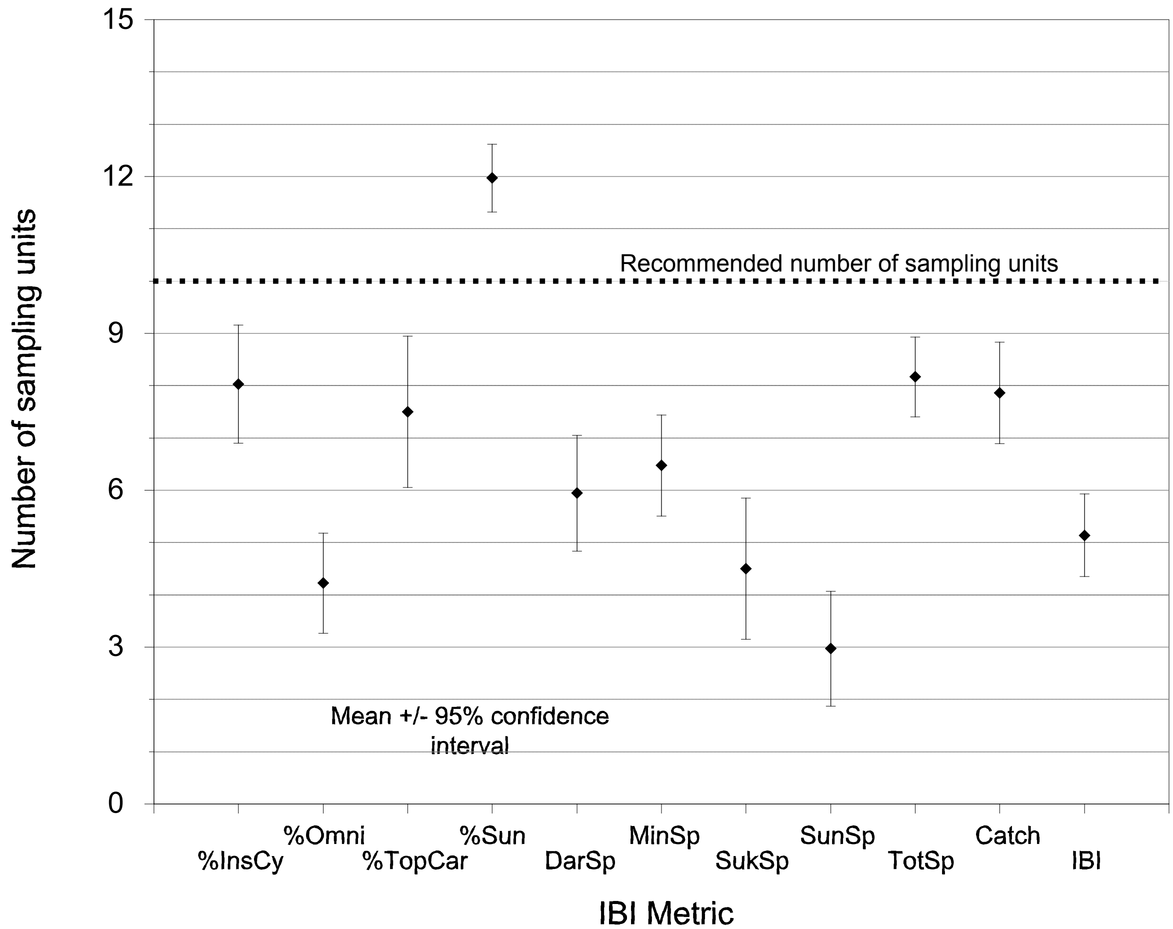


Figure 6. Variation of sampling depletion results for selected IBI metrics.

10 efforts per habitat type would be sufficient, but we tend to err on the side of more sampling than less because over sampling generally does not affect IBI performance nearly as much as under sampling would. Sampling times for the field data were about 2.5 hours for "45+2" efforts collected per site in 2003-04 and about 1.5 hours for "30+2" efforts during 2005 IBI samples. Shorter sampling times are possible if the catch is preserved and identified in the laboratory, but we recommend that as many individuals be identified in the field as possible. The metric percent sunfish deviated substantially from the other metrics relative to number of sampling units required to reach an asymptote.

SAMPLING CONSIDERATIONS

COUNTING AND WEIGHING PROCEDURES

All sampling methods require detaining collected individuals until they are identified or processed in the field, or preserved. Water in a live well or bucket should be changed frequently to minimize mortality of captured fish. Fish are released immediately after they are identified, examined for external anomalies, and weighed if desired. Every effort should be made to minimize handling stress. If individuals are identified to species in the field then any uncertainty about identity requires that the specimen be preserved and returned to the laboratory for verification. Collection procedures used may not be consistently effective for fish less than 20-25 mm in length. Therefore, these young-of-year (YOY) individuals should be disregarded for analytical purposes when using the IBI because large numbers of YOY may bias the procedure's usefulness as an indicator of aquatic ecosystem health (Karr and others, 1986).

For large samples of species that are of similar size class, two methods may be used to determine weight (Ohio EPA, 1987b). For large species the catch may be weighed as separate individuals or in aggregate as a species. For catches of 15 or more individuals per species, a subsample of 15 fish is weighed either as individuals or in aggregate. With smaller species like minnows and darters, mass weighing in aggregate is recommended. If more than 50 individuals of a species are collected, then a subsample of at least 50 individuals is weighed and the remaining individuals counted. If very high numbers of a small species are collected and the individuals are of a uniform size, the number of individuals and total weight may be determined by counting and weighing a subsample. If adults and juveniles of a single species are collected, they are processed as two separate size groups using any of the described techniques yet are analyzed as one species. Individuals weighing less than 1,000 grams are weighed to the nearest gram while individuals weighing more than 1,000 grams are weighed to the nearest 25 grams.

EXTERNAL ANOMALIES

All fish that are counted or weighed, whether individually, in aggregate, or subsampled, are examined for the presence of external anomalies. An external anomaly is defined as the presence of visible skin or subcutaneous disorders and the percent occurrence of a particular anomaly for a species is expressed as the percent of affected fish among all fish weighed for the species. This is computed for each type of anomaly for each species. Anomaly occurrence in the sample is calculated by multiplying percent occurrence by the total number of individuals of a species in the sample. These sample totals can then be summed within anomaly and across species to determine the percent occurrence of external anomalies in the sample (Ohio EPA, 1987b).

The presence of external anomalies is used as an indicator of the presence of multiple, sublethal stresses. A high incidence of anomalies is a good indication of stress caused by sublethal doses of toxicants and chemically contaminated substrates. The effects of temperature, salinity, dissolved oxygen, diet, chemicals, and organic wastes during developmental and larval stages of fishes can cause many types of anomalies and the presence of these anomalies can be integrated into the IBI as a fish health metric.

The following are some of the more common external anomalies observed in wild fish populations (Ohio EPA, 1987b).

♦ Deformities — Deformities can affect the head, spinal vertebrae, fins, and stomach shape, and can result from a variety of causes including toxic chemicals, viruses, bacteria, infections, and protozoan parasites. Extruded eyes or obvious injuries are not considered deformities.

- ♦ Eroded fins — Eroded fins are the result of a chronic disease principally caused by flexibacteria invading the fins causing a necrosis of the tissue. Necrosis of the fins may also be caused by gryodactylids, a small trematode parasite. Erosions on the opercle and preopercle should be included in this category. This anomaly occurs frequently in areas with multiple stresses, particularly low dissolved oxygen and high temperature in combination with chronic toxicity. Care should be taken not to confuse erosion of fins due to spawning activities in such species as darters and suckers with erosion due to disease.

- ♦ Lesions and ulcers — Lesions and ulcers appear as open sores or exposed tissue and are caused by viral and bacterial infections. Prominent bloody areas on fish should be included while small sores left by anchor worms and leeches should not.

- ♦ Tumors — In wild fish populations tumors can be the result of exposure to toxic chemicals and occasionally by viral infections. Parasite masses may look like tumors but should not be identified as such. These masses can be squeezed and broken whereas true tumors are firm and not easily broken.

- ♦ Anchor worms — The anchor worm is a common parasitic copepod (*Lernaea cyprinacea*) identified by the presence of an adult female which appears as a slender, worm-like body with the head attached to or buried in the flesh. A small characteristic sore is left after the anchor worm detaches and if this site becomes infected it should be recorded as a lesion.

- ♦ Black spot — Black spot can be a common disease on fish and is caused by the larval stage of a trematode parasite. It is identified as small black cysts the size of a pin head on the skin and fins. Black spot is commonly reported in conjunction with fish living in shallow streams and lake margins having an abundance of aquatic vegetation, along with snails and fish-eating birds, both of which are intermediate animal hosts. Black spot also increases in frequency in mildly polluted streams and when snails are crowded due to intermittent pooling.

- ♦ Leeches — Leeches are parasites usually greenish brown in color, 5-25 mm long, and may occur almost anywhere on a fish. They have suckers at each end and can contract and elongate their bodies. Leeches are seldom harmful to fishes unless infestation is unusually heavy.

- ♦ Fungus — Fungus appears on a fish’s body as a white cottony growth. Fungus usually attacks an injury or open sore and can lead to further disease or death.

- ♦ Ich (*Ichthyophthirus multifilis*) — Ich is a protozoan that manifests itself on the skin and fins as a white spotting and rarely occurs in wild fish populations.

- ♦ Popeye — Popeye is a disease generally identified with bulging eyes and is caused by gas accumulation in habitats where the water is supersaturated.

SAMPLE PRESERVATION AND LABELING

Systematically collected stream fish samples are valuable environmental documentation. If samples are brought to the laboratory for processing, consideration should be given as to the ultimate disposition of the specimens. This takes relatively little time and money compared to obtaining the original field sample. Unwanted samples complete with a field sampling sheet should be donated to a recognized natural resource fish collection.

If field identification is to be made with no individuals returned to the laboratory, then an adequate number of clean holding buckets should be provided along with any special measuring equipment (weight, length, etc.), equipment to sustain live specimens such as portable aerators, an efficient means to process the samples (adequate field personnel, portable tables, etc.), and proper equipment to preserve voucher and unidentified specimens. Specimens are best preserved in a 10 percent formalin solution mixed on site. Small individuals up to 5 inches in length are preserved adequately by just putting them in the formalin solution. Larger individuals must first be fixed, then preservative can be injected into the body cavities to fix soft parts and expose deep tissue to preservative. Body cavities on very large individuals must be cut open to allow adequate preservation. Small plastic jars or heavy-duty zip lock bags work well for preserving a few specimens while plastic jars of ½- to 1-gallon capacity are needed to hold a complete sample.

When the entire sample is to be preserved the collection jar should be carried by one of the field crew. A sample jar in a nylon or canvas bag attached to a web belt is a very efficient rig in both size and weight. Some samples may require multiple jars to hold the entire catch; however, our experience is that most small stream sites with less than 100 mi^2 of watershed area rarely yield a catch exceeding the capacity of a ½ gallon container. Specimens are removed from nets and put directly into preservative as captured.

Specimens saved for permanent storage must be soaked in tap water then placed in a 70 percent ethanol solution or other suitable preservative medium. All field and laboratory preservation practices should be noted on the field collection form for future reference. A field label should be prepared and placed inside of every sample container returned to the laboratory. At a minimum the stream station name and specific location information, date, county, and any sample numbering code should be written on a water-proof label and put inside the container. This same information and sample number is added to the field collection form so the sample can be associated with the form in the laboratory. Additional labeling can be put on the outside of the container to assist in locating the sample but under no circumstances should outside labeling be used as the primary source of identification.

A field collection form must be completed for every sample. The purpose of this form is to serve as the original documentation of the collection and as a place to record any required environmental data, location information, any notes concerning habitat or life history phenomena observed, collectors, type of collection and gear used, and a preliminary list of species collected. If samples are field processed, the collection form should be designed to accommodate efficient tabulation of data and calculation of assessment metrics.

INDEX OF BIOTIC INTEGRITY

Creating an IBI for a region starts by designing a sampling program that accounts for the variability in stream sizes encountered in the study area, ecoregional differences in aquatic fauna that may influence metric selection and scoring, and the selection of sampling stations to represent the range of human disturbance from minimally or least disturbed reference stations to streams significantly degraded by urban and(or) agricultural stressors. Reference, or minimally disturbed, stations were located in the upper Coosa system, generally in the protected Talladega National Forest and included the headwater reaches of Terrapin and Choccolocco Creeks. Heavily disturbed streams were sampled that drained Anniston, Oxford, Clanton, Piedmont, and lower Terrapin Creek.

Biological responses to stressors in the environment are quantified into measures called metrics which are calculated from fish collection data. Typical IBI metrics can be classified into one of three basic types. Diversity metrics generally evaluate total fish community diversity, such as total native species, or components of community diversity, such as darter or sucker species diversity; trophic metrics evaluate the trophic or production status of a fish community and quantify proportions of fishes in certain feeding guilds; reproduction and fish health metrics measure the relative proportions of species within certain reproductive guilds and the relative presence of health problems that may be environmentally caused such as lesions, tumors, and deformities.

Testing and validating biological responses across a gradient of human disturbance is an important step in IBI development (Karr and Chu, 1997; Smogor and Angermeier, 1999a). The ability of a metric to segregate most from least disturbed sites was evaluated by comparing a sample of stations with similar-sized watershed areas from each end of the disturbance gradient similar to the method of Teels and Danielson (2001). Sixteen samples from each end of the distribution were selected and classified according to watershed area, eight stations were <25 mi^2 and eight stations were $\geq$25 mi^2. The eight smaller stations, from most and least disturbed sites, were compared using the Students t-test. In similar fashion, the eight sites from larger, most and least disturbed watersheds, were also compared with the t-test.

ESTABLISHING THE HUMAN DISTURBANCE GRADIENT

Stresses to aquatic resources are diverse in type and magnitude and affect ecosystem processes variably. A conceptual model for what is termed a generalized stressor gradient has been defined (U.S. EPA, 2005a) to help characterize and better understand environmental processes and mechanisms that generate stresses which lead to biological responses within aquatic communities. Events and activities that alter aquatic ecosystems are termed **disturbances**. Aquatic ecosystems normally operate at varying levels of disturbance within their ambient range of natural variation such as flood events and other extreme weather-related phenomena. Disturbances outside of this ambient range are human induced and exert **pressures** on aquatic systems by changing the fundamental environmental processes and ultimately generating **stressors** on the resident biota. Stressors are defined as physical, chemical, or biological factors that cause an adverse response from aquatic biota (U.S. EPA, 2000) with the degree of response determined by the magnitude, frequency, and duration of exposure to stressors. This conceptual process is outlined in figure 7 with an example of how riparian tree removal leads to altered biological condition. Unstable banks (disturbance), caused by tree removal (pressures), leads to increased erosion of fine sediments from stream banks (mechanism). This mechanism causes in-stream siltation (stressor) which smothers the substrate with fine particles and causes gill irritation in fishes (mechanism). The stressor ultimately leads to fish and invertebrate mortality or emigration (biological response) out of the area of disturbance.

Karr and others (1986) listed five factors that define the structural and functional integrity of aquatic resources and are the major receptors of ecosystem disturbance: water-quality, flow regime, biotic factors, energy source, and habitat structure. Water-quality factors such as hardness, nutrient concentrations, dissolved oxygen, turbidity, toxic trace metals, and toxic organic compounds all affect, either directly or indirectly, the survival of biota. Factors related to flow regime, including velocity gradients, ground water inflows, diversions, dams, and relative variability of stream flows indirectly shape habitat quality. Severe disruption of natural flow regimes can accelerate channel scour, introduce additional bedload material, lower base flows, and weaken stream banks. Biotic factors such as increased rates of disease, parasitism, predation, and competition can directly affect the survival of the resident biota by weakening a population's ability to cope with added environmental stress. Removal of riparian vegetation through logging or urban development disrupts vital sources of energy for the stream, allochthonous organic matter, and larger woody debris. Removal of riparian cover also exposes the stream to more sunlight and, when coupled with increased nutrient input, can lead to excessive algal growth and eutrophic conditions. Reach-specific habitat variables very often are significant determinants of biological integrity.

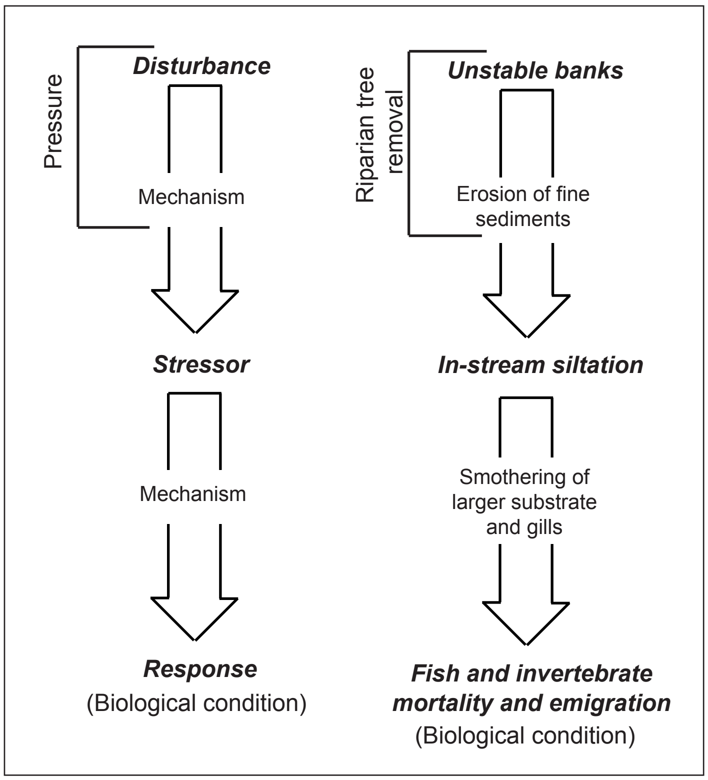


Figure 7. Conceptual model illustrating the relationship between disturbance, stressor, and response (adapted from U.S. EPA, 2005)

Increased embeddedness of a naturally variable substrate with fine sediments can lead to loss of habitat diversity and a parallel loss of species diversity. The degree that finer sediments are embedded between larger substrate particles, the stability and quality of riparian vegetation cover, and the quality of habitat components such as riffles, pools, and runs are all intimately related to biological condition and ultimately to condition of the water resource.

A major use of biological assessment tools is to assist in evaluating stream conditions in relation to human disturbance. Human activities will degrade water resources by altering one or more of the five basic factors of ecosystem structure and function (Karr and Chu, 1999) through the disturbance-stressor-response model. Because the multimetric IBI is sensitive to changes in these five factors, it can be used to quantify biological effects over a broad range of human disturbance activities. Understanding how the IBI and its individual metrics respond to human disturbance (sensitivity) is therefore a basic step in creating and calibrating an effective IBI index for a region or watershed. Plots of metric values in relation to disturbance and a test of the metric for discriminating most from least disturbed sites are presented in appendix B.

The diverse array of human activities can make the task of defining and quantifying human disturbance difficult, but recent advances in geographic information systems (GIS) technology has resulted in more accurate and useful information for quantifying human disturbance at the landscape scale. Landscape features that stream ecologists have qualitatively known for years to be sources of ecosystem stress such as type of land cover, type and intensity of land use, number of road-stream intersections, number of point-source discharges, population density, and agricultural animal density can now be quantified into useable data sets for analysis using GIS.

Disturbance can be quantified on a number of levels ranging from human disturbance metrics that describe landscape-level features (Brown and Vivas, 2003; Fore, 2004) to habitat metrics that describe reach-level features (Rankin, 1989; Barbour and others, 1999). Both landscape and reach-level measures were used in this investigation and are important for quantifying disturbance and relating it to multimetric indices such as the IBI.

Landscape disturbance values were taken from a recent disturbance analysis of the Alabama, Coosa, and Tallapoosa Rivers by ADEM. They used a recently developed U.S. EPA analysis tool known as ATtILA (Analytical Tools Interface for Landscape Assessments) to quantify landscape metrics. It calculates four classes of landscape metrics: landscape characteristics, riparian characteristics, human stressors, and physical characteristics. Landscape characteristics relate to land cover proportions, riparian characteristics describe land cover adjacent to and(or) near stream channels, human stressors are concerned with population, roads, and land-use practices, and physical characteristics provide statistical summaries of attributes such as elevation and slopes. Eight landscape features were used by ADEM in calculating the human disturbance gradient (HDG): human density, NPDES permit density, area percentages for urban, manmade-barren, pasture, and crop land uses, road density, and a measure of stream-road intersection density. The HDG was calculated by weighting the eight selected landscape features by a factor known as the Landscape Development Intensity (LDI) index (Brown and Vivas, 2003) which relates the intensity of human land use to nonrenewable energy flow. The LDI ranges from 0, natural systems, to 10, high intensity central business districts. A statistical distribution of the HDG values calculated for 379 hydrologic units in the Alabama, Coosa, and Tallapoosa River systems along with the HDG values for the watersheds sampled for this study are shown in figure 8 which illustrates that GSA sampling stations were distributed in watersheds ranging from highly disturbed to least disturbed. Some streams that GSA sampled during this study were not evaluated during the ADEM analysis and HDG values were estimated based on the surrounding land use and HDG values from nearby hydrologic units.

The U.S. EPA habitat evaluation protocol (Barbour and others, 1999) was completed at each station for a quantitative measure of habitat quality. The glide-pool or riffle-run protocol was used depending on the type of stream habitat encountered.

The method used to quantify human disturbance for this investigation consisted of a three-step ranking process (table 4). In step one, the habitat score for each station was converted to percent of maximum by dividing the actual on-site score by the maximum possible habitat score and multiplying by 100. These values were then ordered from

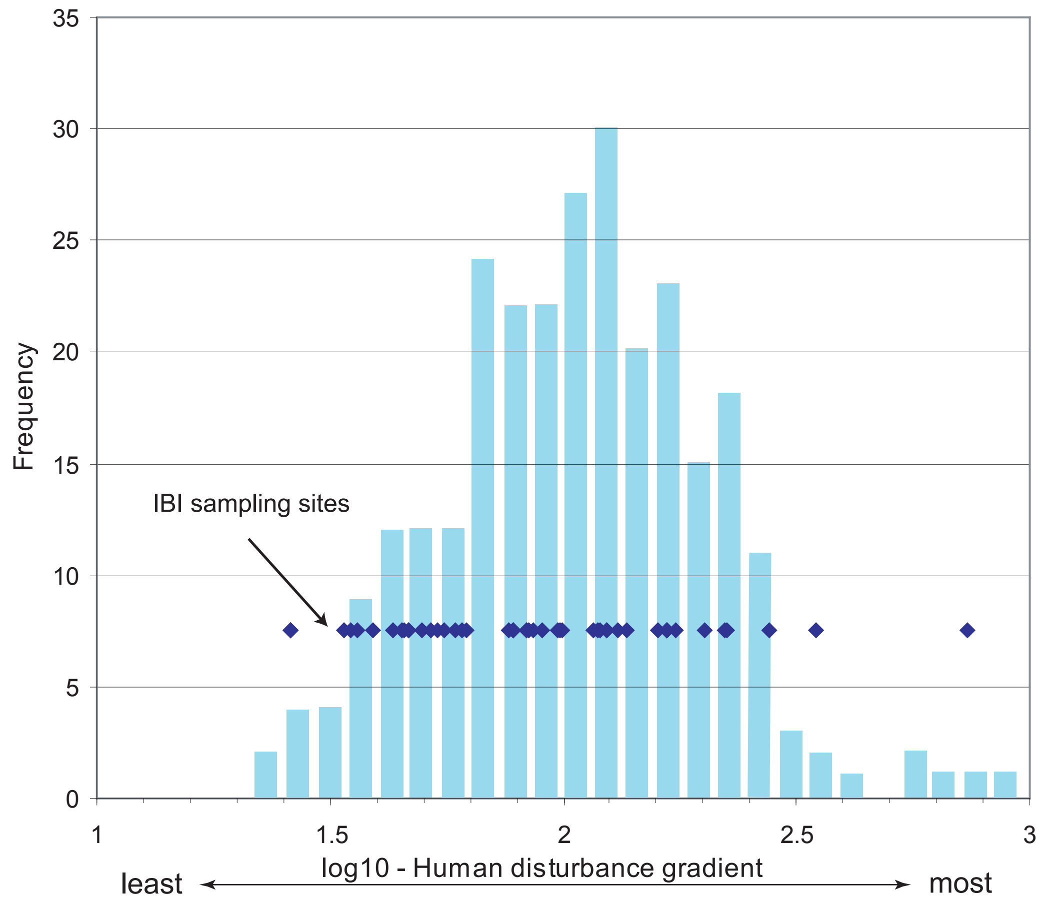


Figure 8. Frequency distribution of HDG values calculated for 379 monitoring units in the Alabama, Coosa and Tallapoosa River systems (data source, Alabama Department of Environmental Management).

Table 4. Rankings for HDG and habitat scores for stations in the Coosa and Tallapoosa River system

Station	Percent of max habitat score	Rank	HDG	Rank	Disturbance score (rank sum)
Snow Creek	51.67	2	736.74	1	3
Big Wills Cr. @ Co. Hwy. 39	53.64	3	223.76	4	7
Big Wills Cr. @ Hwy. 11	57.08	7	201.15	6	13
Nances Cr.	65.00	11	166.18	8	19
Nances Cr. @ Nances Cr Comm.	65.42	12	166.18	8	20
Nances Cr. @ Babbling Brook Rd	65.42	13	166.18	8	21
Cane Cr.	68.33	18	277.33	3	21
Little Canoe Cr.	55.00	4	90.14	19	23
Nances Cr. @ Babbling Brook Rd	65.83	15	166.18	8	23
Chulafinne Cr.	55.83	5	86.10	20	25
Ohatchee Cr.	59.17	8	98.21	17	25
Choccolocco Cr. @ Co. Hwy. 9	47.50	1	62.04	26	27
Yellowleaf Cr.	68.33	18	160.40	9	27
Walnut Cr.	73.33	23	221.08	5	28
Terrapin Cr. @ Co. Hwy. 71	65.42	14	115.97	15	29
Nances Cr. NE of Piedmont	70.00	21	166.18	8	29
Little Cr. @ Co. Hwy. 14	74.58	24	175.00	7	31
Lt. Hillabee Cr.	56.25	6	60.90	27	33
Chewacla Cr. @ Co. Hwy. 10	80.00	31	346.78	2	33
Wedowee Cr.	70.00	21	120.15	13	34
Camp Br.	75.00	25	124.25	12	37
Kelly Cr.	74.58	24	118.63	14	38
Big Canoe Cr.	75.42	26	124.55	12	38
Little Terrapin Cr.	60.83	10	55.37	29	39
Hurricane Cr. @ Co. Hwy. 4	67.50	16	77.79	24	40
Terrapin Cr. @ Co. Hwy. 8	72.92	22	97.38	18	40
Frog Cr. @ Co. Hwy. 12	68.75	19	77.79	24	43
Enitachopco Cr.	83.75	34	130.83	11	45
Camp Cr. @ Co. Hwy. 283	60.42	9	39.24	37	46
Cheaha Cr. @ Co. Hwy 005	88.33	37	136.80	10	47
Mountain Cr. @ Co. Hwy. 123	67.92	17	46.78	33	50
Paint Cr.	69.58	20	53.76	30	50
Socapatoy Cr.	77.08	28	83.78	22	50
Terrapin Cr. @ Co. Hwy. 175	86.67	35	99.03	16	51
Emuckfaw Cr.	67.92	17	45.10	35	52
Hurricane Cr. @ Co. Hwy. 8	79.17	29	77.79	24	53
Talladega Cr.	72.92	22	49.64	32	54
Waxahatchee Cr.	79.17	29	76.69	25	54
Little River @ Canyon Mouth Park	87.50	36	84.02	21	57
Terrapin Cr. @ Co. Hwy. 123	76.25	27	46.78	33	60
Little River @ Co. Hwy. 273	92.08	40	83.04	23	63
Hatchet Cr. @ McConnell	81.25	33	51.83	31	64
Hatchet Cr. @ East Mill	77.08	28	35.05	39	67
Terrapin Cr. @ Co. Hwy. 202	80.00	31	43.32	36	67
Terrapin Cr. nr Vigo Rd	83.75	34	45.34	34	68
Choccolocco Cr.	93.33	41	58.51	28	69
Shoal Cr. @ Pine Glenn	79.58	30	33.83	40	70
Hatchet Cr. @ Dunham	80.83	32	36.28	38	70
Marys Cr.	79.58	30	25.97	42	72
South Fork Terrapin Cr.	88.75	38	25.97	42	80
Trib. To South Fork Terrapin Cr.	90.00	39	25.97	41	80

lowest (most impaired) to highest (least impaired) and a sequential rank assigned beginning with 1. Percent maximum habitat values that were equal were assigned the same rank. In the second step, the ADEM HDG scores were ordered from highest (most impaired) to lowest (least impaired) and a sequential rank assigned beginning with 1. Values that were equal were assigned the same rank. For the final step, the ranks for habitat and HDG were added for each site to yield a disturbance score (table 4). Disturbance scores were used to evaluate the ability of IBI metrics to discriminate least from most disturbed streams.

DESIGNATION OF GUILDS

Biological responses to aquatic ecosystem stressors are manifested through changes in the structure (species diversity and abundance) and function (trophic relationships and reproductive patterns) of faunal communities. Within the fish community, species have to be classified into appropriate trophic and reproductive guilds so accurate and responsive IBI metrics can be constructed (Goldstein and Simon, 1999; Simon, 1999a). Guild determination should be based on regionally specific ichthyology texts and natural history information. Recent books of Alabama fishes (Mettee and others, 1996; Boschung and Mayden, 2004) and fish books of adjoining states, Etnier and Starnes (1993) for Tennessee and Ross (2001) for Mississippi, have excellent information for establishing guild associations for southeastern fishes. O'Neil and Shepard (2000b) provided a list of all Alabama freshwater fishes with ecological and distributional characteristics that included trophic status and tolerance. This list was modified using definitions and descriptions by Smoger and Angermeier (1999a) and Dauwalter and others (2003) to refine trophic guilds and add reproductive guild designations (appendix C).

Two classification factors were considered for assigning reproductive guild, spawning substrate and spawning behavior. Lithophilic spawners obligately use clean mineral substrates (i.e., rocks, sand, gravel) to deposit their eggs in or on top of. The non-lithophilic spawner guild captures the remaining types of substrate or spawning surfaces (aquatic vegetation, coarse organic matter, and other features not related to lithophilic substrates). Simple spawners typically invest little energy in nest preparation or parental care and generally broadcast, or bury, their eggs. Manipulative spawners construct simple nests such as depressions, mounds, or cavities and(or) have some form of parental care such as egg or young guarding. Four reproductive guilds were designated for Alabama fishes: (1) simple lithophils, (2) manipulative lithophils, (3) simple non-lithophilic spawners, and (4) manipulative non-lithophilic spawners.

Trophic guild classifications were slightly more complex, and three classification factors were considered as per Smogor and Angermeier (1999b): number of food types consumed, feeding behavior, and foods consumed. Fish food types were grouped into four categories: detritus, algae or vascular plants, invertebrates, and fish-crayfish. Generalist feeders were those that eat three or more food types, specialists eat only one or at most two types. Benthic versus non-benthic feeding behaviors were also considered in the classification process with benthic behaviors associated with bottom-feeding species. Seven trophic guilds were established: (1) DAH - detritivore, algivore, herbivore. Detritus, algae, and(or) vascular plants comprise the major diet items for this guild with *Campostoma* and *Hybognathus* as examples. (2) AHI - algivore, herbivore, invertivore. This guild is similar to DAH but species consume less detritus and more invertebrates with *Erimyzon*, *Polyodon*, carp, and *Hypentelium* as examples. (3) INV - invertivore. These species consume a variety of invertebrate taxa including crustaceans, insects, and mollusks. Examples are *Moxostoma, Fundulus, Ictalurus*, and *Ameiurus.* (4) INS - insectivore. Many species consume insect immatures as their major food type. Practically all of the darters and many cyprinid species are insectivores. (5) PIS - piscivore. Piscivores, such as *Lepisosteus* and *Morone*, consume fishes almost exclusively as adults. (6) IP - invertivore, piscivore, Many large predators, such as *Micropterus* and *Esox* will consume fishes and larger invertebrates as adults. 7) PAR - parasite. A very restricted classification for those species (such as *Ichthyomyzon*) which may parasitize other fishes. This guild is frequently grouped with piscivores.

SELECTION AND SCORING OF METRICS FOR IBI

A total of 38 candidate metrics were evaluated for inclusion in the Coosa-Tallapoosa IBI (table 5). Candidate metrics were chosen from among those that had been used in other applications of the IBI by GSA (O'Neil and Shepard, 2000b) or

Table 5. Candidate IBI metrics evaluated for use in the Coosa and Tallapoosa River systems upstream of the Fall Line.

Candidate metric	Predicted response to impairment	Discriminates between least and most disturbed ($p \leq .1$)		Correlates with human disturbance gradient ($p \leq .1$)	Rationale as substitute for one of Karr's (1981) original metrics	Redundant with other selected metrics
		<25 mi^2	≥25 mi^2			
SPECIES RICHNESS AND COMPOSITION						
Total number of species	decrease	Y	N	Y		
Total number of native species	decrease	Y	N	Y	Excludes several tolerant introduced species	N
Number of minnow species	decrease	N	N	N	Large taxonomic group in the Mobile Basin. Represents wide range of tolerances	N
Number of shiner species	decrease	N	N	N		
Number of sucker species	decrease	Y	Y	Y	Karr metric	N
Number of sunfish species	decrease	Y	Y	Y	Karr metric	N
Number of *Lepomis* species	decrease	Y	Y	Y		
Number of darter species	decrease	N	Y	N	Karr metric	N
Number of darter+madtom species	decrease	N	Y	Y		
Number of darter+madtom+sculpin species	decrease	N	Y	Y		
Number of terete minnow species	decrease	Y	N	Y		

Table 5. Candidate IBI metrics evaluated for use in the Coosa and Tallapoosa River systems upstream of the Fall Line–Continued

Candidate metric	Predicted response to impairment	Discriminates between least and most disturbed ($p \leq .1$)		Correlates with human disturbance gradient ($p \leq .1$)	Rationale as substitute for one of Karr's (1981) original metrics	Redundant with other selected metrics
		<25 mi^2	≥25 mi^2			
TOLERANCE/ INTOLERANCE						
Percent dominant species	increase	N	N	N		
Percent pioneer species	increase	N	N	N		
Number of intolerant species	decrease	N	Y	N	Karr metric	N
Percent tolerants	increase	Y	Y	Y	Wider response than % green sunfish	N
Percent green sunfish	increase	Y	Y	Y		
Percent stonerollers	increase	N	Y	Y		
Percent green sunfish + yellow bullhead	increase	Y	Y	Y		
Percent green sunfish + bluegill + yellow bullhead + channel catfish	increase	Y	N	Y		
Percent *Lepomis* species	increase	Y	N	N		
TROPHIC						
Percent omnivores	increase	N	Y	Y	Karr metric	N
Percent insectivorous cyprinids	decrease	Y	Y	Y		

Table 5. Candidate IBI metrics evaluated for use in the Coosa and Tallapoosa River systems upstream of the Fall Line–Continued

Candidate metric	Predicted response to impairment	Discriminates between least and most disturbed ($p \leq .1$)		Correlates with human disturbance gradient ($p \leq .1$)	Rationale as substitute for one of Karr's (1981) original metrics	Redundant with other selected metrics
		<25 mi^2	≥25 mi^2			
Percent invertivores	decrease	N	Y	Y	more inclusive than % insectivorous cyprinids	N
Percent benthic invertivores	decrease	N	Y	Y		
Percent piscivores	decrease	Y	Y	Y	Karr metric	N
Percent generalists feeders	increase	Y	Y	Y		
ABUNDANCE, CONDITION, AND REPRODUCTION						
Total catch	decrease below optimum range, increase above	N	Y	Y		
Catch per hour	same as above	N	Y	Y		
Catch per 100 sq. ft.	same as above	N	N	Y		
Catch per unit effort	same as above	N	Y	Y	A measure of relative abundance similar to total catch	N
Percent anomalies (DELT)	increase	Y	Y	N		
Percent hybrids	increase	N	N	N		
Percent DELT + hybrids	increase	Y	Y	Y	DELT's and hybrids are both usually rare. This metric incorporates both.	N

Table 5. Candidate IBI metrics evaluated for use in the Coosa and Tallapoosa River systems upstream of the Fall Line–Continued

Candidate metric	Predicted response to impairment	Discriminates between least and most disturbed ($p \leq .1$)		Correlates with human disturbance gradient ($p \leq .1$)	Rationale as substitute for one of Karr's (1981) original metrics	Redundant with other selected metrics
		<25 mi^2	≥25 mi^2			
Percent simple lithophils	decrease	N	Y	Y		
Percent manipulative spawners	decrease	Y	Y	Y		
Number lithophilic spawners	decrease	N	Y	Y		
Percent non-lithophilic spawners	increase	Y	Y	Y		
Percent simple lithophiles+tolerants	decrease	Y	Y	N		

Table 6. IBI metric scoring criteria for wadeable streams of the Coosa and Tallapoosa River systems

Metric	Watershed Size	Scoring Criteria		
		5	3	1
1. Number of native fish species	<10 mi^2	>16	8-16	<8
	10-50 mi^2	>21	11-21	<11
	>50 mi^2	>23	12-23	<12
2. Number of darter species	<10 mi^2	>3	2-3	<2
	10-50 mi^2	>4	3-4	<3
	>50 mi^2	>5	3-5	<3
3. Number of native minnow species	<10 mi^2	>5	3-5	<3
	10-50 mi^2	>7	4-7	<4
	>50 mi^2	>8	4-8	<4
4. Number of sucker species	<10 mi^2	>2	2	<2
	10-50 mi^2	>3	2-3	<2
	>50 mi^2	>3	2-3	<2
5. Number of intolerant species	<10 mi^2	>1	1	0
	10-50 mi^2	>2	2	<2
	>50 mi^2	>3	2-3	<2
6. Proportion as tolerant species	all sizes	<5%	5-15%	>15%
7. Proportion as omnivores and herbivores	all sizes	<15%	15-30%	>30
8. Proportion as invertivores	all sizes	>80%	50-80%	<50%
9. Proportion as top carnivores	all sizes	>3%	1-3%	<1%
10. Proportion as non-lithophilic spawners	all sizes	>35%	15-35%	<15%
11. Average catch per unit of effort	all sizes	10-20	5 to <10 or >20 to 30	<5 or >30
12. Proportion of individuals with DELT + hybrids	all sizes	<.5%	.5-1%	>1%

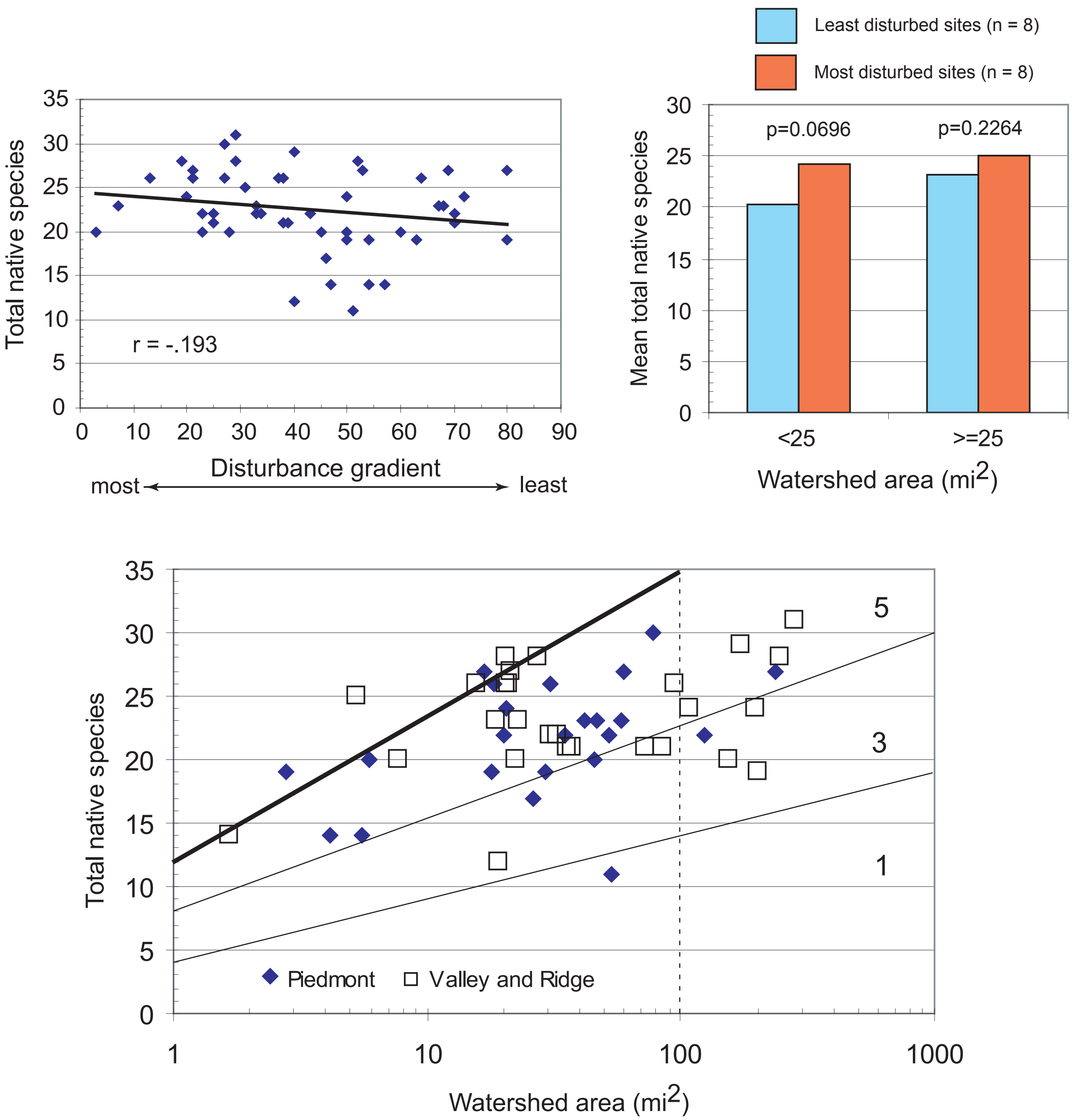


Figure 9. Scoring criteria, relation of metric value to disturbance gradient, and a comparison of most to least disturbed stations for small and large watersheds for the IBI metric - total native species

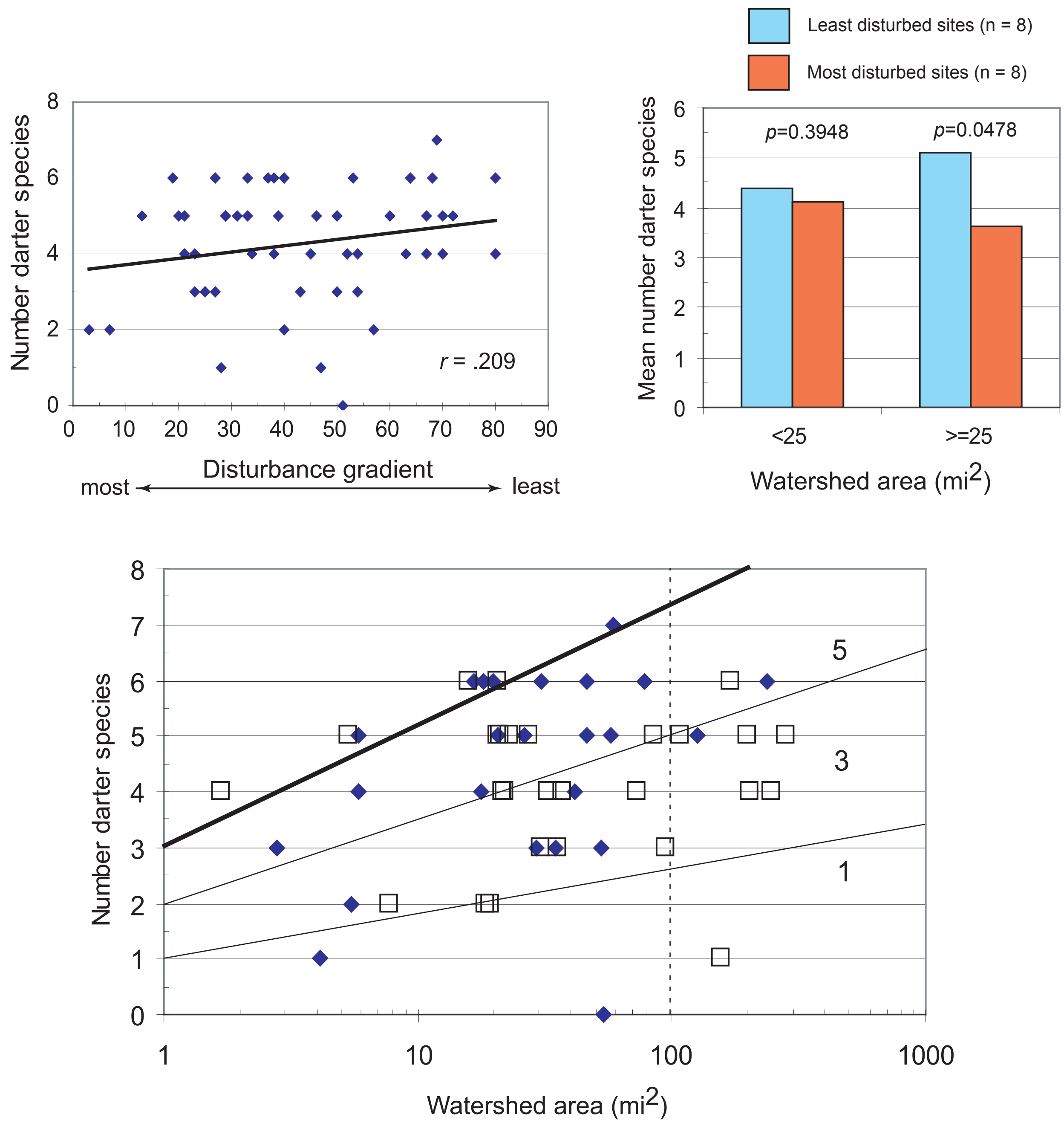


Figure 10. Scoring criteria, relation of metric value to disturbance gradient, and a comparison of most to least disturbed stations for small and large watersheds for the IBI metric - number darter species

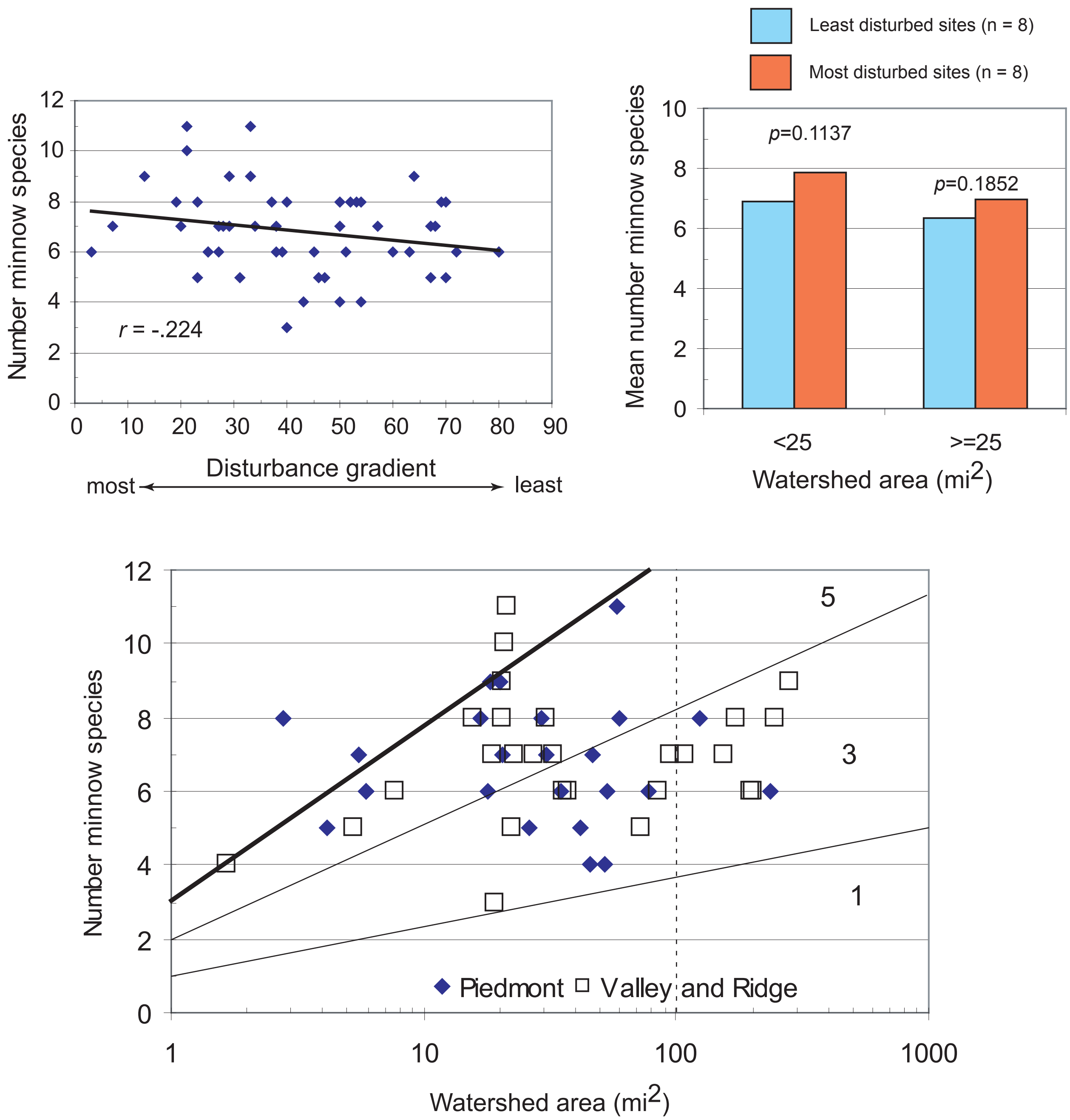


Figure 11. Scoring criteria, relation of metric value to disturbance gradient, and a comparison of most to least disturbed stations for small and large watersheds for the IBI metric - number of minnow species

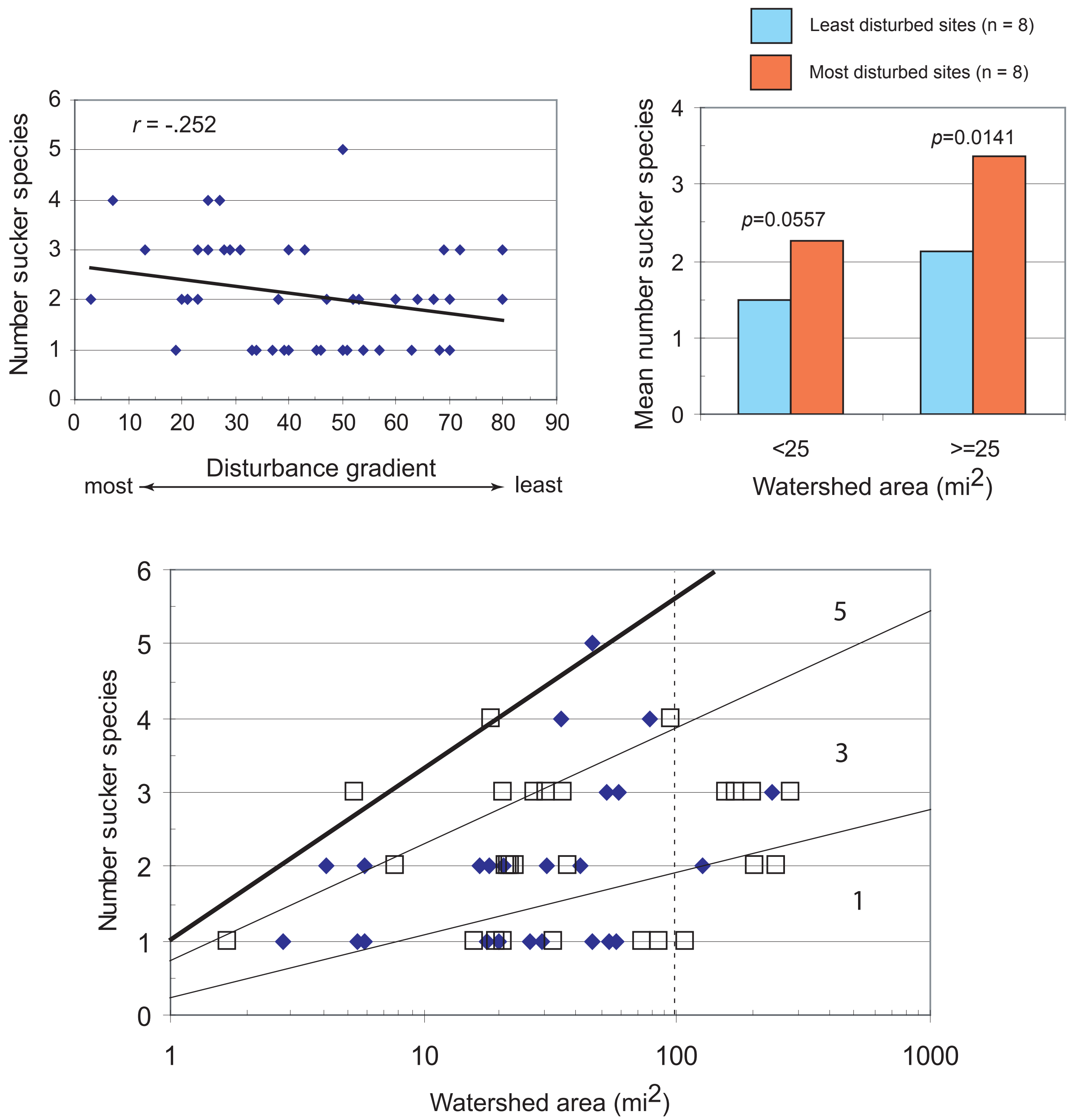


Figure 12. Scoring criteria, relation of metric value to disturbance gradient, and a comparison of most to least disturbed stations for small and large watersheds for the IBI metric - number of sucker species

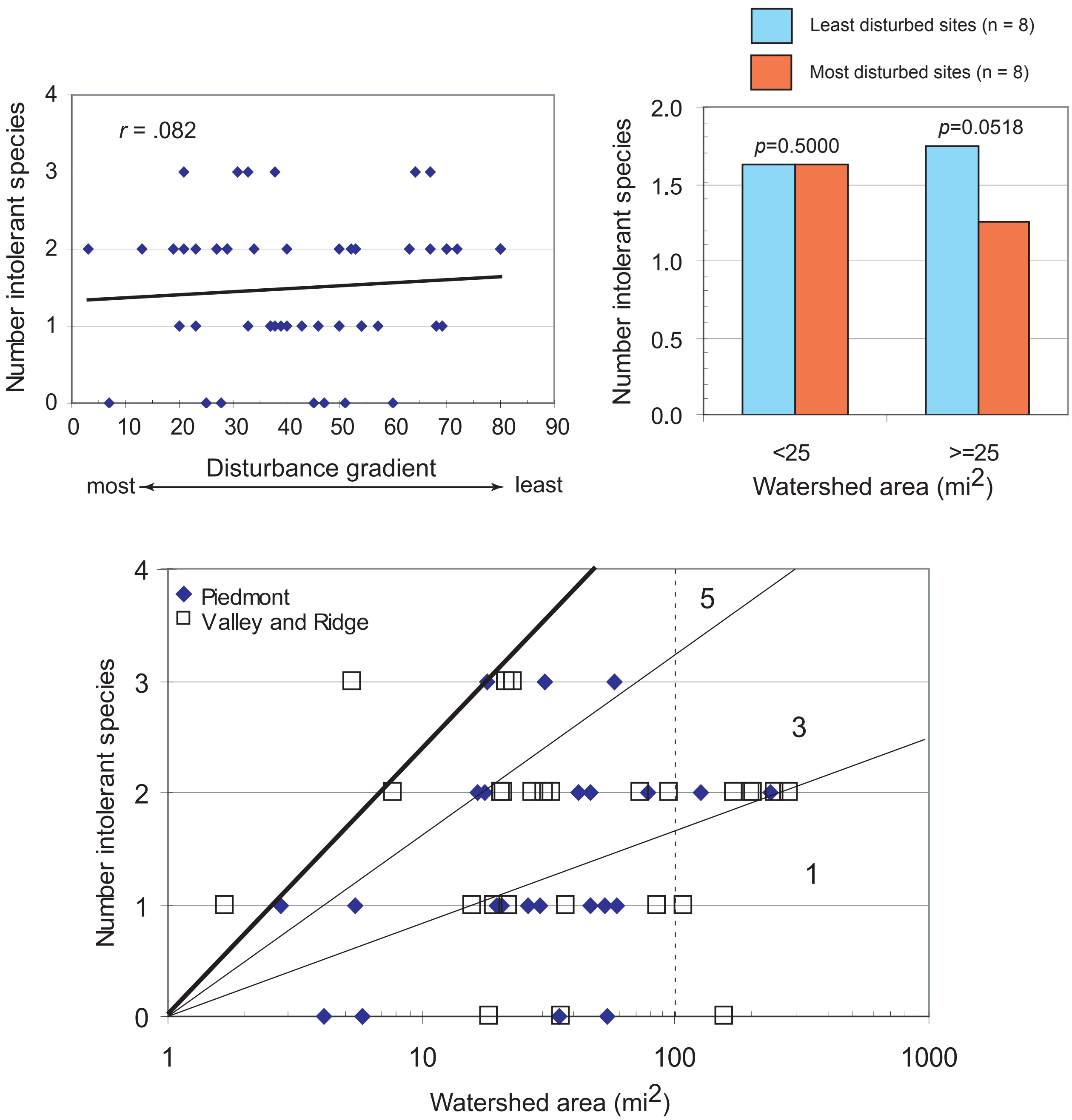


Figure 13. Scoring criteria, relation of metric value to disturbance gradient, and a comparison of most to least disturbed stations for small and large watersheds for the IBI metric - number of intolerant species.

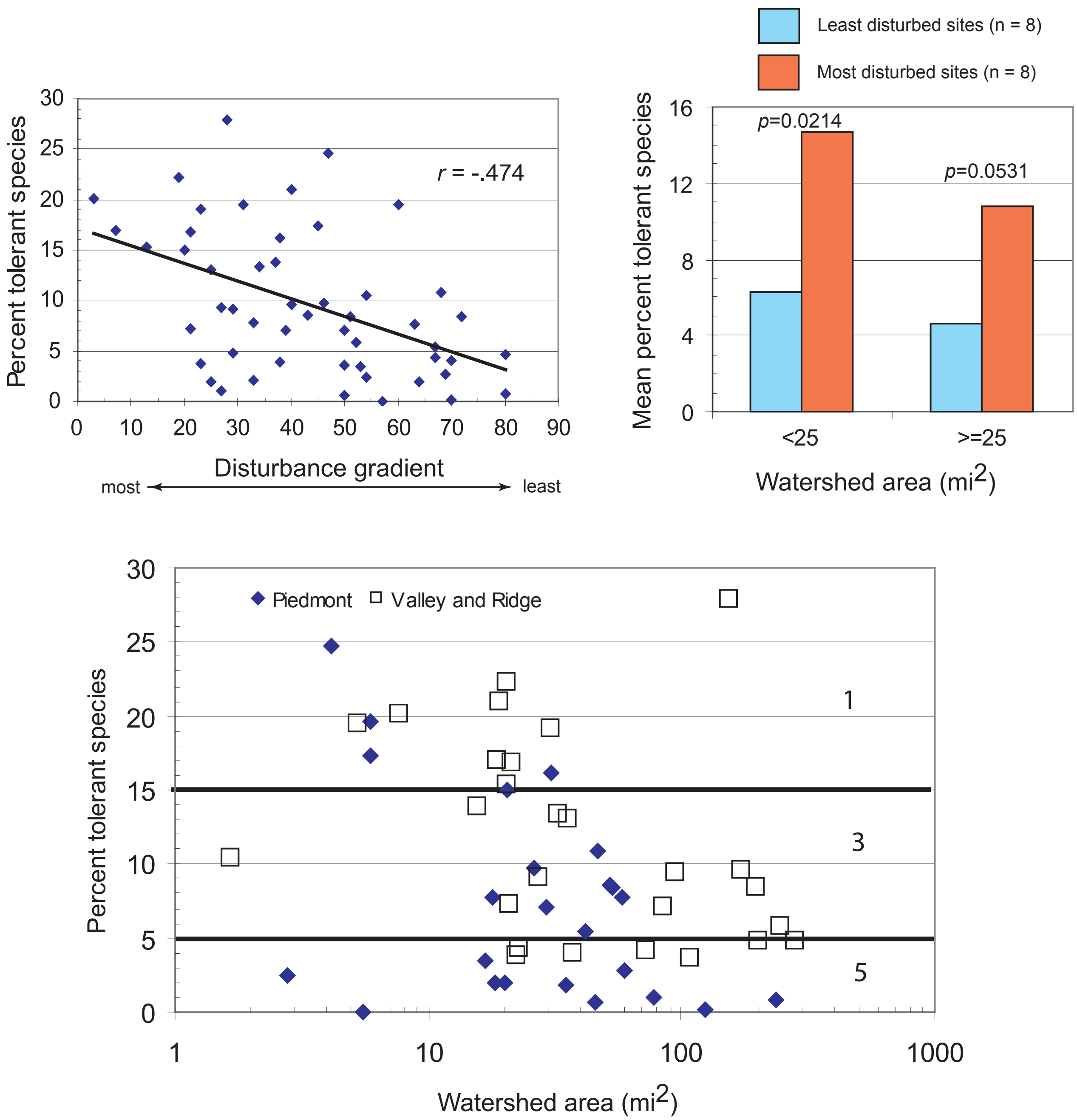


Figure 14. Scoring criteria, relation of metric value to disturbance gradient, and a comparison of most to least disturbed stations for small and large watersheds for the IBI metric - percent tolerant species.

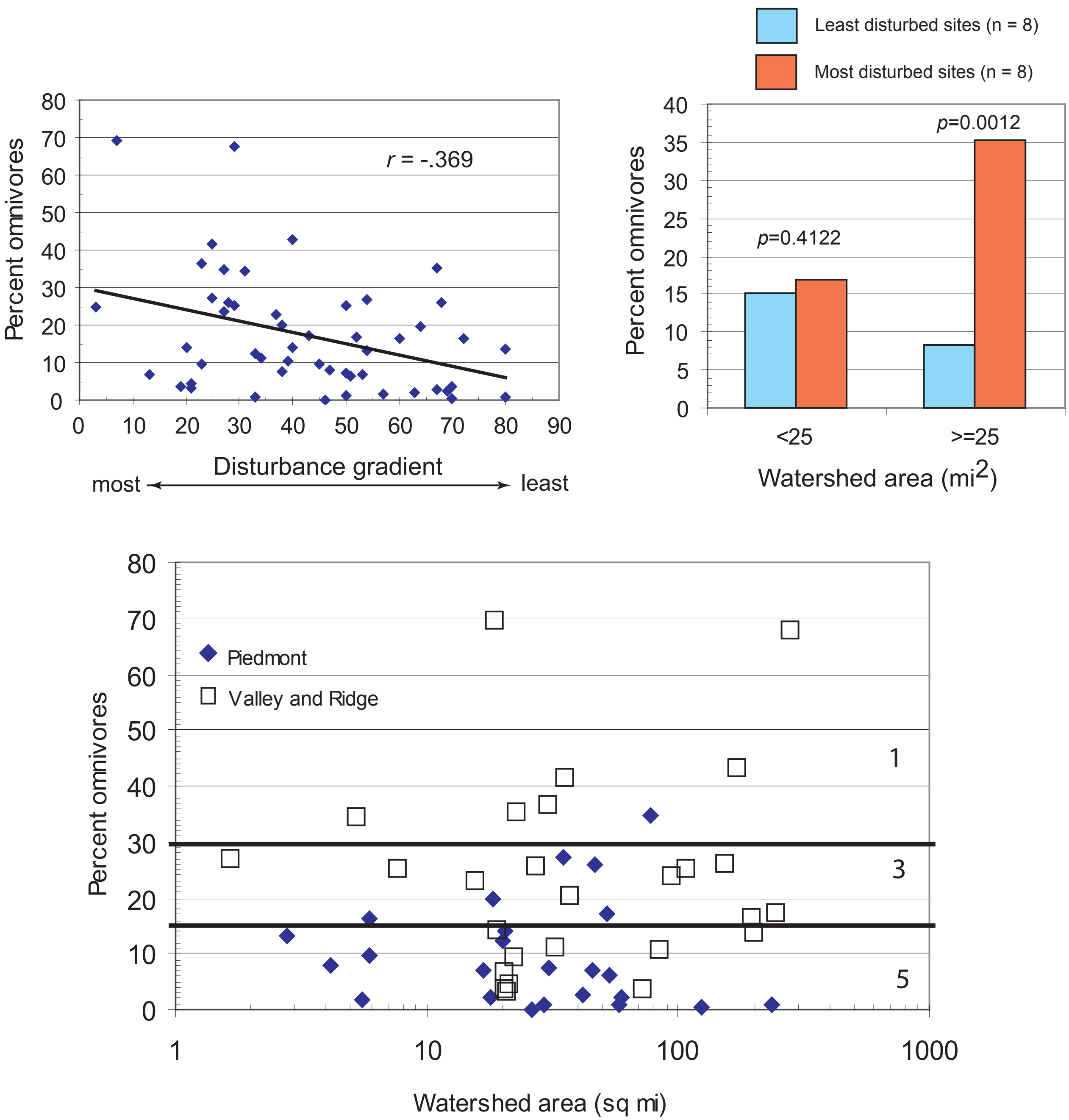


Figure 15. Scoring criteria, relation of metric value to disturbance gradient, and a comparison of most to least disturbed stations for small and large watersheds for the IBI metric - percent omnivores and herbivores

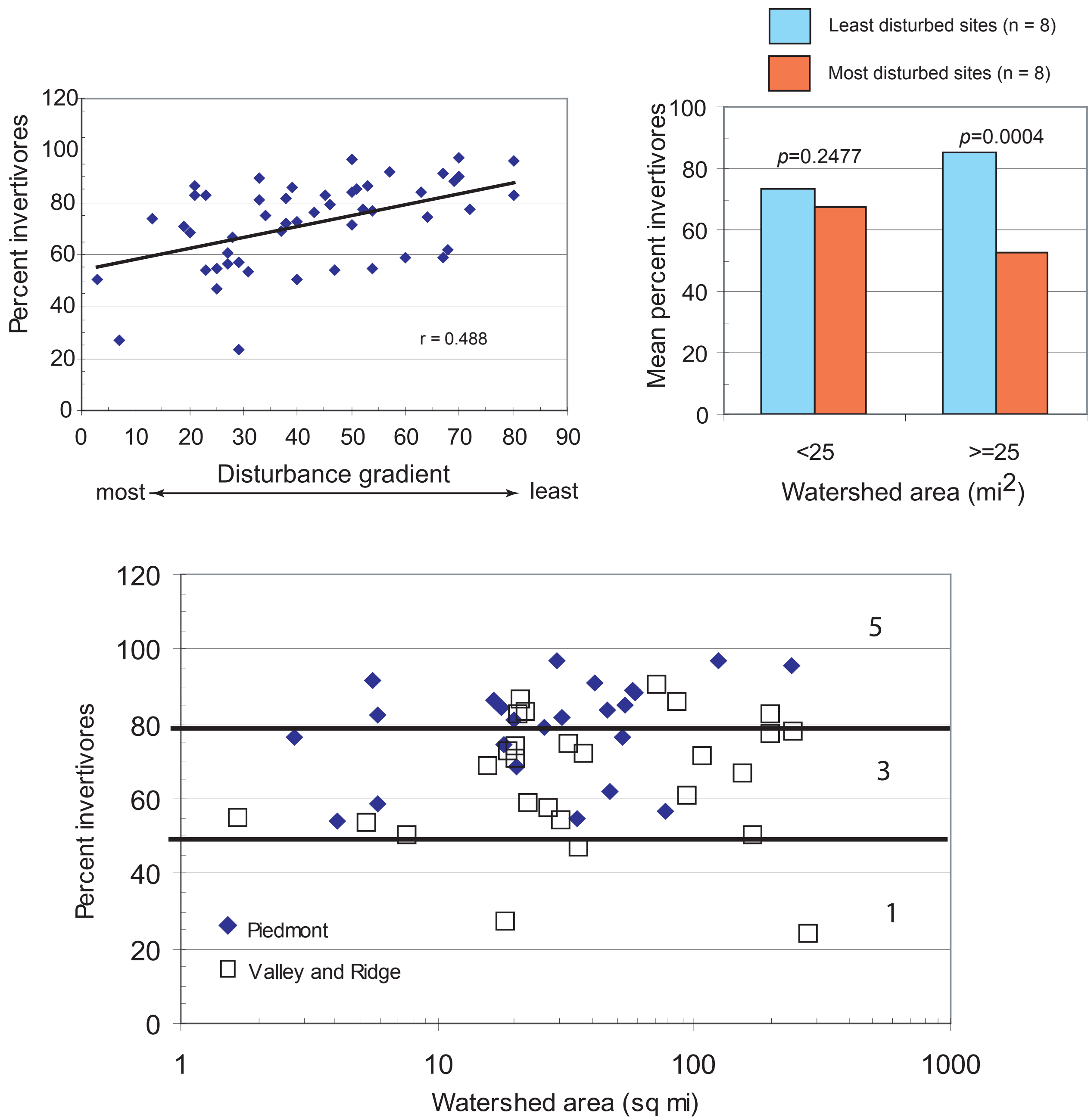


Figure 16. Scoring criteria, relation of metric value to disturbance gradient, and a comparison of most to least disturbed stations for small and large watersheds for the IBI metric - percent invertivores

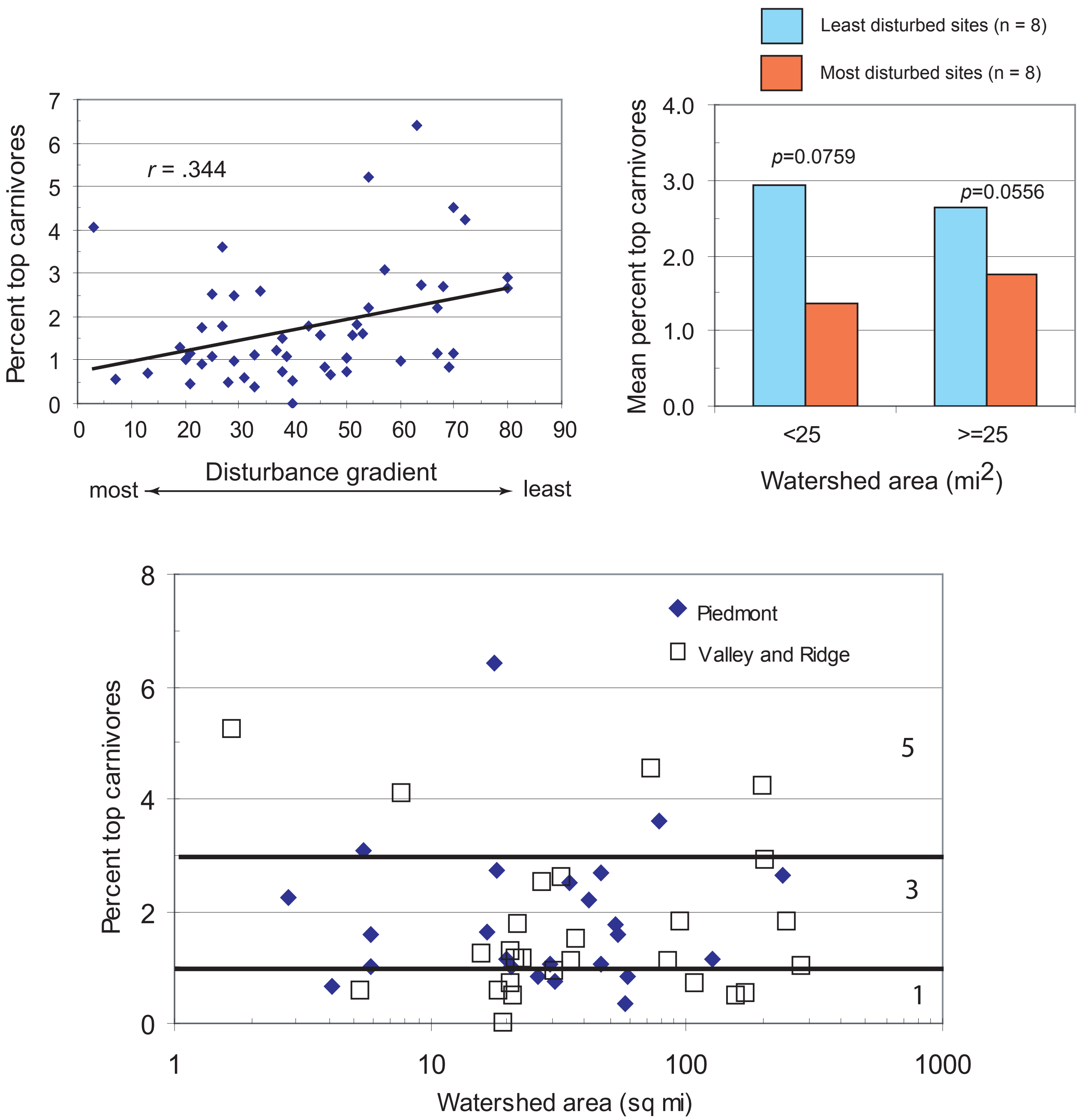


Figure 17. Scoring criteria, relation of metric value to disturbance gradient, and a comparison of most to least disturbed stations for small and large watersheds for the IBI metric - percent top carnivores

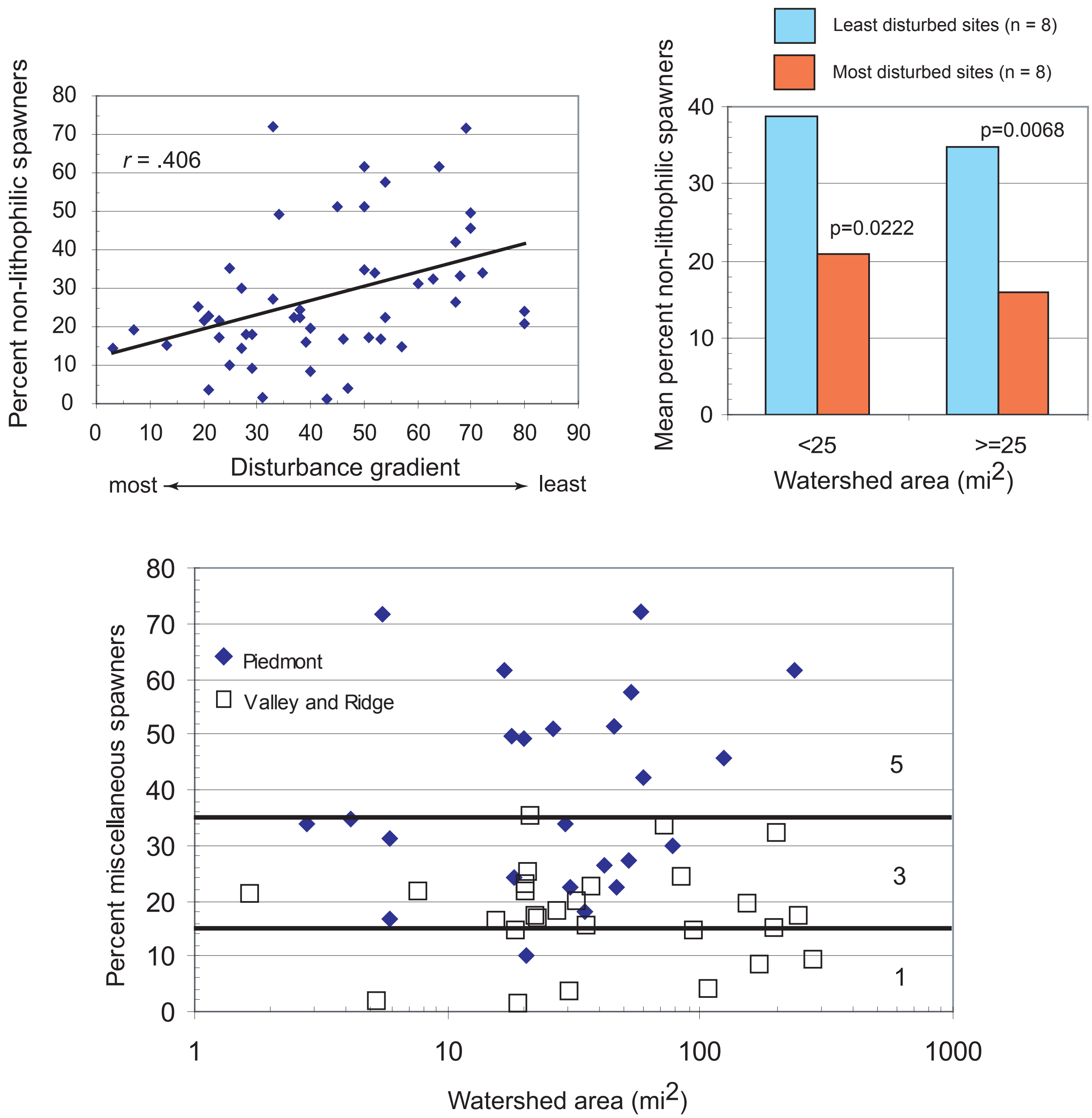


Figure 18. Scoring criteria, relation of metric value to disturbance gradient, and a comparison of most to least disturbed stations for small and large watersheds for the IBI metric - percent individuals as non-lithophilic spawners

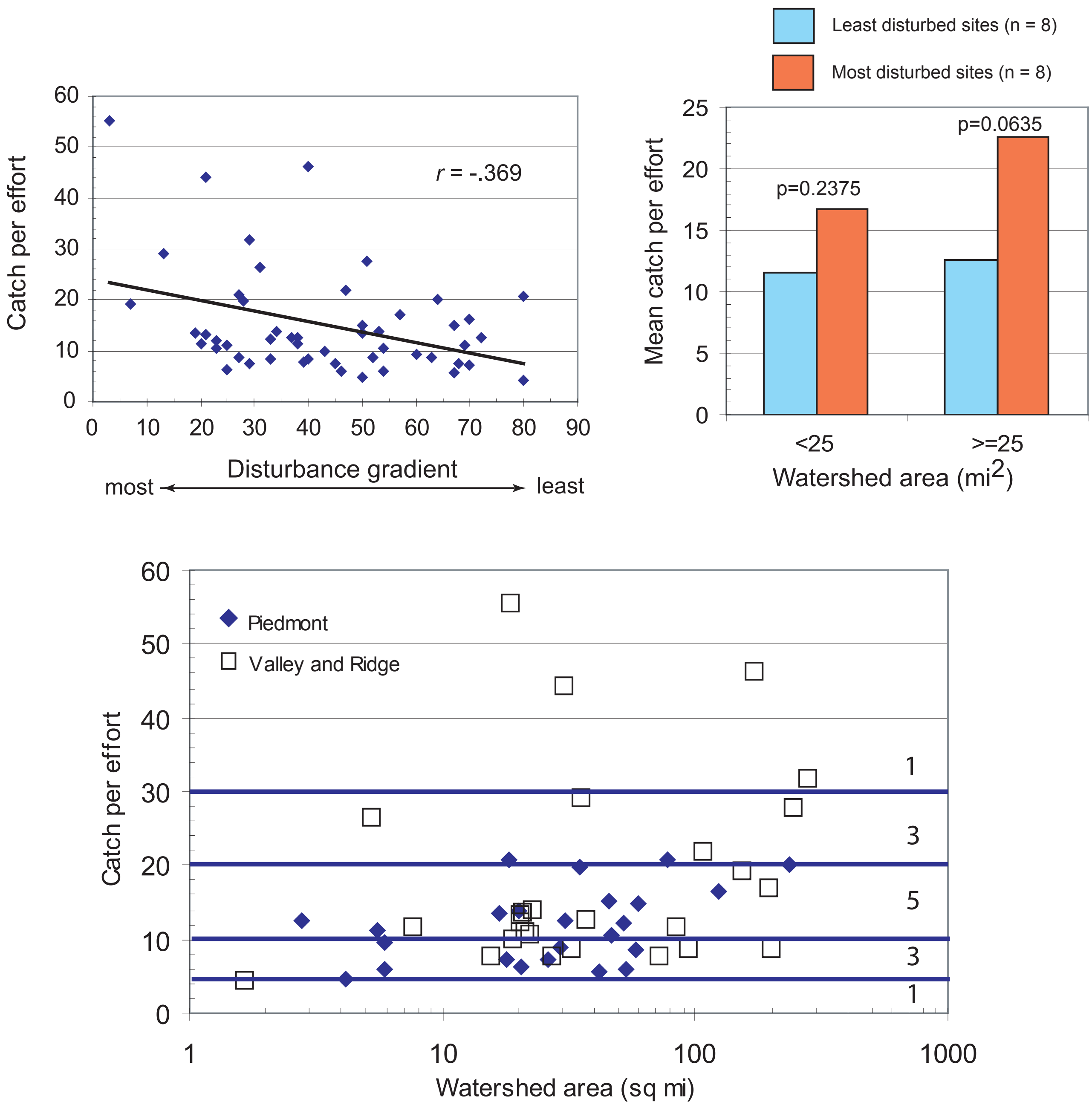


Figure 19. Scoring criteria, relation of metric value to disturbance gradient, and a comparison of most to least disturbed stations for small and large watersheds for the IBI metric - number collected per unit effort

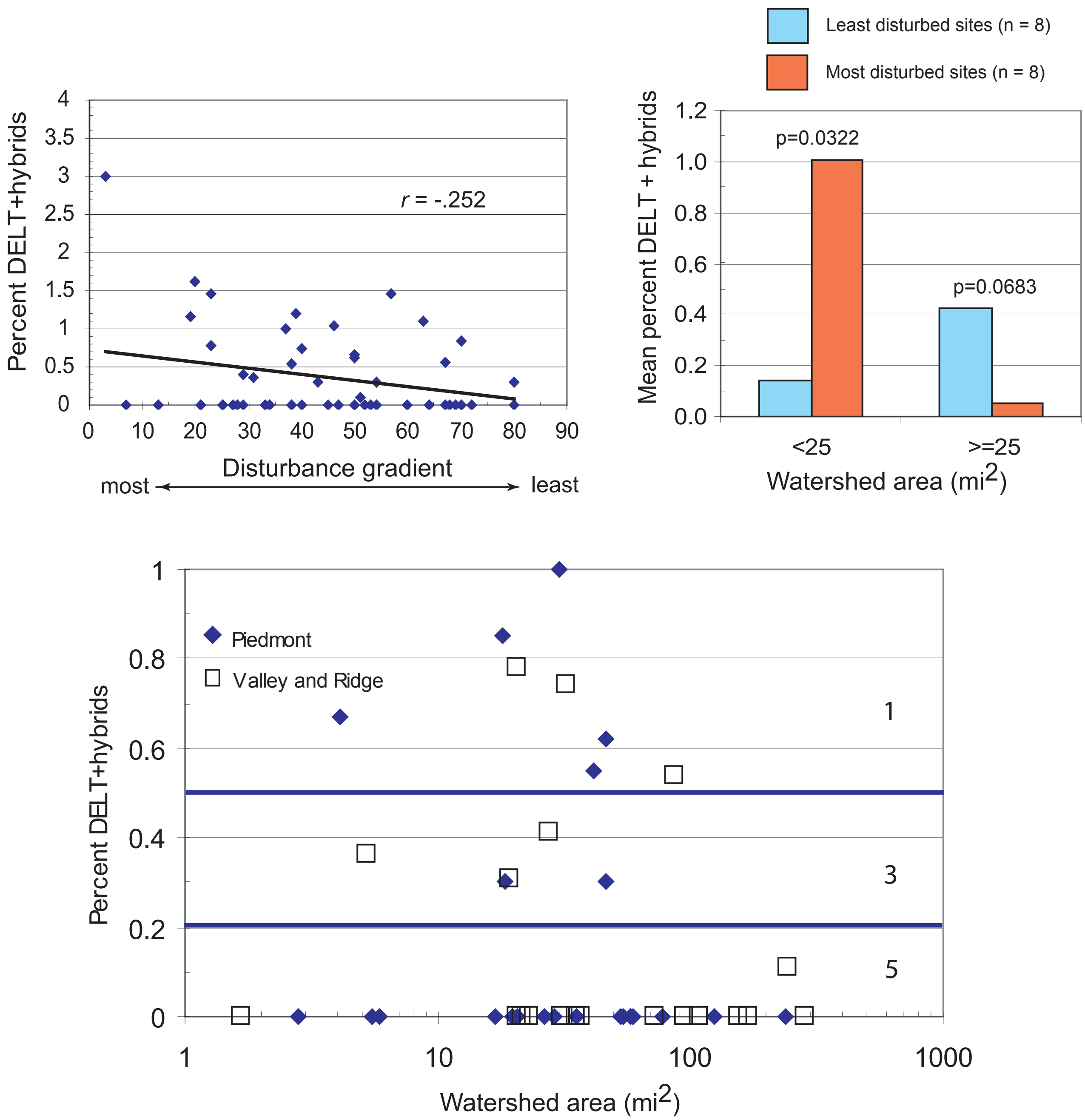


Figure 20. Scoring criteria, relation of metric value to disturbance gradient, and a comparison of most to least disturbed stations for small and large watersheds for the IBI metric - percent individuals with DELT+hybrids

presented in literature sources (Karr, 1981; Barbour and others, 1999; Karr and others, 1986; Miller and others, 1988; Dauwalter and others, 2003; Simon, 1999b; Paller and others, 1996; Schleiger, 2000; Teels and Danielson, 2001) and were screened for inclusion based on our familiarity with the local fauna and the potential suitability of the metrics to conditions in the Coosa and Tallapoosa River systems above the Fall Line. The ability of each metric to discriminate between least disturbed and most disturbed sites and correlation of metrics with the HDG were considerations in the selection process but did not override the ecological rationale behind the metrics along with our experience with the local fauna as well as the work of others. Our sample sizes were not large in this study and the failure of a given metric to discriminate between least and most disturbed sites in many cases may be an artifact of the small sample size and lack of severely impaired stations in our data set.

Angermeier and Karr (1986) conducted a detailed investigation into the relative contribution of various combinations of metrics to IBIs developed for Illinois, Ohio, and West Virginia. One of the important findings of their investigation was that “no metric appeared consistently best or worst at detecting degradation, and an IBI comprising all 12 metrics probably features greater utility than an IBI with fewer metrics.” For this reason we retained 12 metrics divided among the broad categories of species richness and composition, tolerance level, trophic guild, abundance, condition and reproductive guild for the Coosa and upper Tallapoosa River system IBI. Comparison of all evaluated metrics versus station watershed area can be found in appendix D.

The method of Karr and others (1986) was used in scoring the 12 IBI metrics for data sets with some modifications intended to make the index more sensitive to local conditions (table 6). Scoring criteria for metrics 1 through 12 were developed by plotting values for these categories as a function of drainage area (figs. 9 to 20). Based on these plots, maximum species richness lines were drawn, and the area below this line was trisected to derive ranges for the scores: 5 (best), 3, or 1 (worst). Several of the IBI metrics that measure species richness and composition are strongly related to stream size with larger streams supporting more species. This relationship is in many cases drainage specific and generally holds true up to a certain critical watershed size after which species richness remains relatively constant, or declines. Regional differences in faunal composition are strongly apparent in Alabama, with distributions of many species highly correlated with physiography and (or) specific drainage basins (Mettee and others, 1996).

1. NUMBER OF NATIVE SPECIES

The negative relationship between species richness and habitat degradation is well documented (Karr, 1981; Karr and others, 1986; Ohio EPA, 1987a). Species richness was also found to be the metric most closely correlated with overall IBI score in a study of several regional applications of the IBI by Angermeier and Karr (1986). Hughes and Oberdorff (1999) found the species richness metric was used in all IBI applications they examined outside of the U.S. and Canada. Species richness is strongly related to stream size, stream order, and watershed area in small to medium sized watersheds (Karr and others, 1986). In our comparison of candidate metrics we found that both total number of species and total number of native species were negatively correlated with the HDG and discriminated between impaired and unimpaired stations in small watersheds but not larger ones (table 5, fig. 9). In both cases, the mean values for disturbed stations was higher than undisturbed ones, although not at a highly significant level. The failure to discriminate between stations might be related to small sample size and a lack of severely impaired stations in our samples. We selected number of native species over total number of species in order to exclude several species of nonnative fishes in the Mobile Basin which are generally tolerant, invasive, and could detract from the responsiveness of this metric in impaired streams. Hughes and Oberdorff (1999) also recommended that the native species metric was an improvement over total species, particularly where nonnatives are common or highly invasive.

2. NUMBER OF DARTER SPECIES

Darters are a benthic group and generally intolerant of habitat impairments. Karr (1981) used darter species richness as one of the original IBI metrics because, as a group, they are sensitive to disturbance. The darters are an even more speciose group in the Mobile basin than in the midwest with nearly 75 species occurring in Alabama

(Mettee and others, 1996). Several authors (Paller and others, 1996; Shleiger, 2000) have modified the darter metric to include madtoms or madtoms+sculpins since these groups are also benthic and are similar to darters in their feeding and spawning requirements. We evaluated the darter metric alone and with madtoms and with madtoms+sculpins. Although the darter metric did not discriminate between impaired and unimpaired stations in small watershed areas and was not closely correlated with the HDG (table 5, fig. 10), we have retained it as a metric because of its extensive use in most IBI applications. We did not add sculpins and madtoms into this metric because, in our experience in the Mobile Basin, sculpins can be common in disturbed habitats and may be the dominant species in cool-water streams during summer months. Madtoms are benthic, like darters, but the madtom species that are most common in the Mobile basin are more closely associated with root masses and woody debris along the shoreline than with shoals, as are most darters, and may not be as vulnerable to impacts that affect substrate integrity such as excessive sedimentation.

3. NUMBER OF NATIVE MINNOW SPECIES

Minnows are a diverse group in the Mobile Basin with a range of tolerances, habitat preferences, and trophic and reproductive guilds (O'Neil and Shepard, 2000b). Barbour and others (1999) suggest this as a replacement metric for number of sucker species; however, we retain the sucker metric and use minnows as an additional diversity metric. The number of minnow species is expected to decrease with increasing disturbance and increase with stream size. Statistically in our data set, number of minnow species was not correlated with the HDG and the metric did not separate disturbed stations at either watershed size (table 5, fig. 11). This unexpected result might be related to small sample size and a lack of severely impaired stations in our samples.

4. NUMBER OF SUCKER SPECIES

Diversity of sucker species was incorporated in the original midwestern IBI (Karr, 1981) because they are sensitive to physical and chemical degradation and because most species are long-lived and can incorporate environmental changes over a number of years. Although the number of sucker species would be expected to decline with increasing disturbance, our data show a significantly higher number of sucker species at disturbed than undisturbed stations and a negative correlation with the HDG (fig. 12). Small sample size and lack of severely degraded stations is a possible cause for this anomaly in our data.

5. NUMBER OF INTOLERANT SPECIES

The number of intolerant species is used as a metric to distinguish high quality stations from moderately impaired ones (Karr,1981; Karr and others, 1986; Hughes and Oberdorff, 1999). Intolerant species are the first to disappear after some form of disturbance to a stream. Ideally, these species should be sensitive to several types of degradation such as siltation, low dissolved oxygen, or chemical contamination and should represent less than 5 to 10 percent of the total species for a stream (O'Neil and Shepard, 2000b). In our data set, this metric separated least from most disturbed stations in larger drainage areas but not in smaller ones and was not correlated with the HDG (table 5, fig. 13).

6. PROPORTION AS TOLERANT SPECIES

We use proportion as tolerant individuals as a replacement for Karr's (1981) original metric of proportion as green sunfish as recommended by Karr and others (1986), Ohio EPA (1987a), and Hughes and Oberdorff (1999). Previous application of the IBI by GSA (O'Neil and Shepard, 2000b, Shepard and others 1997) replaced the percent green sunfish metric with percent *Lepomis* species since several sunfish species may become dominant in disturbed habitats in the Mobile Basin, but rarely green sunfish alone. Since percent tolerant species is a more inclusive metric, we have adopted it here. The metric successfully discriminates between least and most disturbed sites at small and larger stream sizes and is correlated with the HDG (table 5, fig. 14).

7. PROPORTION AS OMNIVORES AND HERBIVORES

Percent omnivores is one of the original metrics proposed by Karr (1981) and is used to detect alterations in the food base caused by physical or chemical impairment that favor species which consume substantial quantities of plant and animal material (Hughes and Oberdorff, 1999). We include herbivores such as *Campostoma* and *Hybognathus* which can both become dominant in impacted streams, particularly those with high nutrient inputs, following O'Neil and Shepard (2000b) . In our data set, this metric was correlated with the HDG and discriminated between least and most disturbed sites in larger streams, but not smaller ones (table 5, fig. 15).

8. PROPORTION AS INVERTIVORES

We have adopted this metric as a replacement for the original Karr (1981) metric, proportion as insectivorous cyprinids. Hughes and Oberdorff (1999) recommend this metric as a replacement since it is more inclusive and ecologically accurate than percent insectivorous cyprinids as a surrogate for assessing the degree to which the invertebrate community is degraded. This metric decreases with increasing impairment as the invertebrate community declines and invertivores are replaced by omnivores and herbivores (O'Neil and Shepard, 2000b). The metric was correlated with the HDG and discriminated between disturbed and undisturbed stations in large streams but not in smaller streams in our study (table 5, fig. 16).

9. PROPORTION AS TOP CARNIVORES

Karr (1981) proposed this metric because healthy populations of top carnivores indicate a relatively healthy, trophically diverse community. Hughes and Oberdorff (1999) also point out that top carnivores are susceptible to bioaccumulation of toxins and can be affected by long-term physical and chemical impacts since they are typically long-lived. Only species that feed primarily on fish, vertebrates, or crayfish as adults are included (O'Neil and Shepard, 2000b). In our data, the top carnivore metric was correlated with the HDG and separated disturbed from undisturbed stations in small and large streams (table 5, fig. 17).

10. PROPORTION AS NON-LITHOPHILIC SPAWNERS

Non-lithophilic spawners include those species, with either simple or manipulative spawning behaviors, that use a variety of spawning substrates such as snags, aquatic vegetation, and coarse organic matter, or spawn in open water. It was composed predominately of *Cyprinella*, *Pimephales, Ameiurus, Noturus, Micropterus*, and some *Etheostoma* but other species were included in this metric as well.

Many IBI applications have incorporated a different reproduction metric, the proportion as simple, lithophilic spawners since it is negatively related to increase sedimentation and siltation of lithophilic substrates. Simple lithophils were observed to follow this relationship in our data (appendix C); however, the metric proportion as non-lithophic spawners was more strongly related to disturbance, decreasing as disturbance increased, and discriminated most from least disturbed sites in both small and large watersheds (fig. 18) better than simple lithophils. Non-lithophilic spawners have been evaluated by a few researchers (Dauwalter and others, 2003; Smogor and Angermeier, 1999a) but was not included in their final IBI's. When non-lithophilic spawners was substituted for number of *Lepomis* species, we observed better discrimination at the lower and upper ends of the IBI, a desirable trait and function for a metric. This metric may be responding to disturbance in a more comprehensive way than simple lithophils by incorporating not only the effects of substrate siltation but also other more complex disturbances that affect habitats more broadly such as changes in flow regime that scour shoreline habitats and loss of instream large woody debris from riparian vegetation removal.

11. AVERAGE CATCH PER EFFORT

This metric is a measure of the overall density of individuals in the sample area expressed as catch per sampling effort and is the total number of individuals collected in a sample divided by the total number of efforts. Abundance is one of the original Karr (1981) metrics and has been widely employed in IBI applications (Hughes and Oberdorff, 1999). Fish abundance is generally assumed to decrease with increasing habitat disturbance; however, in some streams impacted by nutrient enrichment, increased primary production can lead to very high catch rates due to increased numbers of omnivores and herbivores (O'Neil and Shepard, 2000b; Hughes and Oberdorff, 1999; Barbour and others, 1999). We have observed this phenomenon in many nutrient-rich streams in Alabama, particularly those with reduced canopy cover. We adjusted scoring for this metric to account for disturbed habitats (fig. 19). Extremely high or very low catch per effort values, are scored as "1". Values which deviated moderately, either above or below, what we considered to be an optimum value were scored as "3". Values falling in the optimum range, 10-20 individuals per effort, were scored as "5". Catch per effort was significantly correlated with the HDG and the metric discriminated between most and least disturbed stations at larger stream stations but not at smaller ones.

12. PROPORTION WITH DELT+HYBRIDS

Incidence of unhealthy individuals in a fish community in the form of DELT's (Deformities, Eroded fins, Lesions, and Tumors) is frequently used as a metric to reflect the health and condition of the fish community. These conditions, however, are relatively rare except in highly degraded streams (Karr and others, 1986). Similarly, hybridization between species is indicative of highly disturbed habitats but is usually rare in moderately disturbed streams. Proportion of individuals with DELT's and as hybrids are treated as two separate metrics in the original IBI (Karr and others, 1986). Since both are rare except in highly degraded habitats, we have combined the two as a single metric to help distinguish highly degraded sites from moderately degraded ones and adjusted the scoring criteria accordingly (fig. 20). This metric produced contradictory results when discriminating between disturbed and undisturbed sites in smaller and larger streams (table 5, fig. 20) with least disturbed site scoring higher in larger streams and most disturbed sites scoring higher in smaller streams. The metric was not strongly correlated with the HDG; however, the data was not normally distributed with many streams having a value of zero and only a few with a significant number of DELTs or hybrids.

Integrity classes were assigned similar to those for the Cahaba and Black Warrior Rivers (Shepard and others, 1997; O'Neil and Shepard, 2000b) and are shown in figure 21. The overall statistical correlation for the IBI-HDG relationship (fig. 21) was low (R^2 = 0.141) suggesting that the IBI is poorly related to human disturbance, and from a strict statistical point this is true. However, when sites are classified into more general groupings, we observed that the relative degree of human disturbance was reasonably predictive of biological condition. If the relationship in figure 21 is broken into four quadrants, I (>IBI, <disturbance), II (>IBI, >disturbance), III (<IBI, >disturbance), and IV (<IBI, <disturbance) we see that disturbance correctly predicted biological condition at about 55 percent of the stream sites sampled (quadrants I, III). Sites in quadrant II, high IBI and high disturbance, reflect the inability of our disturbance measures to accurately

classify biological condition. Calibration of the IBI was limited to streams upland of the Fall Line in both river systems. It should not be used to assess streams draining the East Gulf Coastal Plain because of substantial ecoregional differences in the fish faunas and habitat.

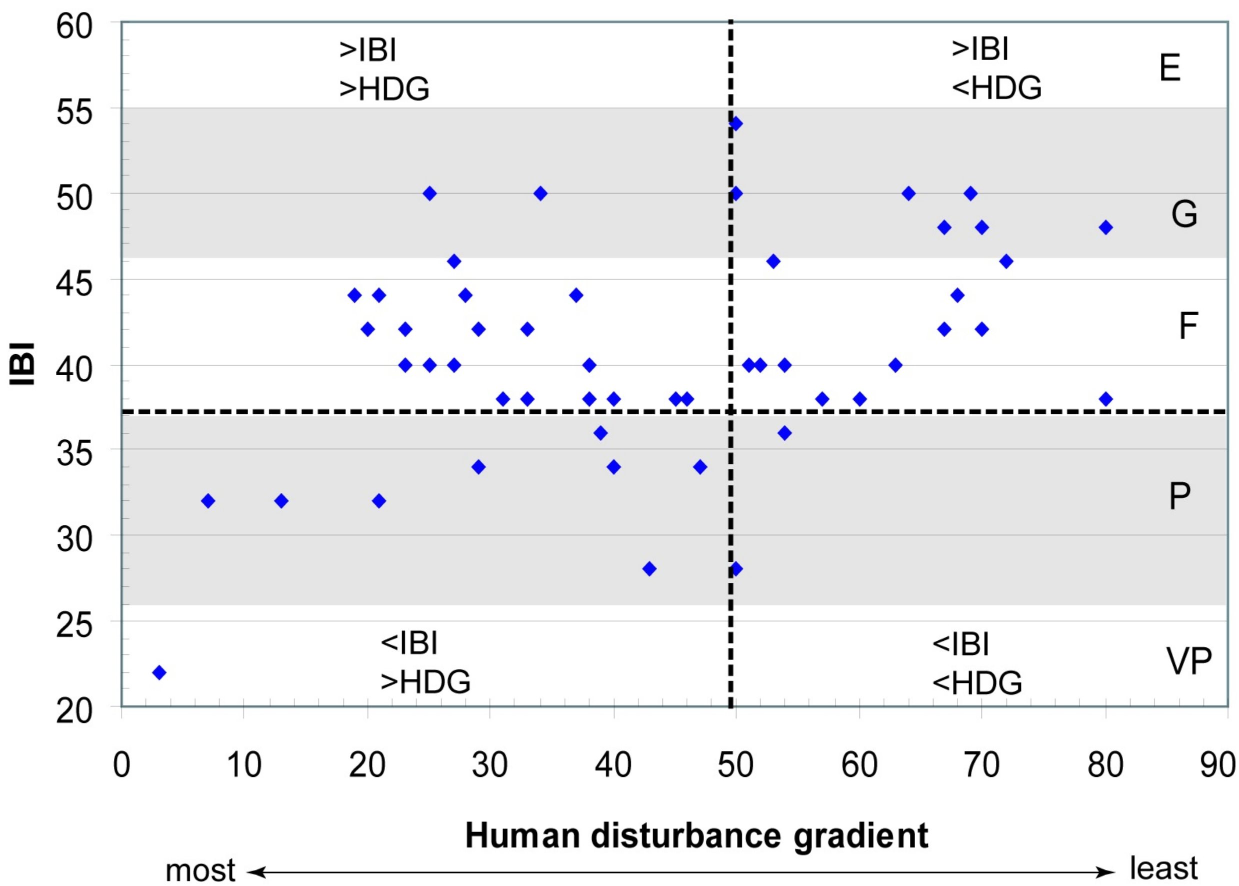


Figure 21. Comparison of IBI to human disturbance gradient for sites in the Coosa and Tallapoosa River systems.

PART 2a: BIOLOGICAL AND HABITAT ASSESSMENT OF THE TERRAPIN CREEK WATERSHED

Terrapin Creek, a Coosa River tributary in northeastern Alabama near the Georgia State Line, has been subject to low levels of point and nonpoint source pollution compared to many other Coosa River tributaries. In 1948 the Alabama Water Improvement Advisory Committee (1949) (AWIC, currently known as the Alabama Department of Environmental Management (ADEM)) measured dissolved oxygen (DO) levels at three stations in Terrapin Creek on eight dates in late summer and found all readings greater than 6.8 milligrams per liter (mg/L). Eight measurements at two stations in Nances Creek, a major tributary of Terrapin Creek, produced a minimum reading of 6.2 mg/L with most values greater than 7.0 mg/L. The AWIC (1976) proposed the Terrapin Creek watershed upstream of the junction with Nances Creek as a watershed suitable for definition of natural water quality due to high water quality and lack of point source and nonpoint source pollution. The commission also stressed the need to relate physical and chemical conditions to the health of the biological community and recommended the use of artificial substrate samplers for sampling the macroinvertebrate community in defining natural water quality. A surface water quality screening assessment of the Coosa River in 2000 by ADEM (2002) found low potential for nonpoint source impairment from sedimentation, row crops, and mining with an overall low potential for impact from nonpoint sources in the upper Terrapin Creek watershed. The lower Terrapin Creek watershed was also estimated to have a low overall potential for impairment from nonpoint sources but with moderate potential of impairment from row crop landuse.

Terrapin Creek is important as the principal source of flow in a section of the old channel of the Coosa River known as the Dead River or the Weiss Bypass. This section of the old channel extends from Weiss Dam 20 miles downstream to the Weiss powerhouse which receives flow from Weiss Lake through a diversion canal (Irwin and others, 2001). Terrapin Creek discharges into the Dead River approximately 7 miles downstream of Weiss Dam. Water-quality studies by Alabama Power Company have shown that cooler more oxygenated water from Terrapin Creek improved water quality in Dead River downstream of the mouth (Kleinscmidt Associates, 2004). During generation at the Weiss powerhouse there is a period of reversed flow in Dead River as water released from the powerhouse fills the channel from the downstream end. The Weiss Bypass is also the overflow for Weiss Dam during high flow conditions. Irwin and others (2001) found that fish species richness and diversity of Dead River downstream of the mouth of Terrapin Creek was higher than in the community upstream of the mouth. They also discussed the importance of Terrapin Creek in restoring the integrity of the Dead River through recolonization if adequate flows were restored.

A survey of the mussel community of the Dead River by Herod and others (2001) produced 19 species including the endangered southern clubshell (*Pleurobema decisum*) and threatened fine-lined pocketbook (*Lampsilis altilis*). Out of 12 sampling stations in the Dead River, their first station downstream of the mouth of Terrapin Creek produced more live mussel species and specimens than any other. The station also produced the only specimen of the fine-lined pocketbook in their study and more live specimens of the southern clubshell than any other station. The objectives of this study were to characterize biological and habitat conditions throughout the Terrapin Creek system and to attempt to identify any factors which may be limiting the condition of the fish community.

STUDY AREA

Terrapin Creek drains an area of 284 mi^2 in Cherokee, Calhoun, and Cleburne Counties in Alabama. A small part of the watershed extends into Haralson and Polk Counties in Georgia. Elevations range from 1,260 feet mean sea level (msl) in the headwaters to approximately 500 feet msl at the mouth. Major tributaries are Nances, Hurricane, Little Terrapin, Mountain, Camp, and South Fork Terrapin Creeks.

The headwaters of the Terrapin Creek watershed are in the Northern Piedmont Upland physographic district (Sapp and Emplaincourt, 1975). This area is characterized by northeast trending ridges with elevations greater than 1,000 feet. The downstream portion of the Terrapin Creek watershed lies in the Alabama Valley and Ridge Physiographic Section and includes portions of the Coosa Valley and Weisner Ridges districts. The downstream section of the watershed is located in the Ridge and Valley (67) level III ecoregion in the Southern Shale Valleys (67g) and Southern Limestone/Dolomite Valley and Low Rolling Hills (67f) while headwaters extend to the Southern Sandstone Ridges (67h) and the Talladega Upland (45d) of the Piedmont (45) (Griffith and others, 2001).

The watershed is mostly forested with row crop and pasture generally confined to areas of lower elevation particularly downstream of the town of Piedmont (fig. 22). A major part of the watershed lies within the boundaries of the Shoal Creek Ranger District of the Talladega National Forest. Piedmont is the only urban area in the watershed.

METHODS

Nineteen stations were sampled in the Terrapin Creek system to assess habitat and biological conditions in the watershed (table 7, fig. 23). At each station, selected water-quality parameters were measured, the physical habitat was evaluated, and an IBI fish sample was collected. The following parameters were measured in situ for each sample: DO was measured in milligrams per liter (mg/L) using a Yellow Springs Instruments (YSI) Model 57 dissolved-oxygen meter; hydrogen-ion concentration (pH) was measured with a Corning Model M-105 pH meter with associated specific-ion electrode; and specific conductance was measured in micro Siemens per centimeter (µS/cm) with a Corning Model CD-55 conductance meter.

HABITAT EVALUATIONS

We adopted the habitat evaluation procedure employed by ADEM (1999b) to assess the physical quality of the habitat at sampling stations in this study. The procedure is detailed in U.S. EPA (1997). The condition of aquatic communities is typically related to the physical quality and availability of the habitat. Three habitat characteristics contribute to the maintenance and persistence of aquatic biological communities: the availability and quality of substrate and instream habitat, channel morphology, and structure of the bank and riparian vegetation (Barbour and others, 1999). In the evaluation process, several parameters are used to assess each of these characteristics and the scores are summed for an overall habitat score. Twelve

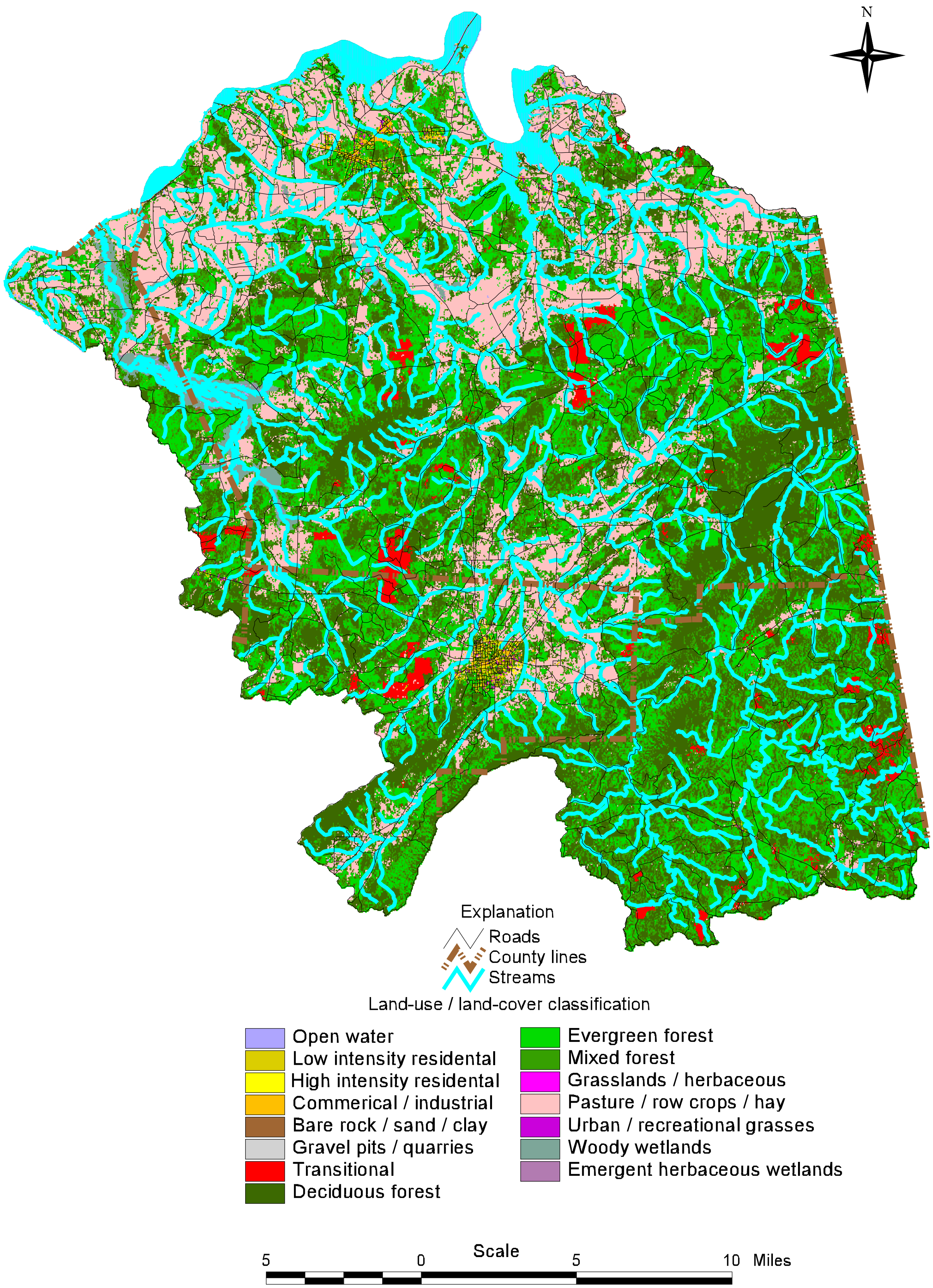


Figure 22. Land cover/land use in the Terrapin Creek system.

Table 7. Summary information on sampling stations in the Terrapin Creek system, 2003-05

Station	Location	County	Section, township, range	Latitude/ Longitude	Area	Date	Sampling time
TC-1a	Terrapin Cr. @ Co. Hwy. 71	Cherokee	sec. 34, T. 10 S., R. 9 E.	34.12333 85.67819	283	18-Sep-03	1420-1630
TC-1b						31-Aug-04	0900-1135
TC-1c						27-Jul-05	0750-0935
TC-2	Terrapin Cr. @ Co. Hwy. 175	Cherokee	sec. 5, T. 12 S., R. 10 E.	34.02769 85.61386	245	17-Sep-03	1545-1810
TC-3a	Terrapin Cr. @ Co. Hwy. 8	Cherokee	sec. 20, T. 12 S., R. 10 E.	33.97922 85.60171	172	12-Aug-03	1410-1610
TC-3b						31-Aug-03	1325-1600
TC-3b						27-Jul-05	1040-1215
TC-4	Terrapin Cr. @ unnumbered Co. Hwy.	Cleburne	sec. 7, T. 13 S., R. 11 E.	33.90597 85.52061	72.9	18-Sep-03	1050-1210
TC-5	Terrapin Cr. @ Co. Hwy. 202	Cleburne	sec. 14, T. 13 S., R. 11 E.	33.89281 85.4612	41.3	18-Aug-03	1155-1310
TC-6	Terrapin Cr. @ Co. Hwy. 123	Cleburne	sec. 32, T. 13 S., R. 12 E.	33.85767 85.39783	5.88	20-Aug-03	0745-0935
LC-1	Little Cr. @ Co. Hwy. 14	Cherokee	sec. 25, T. 11 S., R. 10 E.	34.0599 85.6259	5.312	19-Aug-03	0940-1210
HC-1	Hurricane Cr. @ Co. Hwy. 4	Cherokee	sec. 15, T. 12 S., R. 10 E.	33.99032 85.56699	32.6	12-Aug-03	1020-1235
HC-2	Frog Cr. @ Co. Hwy. 12	Cherokee	sec. 12, T. 12 S., R. 10 E.	34.00494 85.53433	19.2	28-Aug-03	0850-1035
HC-3	Hurricane Cr. @ Co. Hwy. 8	Cherokee	sec. 17, T. 12S., R. 11 E.	33.99069 85.50361	22.9	19-Aug-03	1400-1555

Table 7. Summary information on sampling stations in the Terrapin Creek system, 2003-05--Continued

Station	Location	County	Section, township, range	Latitude/ Longitude	Area	Date	Sampling time
LT-1	Little Terrapin Cr. @ Co. Hwy. 49	Cleburne	sec.10, T. 13 S., R. 11 E.	33.91489 85.46581	15.8	27-Aug-03	1220-1420
NC-1	Nances Cr. NE of Piedmont	Calhoun	sec.28, T. 12 S., R. 10 E.	33.9556 85.59064	27.4	7-Aug-03	0950-1215
NC-2a	Nances Cr. @ Babbling Brook Road	Calhoun	sec. 9, T. 13 S., R. 10 E.	33.91133 85.59486	20.5	27-Aug-03	1545-1725
NC-2b						3-Sep-04	1255-1440
NC-3b						27-Jul-05	1315-1440
NC-3	Nances Cr. near Victory Baptist	Calhoun	sec. 2, T. 14 S., R. 9 E.	33.84675 85.66125	7.7	28-Aug-03	1120-1330
SF-1	Unnamed trib. to South Fork Terrapin Cr.	Cleburne	sec. 24, T. 13 S., R. 10 E.	33.87636 85.54781	1.69	18-Aug-03	1600-1755
SF-2a	South Fork Terrapin Cr. @ Rabbittown Road	Cleburne	sec.30, T. 13 S., R. 11E.	33.86053 85.52238	18.3	6-Aug-03	1050-1400
SF-2b						30-Aug-03	1030-1253
SF-2c						26-Jul-05	1000-1205
SF-3a	Marys Cr. @ Forest Road 500	Cleburne	sec. 36, T. 13 S., R. 10E.	33.84986 85.54169	2.78	8-Aug-03	0850-1115
SF-3b						30-Aug-04	1345-1530
SF-3c						26-Jul-05	1320-1515
CC-1	Camp Cr. @ Co. Hwy. 283	Cleburne	sec. 27, T. 13 S., R. 11 E.	33.86553 85.47194	5.87	20-Aug-03	1035-1230
MC-1	Mountain Cr. @ Co. Hwy. 123	Cleburne	sec. 21, T. 13S., R. 12 E.	33.87619 85.38587	4.11	13-Aug-03	0845-1020

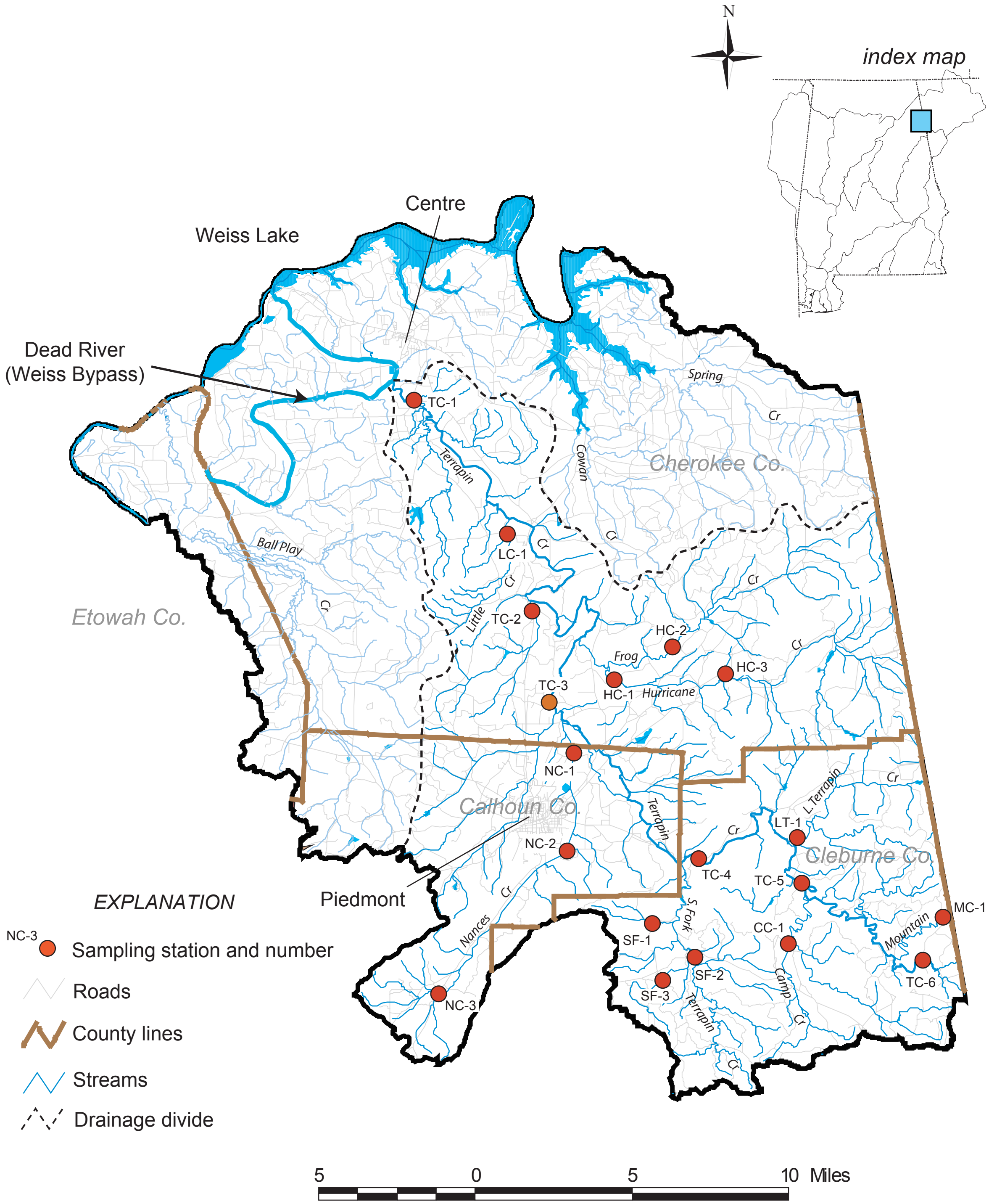


Figure 23. Sampling stations in the Terrapin Creek system.

parameters are used in the riffle/run evaluation and 11 in the glide/pool evaluation (appendix E). Stations in the Terrapin Creek system were evaluated with the riffle/run habitat form. To quantify habitat conditions, a biologist completed the habitat evaluation form at each station, a task requiring about 30 minutes depending on the complexity of the habitat. The following is a brief explanation of the parameters used in the evaluation.

Instream cover: The habitat characteristic of bottom substrate and available cover refers to the availability of habitat for support of aquatic organisms. Diverse substrate objects and habitat types contribute to a diverse and productive aquatic community and reflect a favorable biological condition. Gravel and rocks in flowing streams are generally desirable; however, other objects, such as snags, aquatic vegetation, and undercut banks, provide good habitat for many types of organisms.

Epifaunal surface (riffle/run): This is a measure of the extent and quality of the riffles and runs of a stream. A wide variety and abundance of submerged structure is an important factor in the ability of a stream to support an abundant and diverse community (Barbour and others, 1999). Reaches with little cover tend to support less diverse communities.

Pool Substrate characterization (glide/pool): This is a measure of the type and stability of pool substrates. Stable and varied substrates, such as cobble, snags, and rooted macrophytes, typically support more diverse communities than unstable or uniform substrates such as silt or bedrock.

Embeddedness (riffle/run): Embeddedness is a visual measure of the degree to which boulders, rubble, or gravel are surrounded by fine sediment and indicates suitability of the stream substrate as habitat for benthic macroinvertebrates and spawning habitat for fishes. Larger objects are evaluated as to their degree of burial by fine sediments.

Pool Variability (glide/pool): Streams with a variety of pool types support more diverse communities than those with only one type of pool. Pool types are large-shallow, large-deep, small-shallow, and small-deep. Large pools are those with any pool dimension (length, width, oblique) greater than half the cross-section of the stream and 3 feet is the depth for separating shallow and deep pools (Barbour and others, 1999).

Velocity/depth regimes (riffle/run): Stream flow is related to the ability of a stream to provide and maintain a stable aquatic habitat. Water quantity alone is the most critical factor related to the support of aquatic communities when the flow is $\leq$ 5 cubic feet per second (cfs) whereas both velocity and depth influence benthic macroinvertebrate and fish communities in streams with flow >5 cfs. Velocities and stream flow are best determined in a straight section of stream of uniform depth with few large obstructions. Habitat condition in streams with flow >5 cfs is evaluated based on the presence of four velocity/depth regimes: slow/deep, slow/shallow, fast/deep, and fast/shallow. The critical velocity is 1 foot per second and the critical depth is 1.5 feet when determinations of depth and velocity are required.

Channel alteration: The character of sediment deposits is an indication of the severity of watershed erosion, bank erosion, and stability of the stream. Sediment bars will appear and increase in depth and length with continual erosion in the watershed. Channel alteration can result in deposition on the inside of bends, below channel constrictions, and where stream gradient flattens. Channelization decreases stream sinuosity thereby increasing velocities and the potential for channel and bank scour.

Sediment deposition: This characteristic quantifies the degree of habitat destruction from the process of deposition and scour described in the channel alteration section.

Frequency of Riffles (riffle/run): Riffles provide stable, diverse habitat, and increased occurrence of riffles usually increases abundance and diversity of organisms in a community.

Channel Sinuosity (glide/pool): This is a measure of the frequency of bends in a stream. Bends provide more cover and protection to aquatic organisms than straight reaches.

Bank vegetative protection: The stability of bank soils is generally related to the extent of plant root systems and to the presence of gravel, cobble, or boulder material. This habitat characteristic is a measure of the percentage of cover material present and provides an estimation of bank stability. Right and left banks are scored separately.

Grazing or other disruptive pressure: This habitat parameter evaluates the degree to which riparian vegetation is disrupted by grazing or mowing. Higher disruptive pressure is associated with greater bank erosion and reduced substrate stability. Right and left banks are scored separately.

Riparian vegetative zone: This parameter measures the width of the vegetative buffer zone. A wide vegetative zone controls erosion and serves as a buffer to nutrients and other pollutants entering the stream. Right and left banks are scored separately.

FISH SAMPLING

A fish IBI sample was collected at 19 stations in the Terrapin Creek system in order to determine biological condition. Four of the 19 stations were chosen for longer term sampling and were sampled once in each of the three years of this project. Samples were collected by a four or five person crew using a 10- or 15-foot long, six-foot deep, 3/16-inch mesh seine, and a backpack electrofishing unit following the technique detailed in the "Sampling Methodolgy" section of this report. Most fish specimens were identified, counted, and released back into the stream after capture. A few individuals were retained as vouchers or returned to the lab for confirmation of field ID's. These specimens were preserved in a 10 percent formalin solution. After at least two weeks in formalin, the specimens were soaked in water for several days and then transferred to a 70 percent ethanol solution for permanent storage. All specimens retained in this study are in the GSA fish collection. An IBI score and biological condition ranking for each collection was determined using IBI metrics and scoring criteria developed as part of this project and detailed in the "IBI Development" section of this report.

RESULTS AND DISCUSSION

Twenty-nine fish collections at 19 sampling stations from 2003 to 2005 produced 45 species, a few sunfish hybrids, and hybrids between the blacktail shiner (*Cyprinella venusta*) and the introduced red shiner (*Cyprinella lutrensis*) (table 8, app. F). The largescale stoneroller (*Campostoma oligolepis*) was, by far, the most abundant species

Table 8. Fish species and hybrids collected in the Terrapin Creek system, 2003-05

Species	Common name	Number of specimens	Percent of total catch
Cyprinidae			
Campostoma oligolepis	largescale stoneroller	3,006	22.12
Cyprinella callistia	Alabama shiner	654	4.81
Cyprinella lutrensis	red shiner	31	0.23
Cyprinella trichroistia	tricolor shiner	1,378	10.14
Cyprinella venusta	blacktail shiner	85	0.63
Cyprinella hybrid	minnow hybrid	3	0.02
Cyprinus carpio	common carp	2	0.01
Luxilus chrysocephalus	striped shiner	380	2.80
Lythrurus bellus	pretty shiner	19	0.14
Lythrurus lirus	mountain shiner	26	0.19
Notropis asperifrons	burrhead shiner	106	0.78
Notropis chrosomus	rainbow shiner	408	3.00
Notropis stilbius	silverstripe shiner	888	6.53
Notropis xaenocephalus	Coosa shiner	528	3.89
Phenacobius catostomus	riffle minnow	181	1.33
Rhinichthys atratulus	blacknose dace	1	0.01
Semotilus atromaculatus	creek chub	211	1.55
Catostomidae			
Hypentelium etowanum	Alabama hog sucker	606	4.46
Moxostoma duquesnei	black redhorse	15	0.11
Moxostoma erythrurum	golden redhorse	44	0.32
Moxostoma poecilurum	blacktail redhorse	10	0.07
Ictaluridae			
Ameiurus natalis	yellow bullhead	17	0.13
Ictalurus punctatus	channel catfish	18	0.13
Noturus leptacanthus	speckled madtom	48	0.35
Fundulidae			
Fundulus stellifer	southern studfish	64	0.47
Poecilidae			
Gambusia affinis	western mosquitofish	30	0.22
Centrarchidae			
Ambloplites ariommus	shadow bass	29	0.21
Lepomis auritus	redbreast sunfish	538	3.96
Lepomis cyanellus	green sunfish	318	2.34
Lepomis gulosus	warmouth	15	0.11
Lepomis macrochirus	bluegill	430	3.16
Lepomis megalotis	longear sunfish	376	2.77
Lepomis microlophus	redear sunfish	5	0.04
Lepomis miniatus	redspotted sunfish	42	0.31
Lepomis hybrids	sunfish hybrids	9	0.07
Micropterus coosae	redeye bass	127	0.93
Micropterus punctulatus	spotted bass	24	0.18
Micropterus salmoides	largemouth bass	20	0.15
Percidae			
Etheostoma coosae	Coosa darter	245	1.80
Etheostoma jordani	greenbreast darter	598	4.40
Etheostoma stigmaeum	speckled darter	164	1.21
Percina kathae	Mobile logperch	70	0.52
Percina nigrofasciata	blackbanded darter	209	1.54
Percina palmaris	bronze darter	242	1.78
Percina shumardi	river darter	1	0.01
Sciaenidae			
Aplodinotus grunniens	freshwater drum	13	0.10
Cottidae			
Cottus carolinae	banded sculpin	1,355	9.97
Total specimens		13,589	100.00
Total species		45 + 2 hybrids	

in the study and accounted for 22.12 percent of total specimens (table 8). Tricolor shiners (*Cyprinella trichroistia*) were the second most common species at 10.14 percent followed closely by the banded sculpins (*Cottus carolinae*) at 9.97 percent. The number of species collected ranged from a high of 30 at SF-2 (South Fork Terrapin Creek), to a low of 12 at station HC-2 (Frog Creek) (table 9). IBI scores ranged from a low of 28 at both HC-2 and MC-1 (Mountain Creek) to a high of 52 at both SF-2 and SF-3 (Marys Creek). Overall, two stations (SF-2 and SF-3) were ranked as having an average biological condition of good, four stations (TC-3, HC-2, LT-1, and MC-1) were ranked as having poor condition, and the other 13 had fair biological condition on average (table 9, fig. 24).

Habitat scores ranged from a low of 145 (60 percent of maximum score) in Camp Creek (CC-1) to a high of 216 (89 percent) in a tributary to South Fork Terrapin Creek (SF-1) (table 10). Habitat was more degraded by fine sediments at stations in predominately agricultural areas in the Coosa Valley than at stations with predominately forested watersheds; however, erosion associated with clearcuts had degraded habitat conditions at several upland stations such as Camp Creek (CC-1) and Mountian Creek (MC-1).

Values for DO ranged from 6.0 mg/L at LT-1 to 9.2 mg/L at LC-1 (Little Creek) (table 11). Specific conductance values ranged from 24 µS/cm at MC-1 to 204 µS/cm at HC-2 (Frog Creek) and pH values ranged from 6.2 at MC-1 to 8.0 at station HC-3 (Hurricane Creek).

TRIBUTARIES

LITTLE CREEK (station LC-1)

Little Creek is a small tributary to Terrapin Creek with a drainage area of about 6 mi^2 located in the Coosa Valley. Land use in the watershed is predominately mixed forest and agriculture in the form of row crops and pastureland (fig. 22). Habitat quality was good at station LC-1 with an overall score of 179 (75 percent) (table 10). The substrate at the station was mostly composed of cobble and gravel and was not highly embedded with fine sediments (table 12). Specific conductance was relatively high at

Table 9. Summary information of fish samples collected at 19 stations in the Terrapin Creek system, 2003-05

Station number	Total species	Total specimens	IBI	Biological condition
TC-1a	29	363	40	Fair
TC-1b	33	1,014	34	Poor
TC-1c	31	340	42	Fair
TC-2	28	883	40	Fair
TC-3a	27	470	32	Poor
TC-3b	29	1,477	34	Poor
TC-3C	25	719	36	Poor
TC-4	21	244	44	Fair
TC-5	23	183	42	Fair
TC-6	20	302	38	Fair
LC-1	25	841	38	Fair
HC-1	22	269	38	Fair
HC-2	12	320	28	Poor
HC-3	23	440	46	Fair
LT-1	26	247	36	Poor
NC-1	28	241	42	Fair
NC-2a	26	426	44	Fair
NC-2b	26	428	44	Fair
NC-2c	28	387	42	Fair
NC-3	20	369	42	Fair
SF-1	14	134	38	Fair
SF-2a	28	390	52	Good
SF-2b	26	662	48	Good
SF-2c	30	533	52	Good
SF-3a	20	354	52	Good
SF-3b	19	405	46	Fair
SF-3c	24	840	48	Good
CC-1	20	190	38	Fair
MC-1	14	150	28	Poor

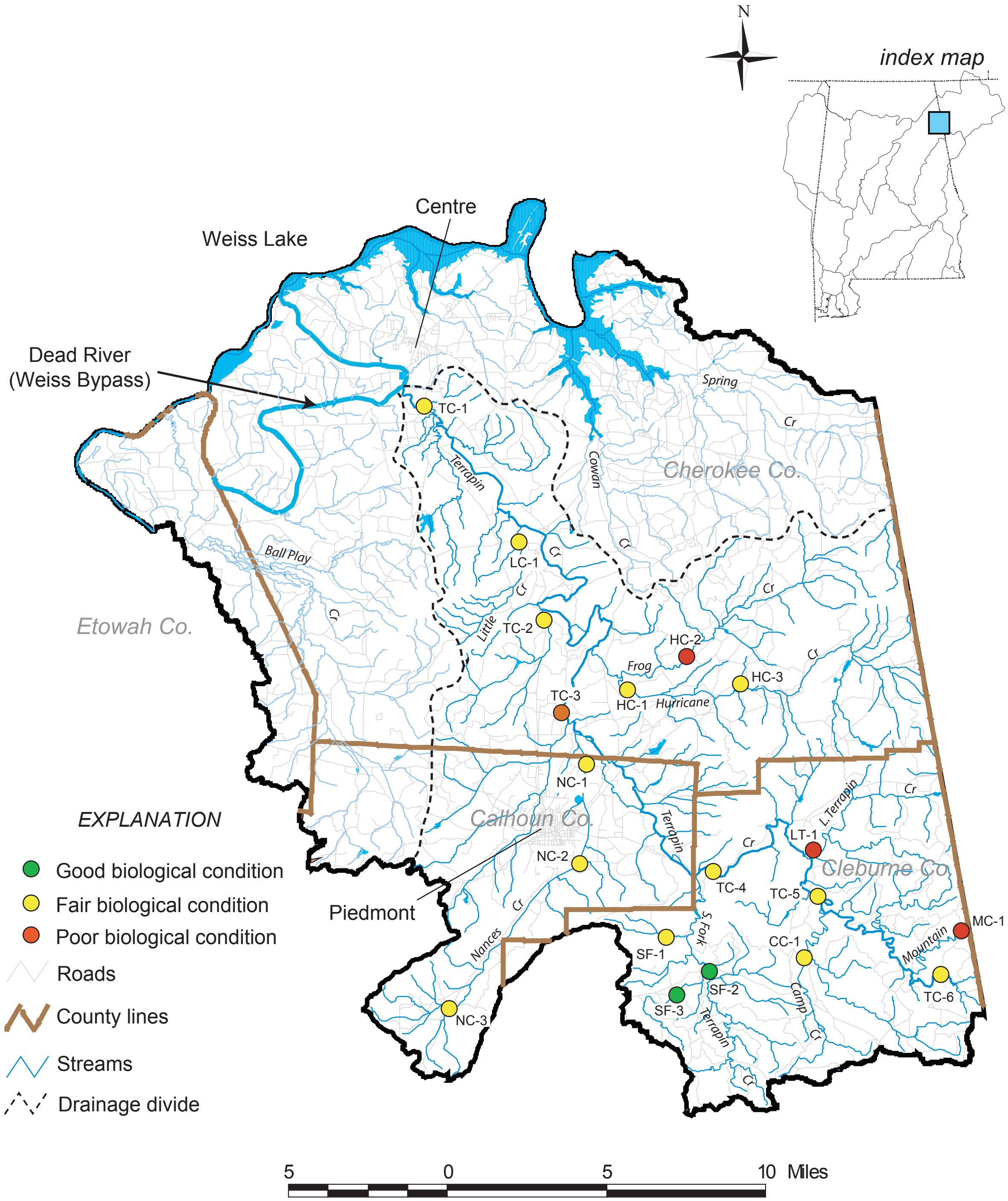


Figure 24. Biological condition at sampling stations in the Terrapin Creek system.

Table 10. Habitat scores at 19 stations in the Terrapin Creek system, 2003-05--Continued

Station number	Instream cover	Epifaunal surface	Embed-dedness	Velocity/ depth regimes	Channel alteration	Sediment deposition	Frequency of riffles	Channel flow status
TC-1a	15	11	11	16	17	10	10	16
TC-1b	13	14	13	16	16	14	10	17
TC-1c	15	10	11	12	17	13	11	17
TC-2	17	19	14	17	20	17	19	17
TC-3a	17	18	15	16	20	16	15	18
TC-3b	16	16	14	16	16	10	17	16
TC-3c	18	17	17	16	19	16	12	18
TC-4	18	17	15	15	19	10	19	18
TC-5	16	15	15	16	18	15	16	16
TC-6	16	16	12	11	18	16	17	16
LC-1	16	17	11	13	16	14	18	17
HC-1	13	14	10	13	16	10	12	16
HC-2	16	14	12	12	16	14	11	16
HC-3	17	17	12	15	18	16	16	16
LT-1	9	10	8	12	16	5	14	16
NC-1	17	8	13	16	17	10	16	17
NC-2a	13	11	13	12	12	12	13	16
NC-2b	12	11	10	14	12	10	17	16
NC-2c	12	13	11	13	13	16	11	17
NC-3	14	14	13	12	11	13	13	15
SF-1	16	16	20	10	20	20	20	16
SF-2a	17	16	12	15	20	11	14	20
SF-2b	18	18	16	15	20	18	16	18
SF-2c	18	19	15	15	17	17	16	17
SF-3a	17	18	15	14	20	16	19	19
SF-3b	17	13	15	15	16	16	17	17
SF-3c	18	18	14	14	17	17	11	18
CC-1	12	10	5	13	18	5	17	17
MC-1	11	14	8	13	20	7	13	16

Table 10. Habitat scores at 19 stations in the Terrapin Creek system, 2003-05--Continued

Station number	Condition of banks	Bank vegetative protection		Disruptive pressure		Riparian vegetative zone		Total score	Percent of max. habitat score
		left bank	right bank	left bank	right bank	left bank	right bank		
TC-1a	10	6	6	6	6	5	5	150	63
TC-1b	10	5	5	7	7	5	5	157	65
TC-1c	11	8	8	8	8	3	5	157	65
TC-2	18	9	9	9	9	7	7	208	87
TC-3a	15	7	7	7	7	7	7	192	80
TC-3b	12	8	8	7	7	6	6	175	73
TC-3c	15	9	9	9	9	9	8	201	84
TC-4	18	9	9	8	8	9	9	201	84
TC-5	15	8	8	9	9	8	8	192	80
TC-6	15	8	8	9	9	6	6	183	76
LC-1	13	7	7	8	8	7	7	179	75
HC-1	12	8	8	8	8	7	7	162	68
HC-2	16	8	8	6	6	5	5	165	69
HC-3	15	8	8	8	8	8	8	190	79
LT-1	12	7	7	8	8	7	7	146	61
NC-1	12	7	7	8	8	6	6	168	70
NC-2a	13	8	8	7	7	6	6	157	65
NC-2b	14	7	7	8	8	3	7	156	65
NC-2c	12	8	8	7	7	5	5	158	66
NC-3	16	7	7	6	6	5	5	157	65
SF-1	18	10	10	10	10	10	10	216	90
SF-2a	18	9	9	10	10	10	10	201	84
SF-2b	18	9	9	10	10	9	9	213	89
SF-2c	17	9	9	9	9	10	10	207	86
SF-3a	18	8	8	10	10	10	10	212	88
SF-3b	17	9	9	8	8	7	7	191	80
SF-3c	12	8	9	8	9	5	9	187	78
CC-1	12	6	6	7	7	5	5	145	60
MC-1	15	7	7	7	7	9	9	163	68

Table 11. Water-quality values measured at 19 stations in the Terrapin Creek system, 2003-05

Station number	Water temperature (°C)	Dissolved oxygen mg/L	Dissolved oxygen percent sat.	Specific cond. (u S/cm)	pH
TC-1a	ND	8.6	99	171	8.0
TC-1b	26.0	7.9	ND	178	7.4
TC-1c	27.1	7.7	98	154	7.8
TC-2	21.8	8.7	98	186	8.0
TC-3a	23.6	8.9	105	111	7.7
TC-3b	26.0	8.0	ND	163	7.8
TC-3C	26.2	6.9	87	128	8.0
TC-4	20.9	8.3	94	51	7.5
TC-5	ND	8.0	100	37	6.5
TC-6	23.4	8.2	96	42	5.7
LC-1	24.7	8.9	106	165	7.2
HC-1	21.8	8.5	102	171	7.6
HC-2	18.9	8.8	101	204	7.5
HC-3	23.1	9.2	108	130	8.0
LT-1	28.7	6.0	79	60	6.6
NC-1	22.9	7.9	94	180	7.1
NC-2a	23.7	7.6	93	181	7.8
NC-2b	19.0	8.3	ND	195	6.4
NC-2c	25.0	7.4	89	173	8.0
NC-3	21.9	8.3	101	193	7.7
SF-1	23.6	8.4	99	31	6.9
SF-2a	22.7	7.9	92	40	6.8
SF-2b	24.0	7.9	ND	54	6.1
SF-2c	26.1	8.6	106	51	7.3
SF-3a	21.1	8.5	96	46	6.3
SF-3b	25.0	7.4	ND	57	6.5
SF-3c	ND	ND	ND	ND	ND
CC-1	25.1	7.7	95	57	7.0
MC-1	22.2	8.5	96	24	6.2

ND-not determined

Table 12. Substrate composition (percent) at 19 stations in
the Terrapin Creek system 2003-05

Station	Bedrock	Boulder	Cobble	Gravel	Sand	Snag
TC-1a	--	5	30	30	35	--
TC-1b	--	10	40	30	20	--
TC-1c	--	--	30	30	35	5
TC-2	--	10	50	20	20	--
TC-3a	5	5	50	30	10	--
TC-3b	--	10	30	30	30	--
TC-3C	5	10	45	30	10	--
TC-4	5	60	10	10	15	--
TC-5	20	30	30	10	10	--
TC-6	20	30	30	10	10	--
LC-1	--	15	50	20	15	--
HC-1	--	5	20	45	30	--
HC-2	5	5	50	20	20	--
HC-3	--	20	40	20	20	--
LT-1	--	5	10	20	65	--
NC-1	50	20	15	5	10	--
NC-2a	5	5	20	30	40	--
NC-2b	5	15	20	20	40	--
NC-2c	--	5	25	50	15	5
NC-3	10	10	40	25	15	--
SF-1	50	20	20	5	5	--
SF-2a	50	20	10	10	10	--
SF-2b	20	10	30	20	20	--
SF-2c	20	30	10	30	10	--
SF-3a	15	5	30	30	20	--
SF-3b	5	5	30	40	20	--
SF-3c	10	5	20	40	20	5
CC-1	10	5	10	30	45	--
MC-1	10	20	20	20	30	--

the station with a value of 165 µS/cm and pH was near neutral at 7.19. The DO value at LC-1 was 8.89 mg/L, 106 percent of saturation (table 11).

The station produced 25 species including a large number of rainbow shiners (*Notropis chrosomus*) (table 9, app. F). Abundance was relatively high at the station with 841 individuals in the collection. The IBI score was 38 indicating fair biological condition (table 9).

HURRICANE CREEK (stations HC-1, HC-2, and HC-3)

Hurricane Creek is the largest tributary of Terrapin Creek with a drainage area of about 55 mi^2. Two sampling stations (HC-1, HC-3) were located on the main stem of Hurricane Creek and another (HC-2) was located on Frog Creek. The headwaters of Hurricane Creek were forested; however, the more downstream reach including Frog Creek was mostly agricultural lands. Habitat condition was higher in the most upstream station (HC-3) than at the more downstream station (HC-1) or Frog Creek (HC-2) with scores of 190 (79 percent), 162 (68 percent), and 165 (69 percent), respectively (table 10). Land use was mostly cornfields immediately adjacent to HC-1 and pastureland adjacent to HC-2. Dissolved oxygen ranged from 8.5 mg/L at HC-1 to 9.2 mg/L at HC-3 (table 11), while pH values ranged from 7.5 at HC-2 to 8.02 at HC-3. Specific conductance was lowest at HC-3 with a value of 130 µS/cm compared to 171 µS/cm at HC-1 and 204 µS/cm at HC-2. Frog Creek (HC-2) had a noticeable spring influence with water temperatures several degrees cooler than at other stations (table 11).

Frog Creek produced the lowest number of species of any station in our study at 12 (table 9). Stations HC-1 and HC-3 produced 22 and 23 species, respectively. Biological condition was poor in Frog Creek, but fair at the other two stations (table 9, fig. 24). A macroinvertebrate assessment of Frog Creek by ADEM in 1999 produced eight EPT families indicating good condition (ADEM, 2000).

LITTLE TERRAPIN CREEK (station LT-1)

Little Terrapin Creek is a small tributary to Terrapin Creek with a drainage area of about 16 mi^2. Land cover was mostly mixed forest with limited agriculture in the watershed (fig. 22). The habitat score at Little Terrapin Creek was among the lowest in this study at 146 (61 percent) (table 10). Fresh deposits of fine sediments were a problem at the station, and sand was the major component of substrate composition (table 12). The DO level at station LT-1 was 6.0 mg/L, the lowest in this study (table 11). Conductance at the station was 60 µS/cm with a pH of 6.6. Although 26 species were collected at LT-1, the station produced an IBI score of 36, indicating poor biological condition (table 9).

NANCES CREEK (stations NC-1, NC-2, and NC-3)

Nances Creek is one of the larger tributaries to Terrapin Creek with a drainage area of about 28.7 mi^2. Land use is mixed forest and pastureland in the watershed, and the creek flows through the town of Piedmont near the junction with Terrapin Creek (fig. 22). The channel of Nances Creek was very straight at stations NC-2 and NC-3 and appeared to have been channelized in the past. The banks showed no fresh signs of disturbance. Habitat scores ranged from 156 (65 percent) in one sample at NC-2 to 168 (70 percent) at station NC-1 (table 10). The substrate at station NC-1, was mostly bedrock while it was mostly composed of cobble, gravel, and sand at the other two stations (table 12). In Nances Creek DO ranged from 7.4 to 8.3 mg/L in two measurements at NC-3 (table 11). Conductance values ranged from 173 to 195 µS/cm and pH values ranged from 6.4 to 8.0 also at NC-2.

Station NC-3 produced the lowest number of species for the watershed at 20 compared to 26 to 28 at the other two stations (table 9). IBI scores were very consistent between the three stations in Nances Creek and the three samples at NC-2 with stations NC-1 and NC-3 receiving scores of 42, and scores of 44, 44, and 42 for the three collections at NC-2 (table 9). All of the stations were ranked as having fair biological condition (fig. 24).

CAMP CREEK (station CC-1)

Camp Creek flows into Terrapin Creek in the southeast section of the watershed in Cleburne County. The watershed is largely wooded but there are significant amounts of pastureland in the watershed as well (fig. 22). There was also a recent clearcut near our sampling station in Camp Creek. Habitat was somewhat degraded with a score of 145 (60 percent) due to fresh deposits of sand in the channel (tables 10, 12). DO was 7.7 mg/L at CC-1 with conductance and pH values of 57 µS/cm and 7.0, respectively (table 11). In spite of the sediment problem, 20 fish species were collected in Camp Creek and the station had an IBI score of 38 at the low end of the fair category (table 9).

MOUNTAIN FORK (station MC-1)

Mountain Fork is a small tributary with a drainage area of about 6 mi^2. Although the watershed is forested (fig. 22), a clearcut on a ridge top adjacent to our sampling station had caused sediment deposition resulting in a suboptimal habitat score of 163 (68 percent) (table 10). Values for DO, conductance, and pH at the station were 8.5 mg/L, 24 µS/cm, and 6.2 respectively (table 11). Only 14 fish species and 150 specimens were collected at MC-1 (table 9). The sample produced an IBI score of 28 indicating poor biological condition.

SOUTH FORK TERRAPIN CREEK (stations SF-1, SF-2, and SF-3)

The South Fork of Terrapin Creek watershed drains about 28 mi^2 in the southwestern section of the Terrapin Creek drainage. The watershed is mostly located in the Talladega National Forest and the best habitat and biological conditions in the Terrapin Creek watershed were found there. Habitat was good at all three stations with scores ranging from 187 (78 percent) at Marys Creek (SF-3) to 216 (89 percent) at an unnamed tributary to South Fork Terrapin Creek (SF-1) (table 10). Dissolved oxygen measurements ranged from 7.4 mg/L in a reading from Mary's Creek to 8.6 mg/L in one reading at SF-2 (South Fork Terrapin Creek at Rabbittown Road) (table 11). Conductance values were low at all stations and ranged from 31 µS/cm at SF-1 to 57 µS/cm at SF-3. The pH range was from 6.1 to 7.3 with both values from samples at station SF-2.

Biological condition was good in five of the seven fish samples collected at the three stations in the watershed and fair in the other two (table 9, fig. 24). Station SF-1 was a headwater stream, but still supported 14 species while the three samples at SF-2 produced from 26 to 30 species and the three samples at Marys Creek produced from 19 to 24 species (table 9). The IBI scores at station SF-2 ranged from 48 to 52, all in the good range. At station SF-3, IBI scores ranged from 46 to 52 with an average of 48.7 also in the good category. Station SF-1 was a small high gradient, headwater stream and scored only 38 in the fair range. Headwater streams present less stable conditions than more permanent streams and would require a special set of IBI metrics and scoring criteria to accurately evaluate the condition of the fish community. Such a headwater IBI has yet to be developed for any system in Alabama.

TERRAPIN CREEK MAIN CHANNEL

UPSTREAM OF NANCES CREEK (stations TC-4, TC-5, and TC-6)

Terrapin Creek upstream of the junction with Nances Creek drains an area of about 119 mi^2. The watershed is mostly forested although there is some urban development near Piedmont and the town of Vigo, and scattered pastureland and row crop agriculture throughout the area (fig. 22). Major tributaries that join Terrapin Creek in this reach are South Fork Terrapin Creek, Little Terrapin Creek, Camp Creek, and Mountain Creek. Habitat conditions were good at stations TC-4 (Terrapin Creek near Vigo), TC-5 (Terrapin Creek at Cleburne County Highway 202), and TC-6 (Terrapin Creek at Cleburne County Highway 123) with scores from 183 (76 percent) to 201 (84 percent) (table 10). Substrates were mostly composed of bedrock, boulders, and cobble, with some gravel and sand (table 12). Dissolved oxygen values ranged from 8.0 to 8.3 mg/L with conductance values of 37 to 51 µS/cm and pH values from 5.7 at TC-6 to 7.5 at TC-4 (table 11).

All stations on the main stem of Terrapin Creek in this section produced 20 or more species with 20 at TC-6, 21 at TC-4, and 23 at TC-5 (table 9). Biological condition was fair at the three stations with IBI scores of 44, 42, and 38, respectively, for stations TC-4, TC-5, and TC-6 (fig. 24).

MOUTH OF TERRAPIN CREEK TO NANCES CREEK (stations TC-1, TC-2, and TC-3)

Downstream of Nances Creek, Terrapin Creek is more impacted by agriculture in the form of row crops and pastureland as well as urban runoff from the city of Piedmont compared to the upstream section. Drainage areas in this section range from 284 mi^2 at the mouth to 171 mi^2 at station TC-3. Hurricane Creek and Nances Creek are the major tributaries that join Terrapin Creek in this reach. Habitat was degraded by heavy deposits of sand and silt in pools and poor bank structure, and vegetative bank protection at the most downstream station (TC-1) with habitat scores of 150 to 157 (63 to 65 percent) in three samples (tables 10, 12). The stream at this station was bordered by fields on both sides with a narrow to nonexistent riparian vegetative zone. Habitat condition was better at the two upstream stations with scores of 208 (87 percent) at TC-2 and 175, 192, and 201 for the three samples at TC-3 (73, 80, and 84 percent, respectively). An intensive study of water quality at stations TC-1 and TC-3 was conducted by Marlon Cook and the staff of the GSA hydrogeology group from May 2003 to May 2004. The detailed results of that study are presented in a separate section. The study found that contaminants causing water-quality impacts in lower Terrapin Creek were sediments, nutrients, and bacteria. While nitrate did not exceed a criterion of 0.5 mg/L in any sample, total dissolved phosphorous did exceed a standard of 0.05 mg/L in four of nine samples at TC-1 and two of nine samples at TC-3. The fecal coliform bacterial standard for streams classified as Fish and Wildlife of 2,000 colonies per 100 milliliter sample for single samples was exceeded in three of six samples at TC-1 and two of six samples at TC-3. Potential sources of contamination were identified as runoff from agriculture and timbering operations as well as residential and urban runoff. Based on measurements in that study and our readings at the time of the fish samples, DO ranged from 6.9 to 12.4 mg/L at TC-3 and 7.7 to 12.1 mg/L at TC-1. Station TC-2 had a value of 8.7 mg/L (table 11). Conductance ranged from 25 μS/cm at TC-3 to 186 μS/cm at TC-2. Values for pH ranged from 7.4 at TC-1 to 8.0 at TC-2 and TC-3.

Fish collections at stations in the lower section of Terrapin Creek produced from 29 to 31 species at TC-1, 25 to 29 species at TC-3, and 28 species at TC-2. An introduced species, the red shiner, represented almost 2 percent of the total catch at station TC-1 but was not found at any other station in the study (appendix F). A few hybrids between the red shiner and the blacktail shiner were also collected at the station. The average IBI score for the three collections at TC-1 was 38.7, at the low end of the fair category (table 9, fig. 24). Station TC-2 also had fair condition with an IBI score of 40. Station TC-3 had an average IBI score of only 34 in the poor category. It was surprising that station TC-1 displayed marginally better biological condition than TC-3 since habitat was considerably more degraded at that station than at TC-3.

PART 2b: SURFACE-WATER QUALITY ASSESSMENT OF THE TERRAPIN CREEK WATERSHED

by Marlon R. Cook

HYDROGEOLOGY AND GEOMORPHOLOGY

The data presented in this section characterize water quality and stream discharge at two stations (TC-1 and TC-3) in the Terrapin Creek watershed. The water quality and stream discharge data sets (appendix G) consist of samples collected during a 12-month period from May 2003 to May 2004 that were used to determine the quality of water and the effects of land-use practices in the watershed.

The headwaters of the Terrapin Creek watershed are included in the Northern Piedmont Upland physographic district (Sapp and Emplaincourt, 1975). This area is characterized by northeast trending ridges with elevations greater than 1,000 feet. The area is underlain by quartzite and metasiltstone (fig. 25). The downstream portion of the Terrapin Creek watershed lies in the Alabama Valley and Ridge physiographic section and includes portions of the Coosa Valley and Weisner Ridges districts. It is underlain by rocks of Cambrian age consisting of primarily sandstone and limestone. The Weisner and Wilson Ridge Formations undifferentiated include sandstone and conglomerate that form ridges including the most prominent topographic feature in the watershed, Weisner Mountain. Valleys in the watershed are primarily underlain by limestone of the Conasauga Formation.

Ground water moving through these geologic units issues from seeps and springs in the stream valleys and is the major source of stream discharge during drought conditions. The topographic and geomorphologic characteristics of these streams cause flashy storm runoff. Stream water levels are highly variable, especially during winter and spring. Stream channels are characterized by steep banks and

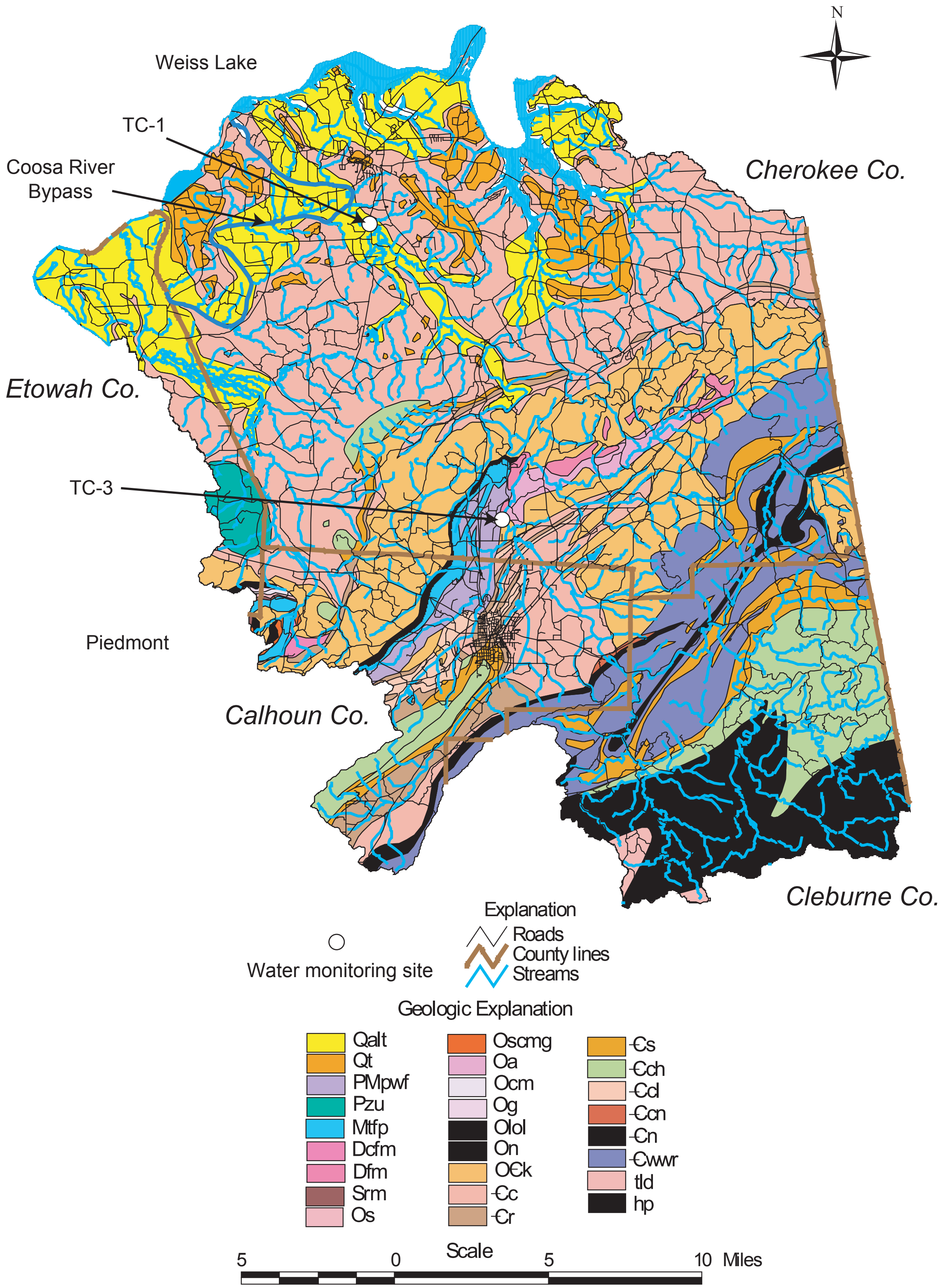


Figure 25. Geology of the Terrapin Creek watershed.

stream beds composed of bedrock overlain by silt, sand, and gravel along some stream reaches.

Two water-quality monitoring stations were established in the watershed. The upstream station was at the Cherokee County Highway 8 crossing (station TC-3) and included 171 mi^2 of the watershed upstream from the station. The downstream station was at Cherokee County Highway 71 crossing (station TC-1) and included 283 mi^2 of drainage area (fig. 23).

Land use in the watershed is primarily controlled by the geology of the area. Row crop and pasture are generally confined to areas of lower elevation while ridges are covered by forests. Land use in areas northeast of Piedmont and the downstream portion of the watershed near Weiss Lake are underlain by the Conasauga Formation. Soils in these areas are formed from weathered limestone and are conducive to row crop agriculture and hay/pasture (fig. 22). Potential sources of contaminants identified from land-use mapping include runoff from agricultural and timbering operations, and residential and urban areas in Piedmont.

PHYSICAL AND CHEMICAL PARAMETERS

STREAM DISCHARGE

Discharge is a primary physical parameter that influences surface-water quality. Ionic concentrations, specific conductance, dissolved oxygen (DO), biochemical oxygen demand (BOD), total suspended solids (TSS), bedload sediment, and bacteria concentrations are all influenced by the volume of stream discharge. Discharge is an essential component of constituent loading calculations and interwatershed comparisons of ionic concentrations and normalization of data.

Terrapin Creek attained low flow during early September 2003. Except for occasional runoff from isolated cyclonic storms, most of the discharge from the watersheds during September, October, and much of November was attributed to ground-water seepage. Field observations indicate that storm-water runoff was flashy and characterized by rapid rise and fall of stream water levels. Although no severe flooding occurred during the monitoring period, flooding occurs periodically and is caused by cyclonic storms associated with spring weather fronts or by summer and fall tropical storms or hurricanes that occasionally move through northeast Alabama.

The GSA discharge data set is composed of periodic measurements from May 2003 to March 2004 (fig. 26) using a Price AA flow meter attached to a top set wading rod or a bridge board according to United States Geological Survey (USGS) flow measurement guidelines (Carter and Davidian, 1968). Continuously collected water level data were available at a U.S. Geological Survey (USGS) gauging station at the Highway 9 crossing. These data were utilized, in combination with periodic discharge measurements, to calculate average daily discharge values for the monitoring stations during the study period. Average daily discharge values for stations TC-1 and TC-3 were used in some of the statistical analyses requiring long-term and daily discharge data, included later in this report.

Low flow discharge is important in determining the contribution of ground water to surface-water discharge during periods of drought. Low flow is also important in determining the volume of minimum flow that can be expected during specific intervals of time. Two classifications of low flow, 7-day Q_2 and 7-day Q_{10}, are generally accepted for characterizing minimal stream flow conditions. The 7-day Q_2 is defined as the lowest discharge in a stream that occurs over 7 consecutive days during a 2-year period. The 7-day Q_{10} discharge generally occurs during extreme drought conditions and is defined as the lowest discharge in a stream that occurs over 7 consecutive days during a 10-year period. These low flow discharge rates were determined using calculated values from measured discharge (Hayes, 1978).

During the study period a maximum discharge of 7000 cfs was measured at Terrapin Creek TC-1 on May 6, 2003. Minimum discharge during the monitoring period was 64 cfs measured on September 18, 2003. The 7-day Q_2 discharge for Terrapin Creek station TC-1 is 78 cfs (0.275 cfs per mi^2 of drainage area (cfsm). The 7-day Q_{10} discharge is 38 cfs (0.134 cfsm)).

WATER QUALITY

Surface water in Terrapin Creek is characterized by a unique specific conductance profile based on physical and chemical properties. Conductivity is

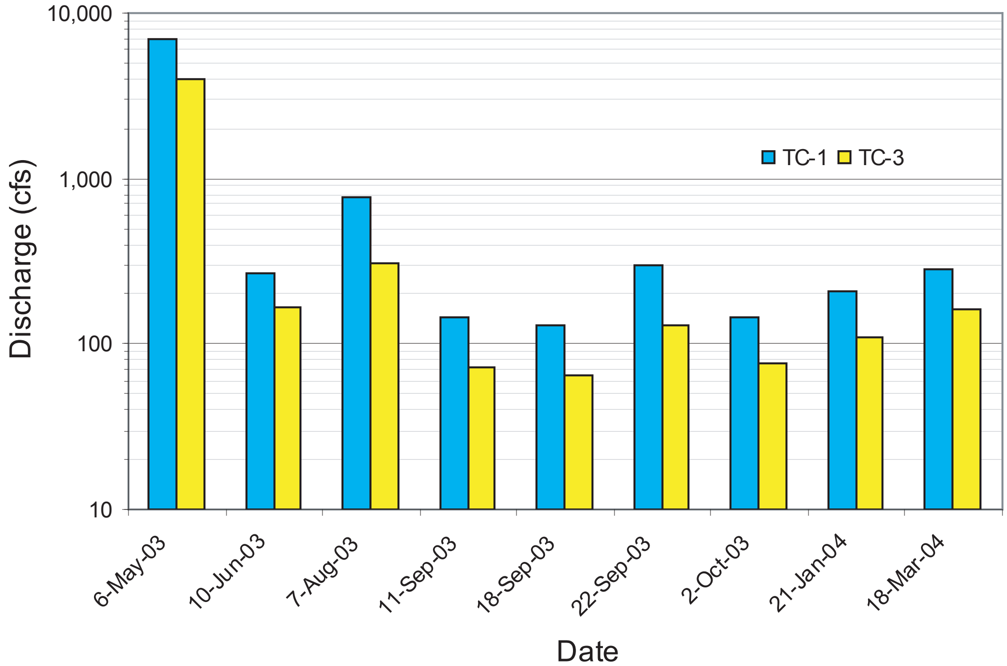


Figure 26. Discharge measured at stations TC-1 and TC-3.

influenced by stream temperature, total dissolved solids, local geology and soil conditions, input of polluted runoff, and discharge. The diluting effects of increased stream flow is a major controlling factor for conductivity, as shown in figures 27 and 28. Measurements made on May 6 and June 10, 2003, illustrate the degree to which high discharge dilutes conductivity in Terrapin Creek. The character of specific conductance in Terrapin Creek is summarized in table 13.

Dissolved oxygen (DO) concentration affects the biological health and the chemical composition of surface waters. Biological processes, oxidation, and sediment loads all contribute to depletion of DO in surface water. The ADEM water-quality criterion for DO in surface water classified as Fish and Wildlife is 5.0 mg/L except under extreme conditions when it may be as low as 4.0 mg/L. This DO criterion was not violated at the two monitoring stations during the study period. Generally, annual trends of dissolved oxygen concentrations indicate that DO is highest during winter months when water temperatures are cooler and discharge is higher than during the rest of the year. Although the highest DO concentrations occurred during March, relatively small fluctuations occurred during the monitoring period. Minimum and maximum measured dissolved oxygen values are given in table 13.

Biochemical oxygen demand (BOD) is an empirical measure of the amount of oxygen used for the degradation of organic matter by the microbial population. This parameter is used to indirectly measure the presence and magnitude of organic pollutants and often is used to determine the effect of waste discharges on the oxygen resources of receiving waters. The BOD limitations for domestic wastewater effluent, established by the USEPA for biologically treated municipal wastewater, is 30 mg/L. Criteria established by some states for water-quality sensitive surface-water bodies may be as low as 5 mg/L (Mays, 1996). Average BOD for Terrapin Creek was relatively low for the study period (table 13). Measured BOD values and discharge for stations TC-1 and TC-3 are shown in figures. 29 and 30. Turbidity values measured from water samples may be utilized to formulate a rough estimate of long-term trends of total suspended solids (TSS) content in streams. The character of turbidity values for Terrapin Creek is summarized in table 13.

Figure 27. Specific conductance and discharge measured at station TC-1.

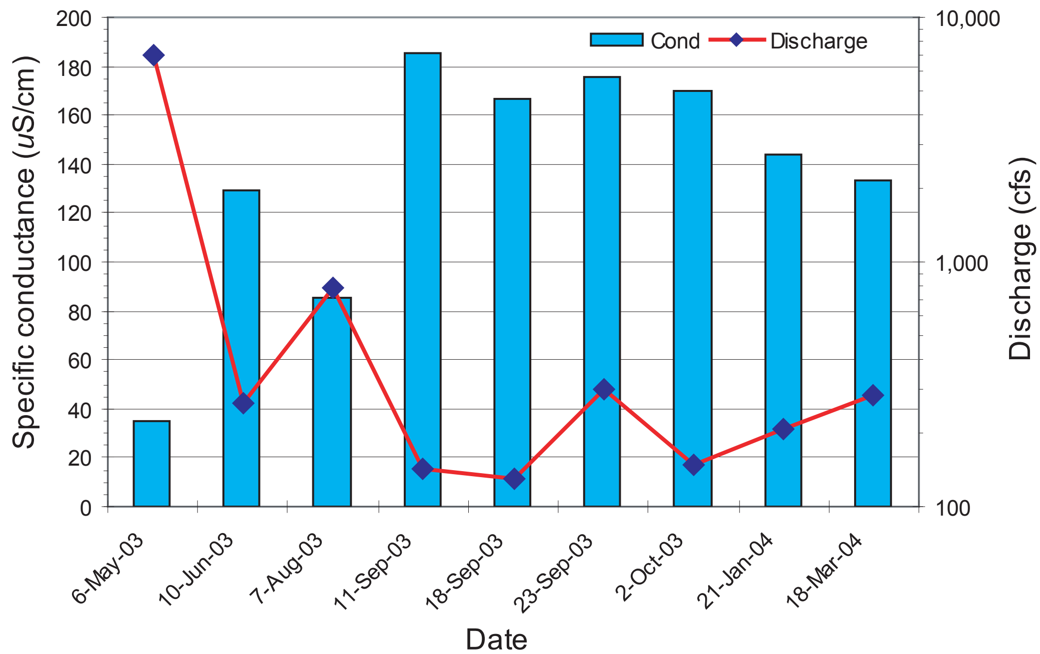


Figure 28. Specific conductance and discharge measured at station TC-3.

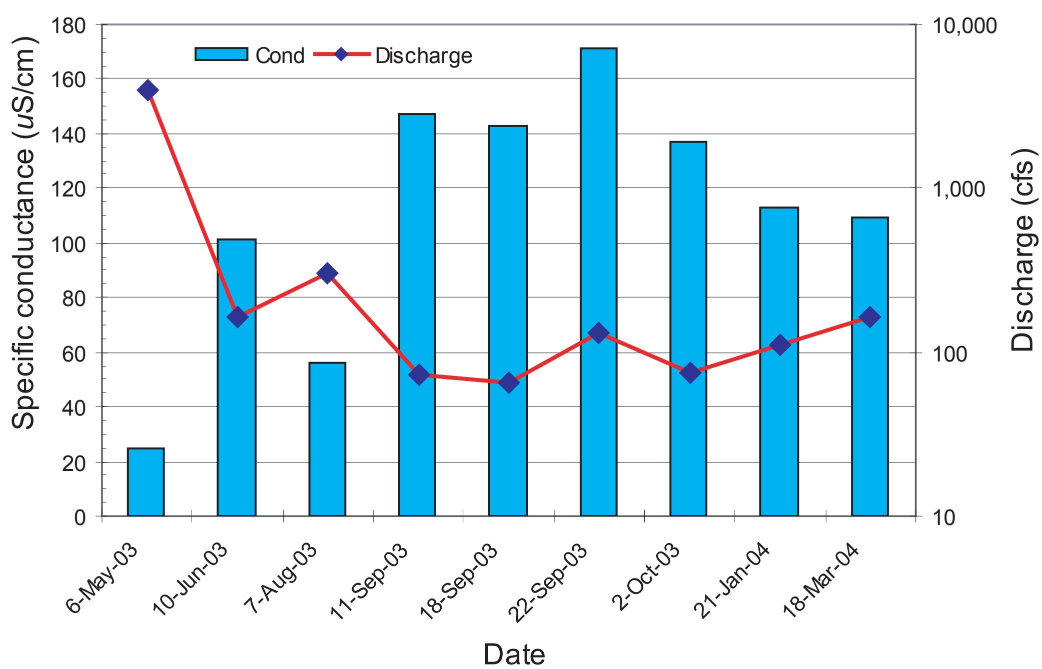


Table 13. Summary of selected water-quality constituents for Terrapin Creek

Station	Minimum	Maximum	Average
	Specific conductance (μS/cm)		
TC-1	35	185	136
TC-3	25	171	111
	Dissolved oxygen (mg/L)		
TC-1	7.7	12.1	9.0
TC-3	7.0	12.4	9.0
	Biochemical oxygen demand (mg/L)		
TC-1	0.5	5.5	1.5
TC-3	0.5	4.1	1.6
	Turbidity (nephelometric turbidity units-NTU)		
TC-1	2	357	59
TC-3	1	200	38
	Chlorophyll-*a* (mg/L)		
TC-1	0.0007	0.0035	0.0019
TC-3	0.0007	0.0331	0.0059

Figure 29. Biochemical oxygen demand and discharge measured at station TC-1

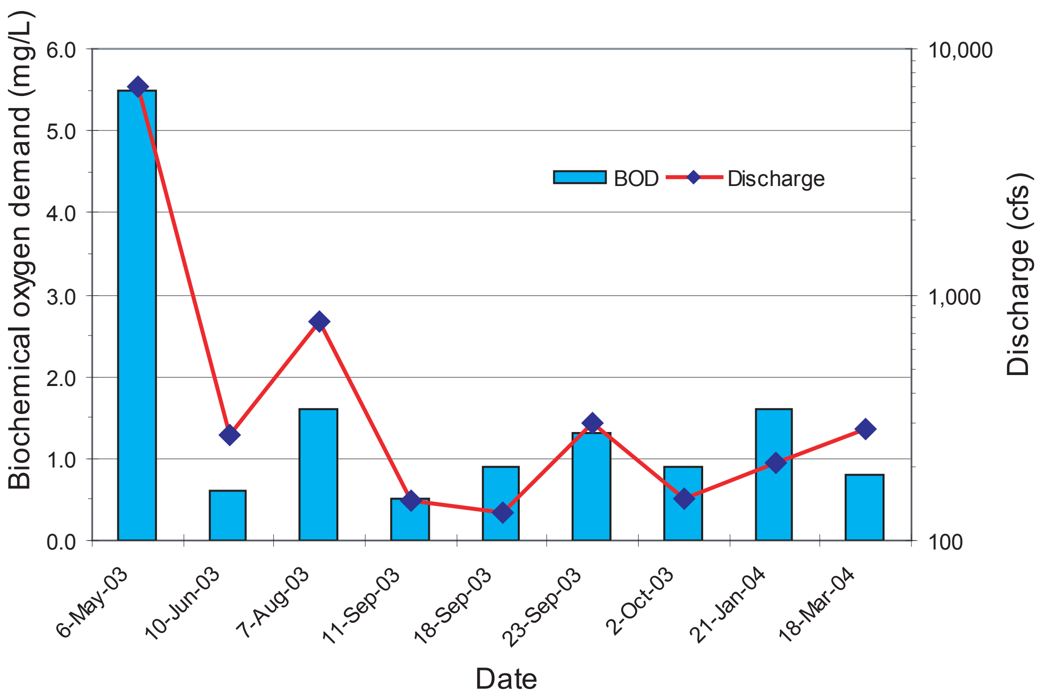
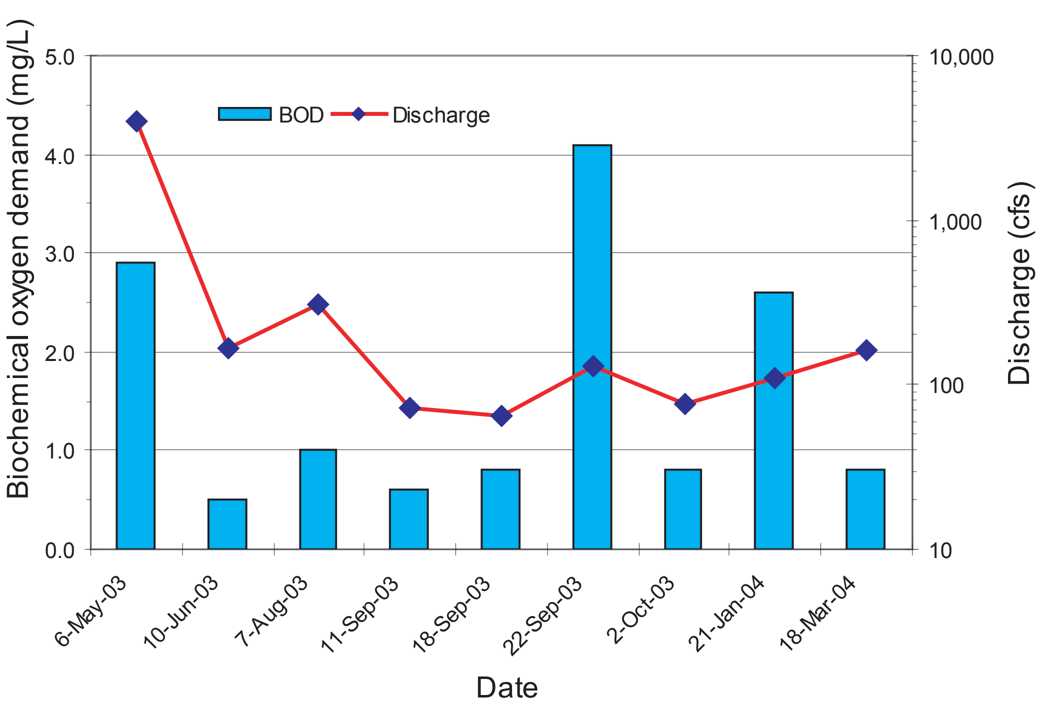


Figure 30. Biochemical oxygen demand and discharge measured at station TC-3



CONSTITUENT LOADING IN TERRAPIN CREEK

The basic concept of constituent loading in a river or stream is simple. However, the mathematics of determining a constituent load may be quite complex. The constituent load is the mass or weight of a constituent that passes a cross-section of a stream in a specific amount of time. Loads are expressed in mass units (e.g., tons or kilograms) and are considered for time intervals that are relative to the type of pollutant and the watershed area for which the loads are calculated. Loads are calculated from concentrations of constituents obtained from analytical analyses of water samples and stream discharge.

The computer model Regr_Cntr.xls (*Regression with Centering*) was used to calculate constituent loads for this project. The program is an Excel implementation of the USGS seven-parameter regression model for load estimation (Cohn and others, 1992). It estimates loads in a manner very similar to that used most often by the Estimatr.exe (*USGS Estimator*) program. The Regr_Cntr.xls program was adapted by R. Peter Richards at the Water Quality Laboratory at Heidelberg College (Richards, 1999). The program establishes a regression model using a calibration set of data consisting of constituent concentrations and discharge values measured at the time of water sampling. Constituent loads can be estimated for any year for which mean daily discharge data are provided.

SEDIMENTATION

Sedimentation is a process by which eroded particles of rock are transported by moving water from areas of relatively high elevation to areas of relatively low elevation where the particles are ultimately deposited. Upland sediment transport is primarily accomplished by overland flow and rill and gully development. Lowland or floodplain transport occurs in varying order streams where upland sediment joins sediment eroded from flood plains, stream banks and stream beds. Erosion rates are accelerated by human activity related to agriculture, construction, timber harvesting, unimproved roadways or any activity where soils or geologic units are exposed or disturbed. Sedimentation is detrimental to water quality, destroys biologic habitat, reduces storage volume of water impoundments, impedes the usability of aquatic recreational areas, and causes damage to structures.

Sediment loads in streams are composed of relatively small particles suspended in the water column (suspended solids) and larger particles that move on or periodically near the stream bed (bedload). Coastal Plain streams typically have stream beds composed of gravel, sand, and silt whereas streams in north Alabama have beds composed primarily of bedrock or cobbles and boulders and to a lesser extent, gravel, sand, and silt. The stream bed at station TC-1 was composed of cobbles and gravel with isolated sand and silt. The stream bed at station TC-3 was composed of cobbles and boulders with small isolated accumulations of sand. During normal flows no bedload movement was detected at either site, and during high flows all sediment was assumed to be suspended due to relatively high stream flow velocities and hard stream beds that promote the suspension of sediment particles moving downstream.

Suspended solids are defined as that portion of a water sample that is separated from the water by filtering. This solid material may be composed of organic and inorganic material that includes algae, industrial and municipal wastes, urban and agricultural runoff, and eroded material from geologic formations. These materials are transported by overland flow related to storm-water runoff to stream channels.

Water samples were collected during several storm events during the sampling period and concentrations of total suspended solids (TSS) in mg/L were determined by laboratory analysis. Comparisons of storm samples with samples collected during normal flows indicate that TSS concentrations of storm samples varied from three times to more than ten times that of normal flow samples in Terrapin Creek generally due to increased stream discharge and increased influx of organic material. The character of TSS concentrations and the calculated TSS loads are shown in table 14, TSS concentrations and discharge measured in Terrapin Creek are shown in figures 31 and 32. The TSS load in Terrapin Creek was compared to other streams in Alabama (fig. 33) and is about 1/10th that of urban streams (Tuscaloosa) and similar to TSS loads observed in agricultural watersheds (streams LKC and BC) in south Alabama.

Table 14. Total suspended solids, nitrate, and orthophosphate summary and estimated loadings for Terrapin Creek.

Station	Concentration (mg/L)			Loadings tons/yr (tons/mi^2/yr)
	Minimum	Maximum	Average	
	Total suspended solids			
TC-1	<4	43	13	20,400 (72)
TC-3	<4	119	17	13,600 (80)
	Nitrate (NO_3 as N)			
TC-1	0.17	0.37	0.25	152 (0.54)
TC-3	0.10	0.42	0.28	71 (0.42)
	Orthophosphate (PO_4 as P)			
TC-1	<0.02	0.08	0.028	18.5 (0.07)
TC-3	<0.02	0.08	0.020	13.1 (0.08)

NUTRIENTS

Plants and animals in aquatic ecosystems are composed of carbon, hydrogen, oxygen, nitrogen, phosphorus, and sulfur. Upon death, the biota decomposes and releases nutrients for reuse back into the biological system. However, excessive concentrations of nutrients, primarily nitrogen and phosphorus, in the aquatic environment will enhance the eutrophication process and can lead to increased biological activity, decreased dissolved oxygen concentrations, and decreased numbers of species (Mays, 1996).

NITRATE

The USEPA maximum contaminant level (MCL) for nitrate in drinking water is 10 mg/L (USEPA, 2002). Typical nitrate (NO_3 as N) concentrations in streams vary from 0.5 to 3.0 mg/L whereas concentrations of nitrate in streams without significant nonpoint sources of pollution vary from 0.1 to 0.5 mg/L (Maidment, 1993). Streams fed by shallow ground water draining agricultural areas may approach 10 mg/L (Maidment,

Figure 31. Measured total suspended solids and discharge measured at station TC-1

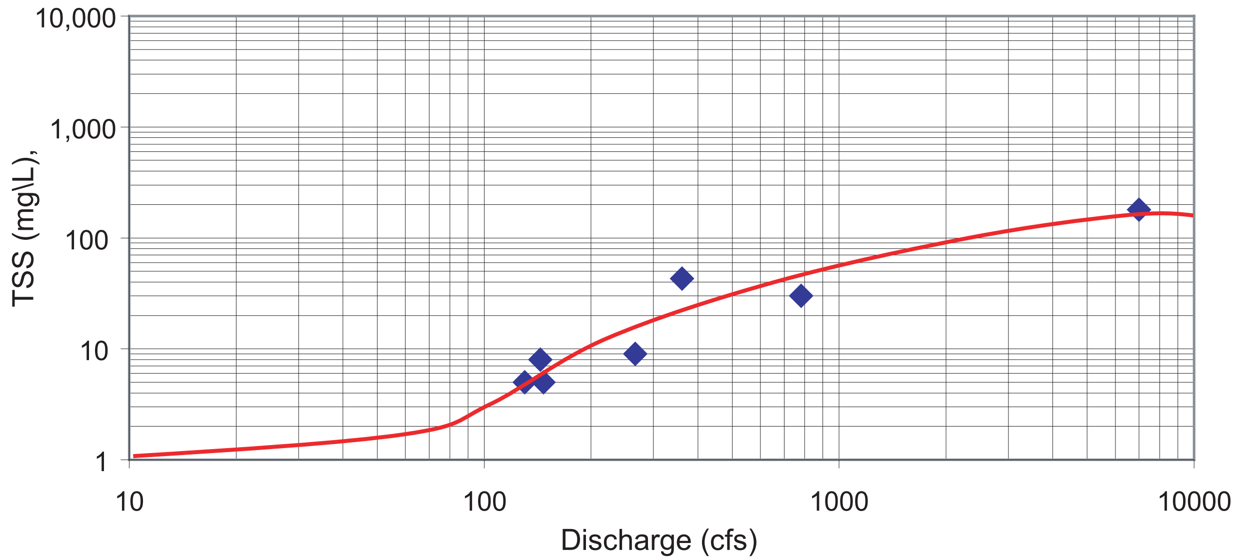


Figure 32. Measured total suspended solids and discharge measured at station TC-2

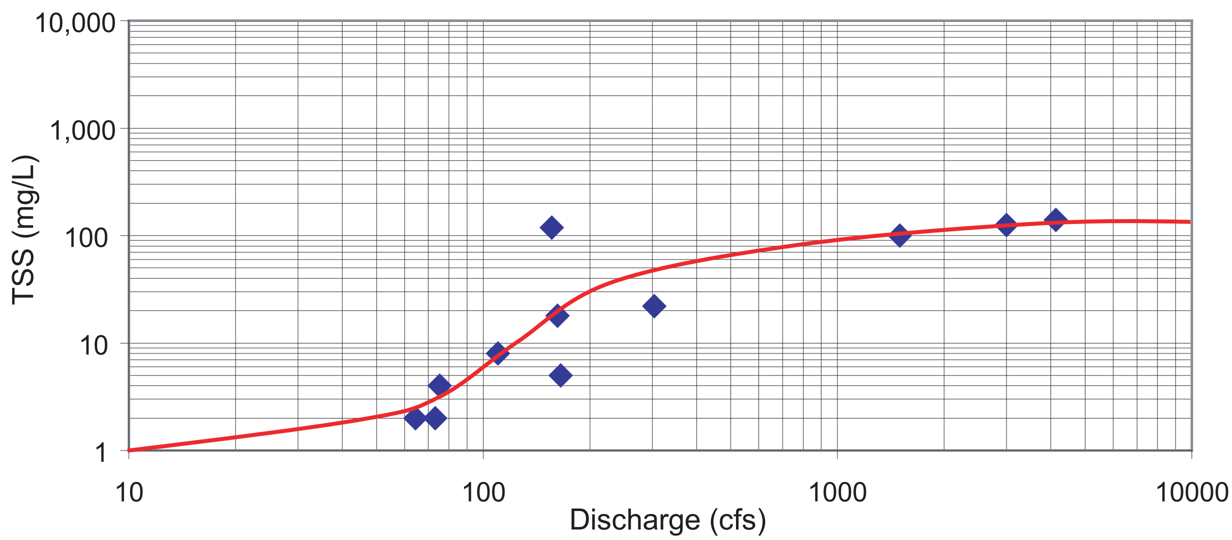
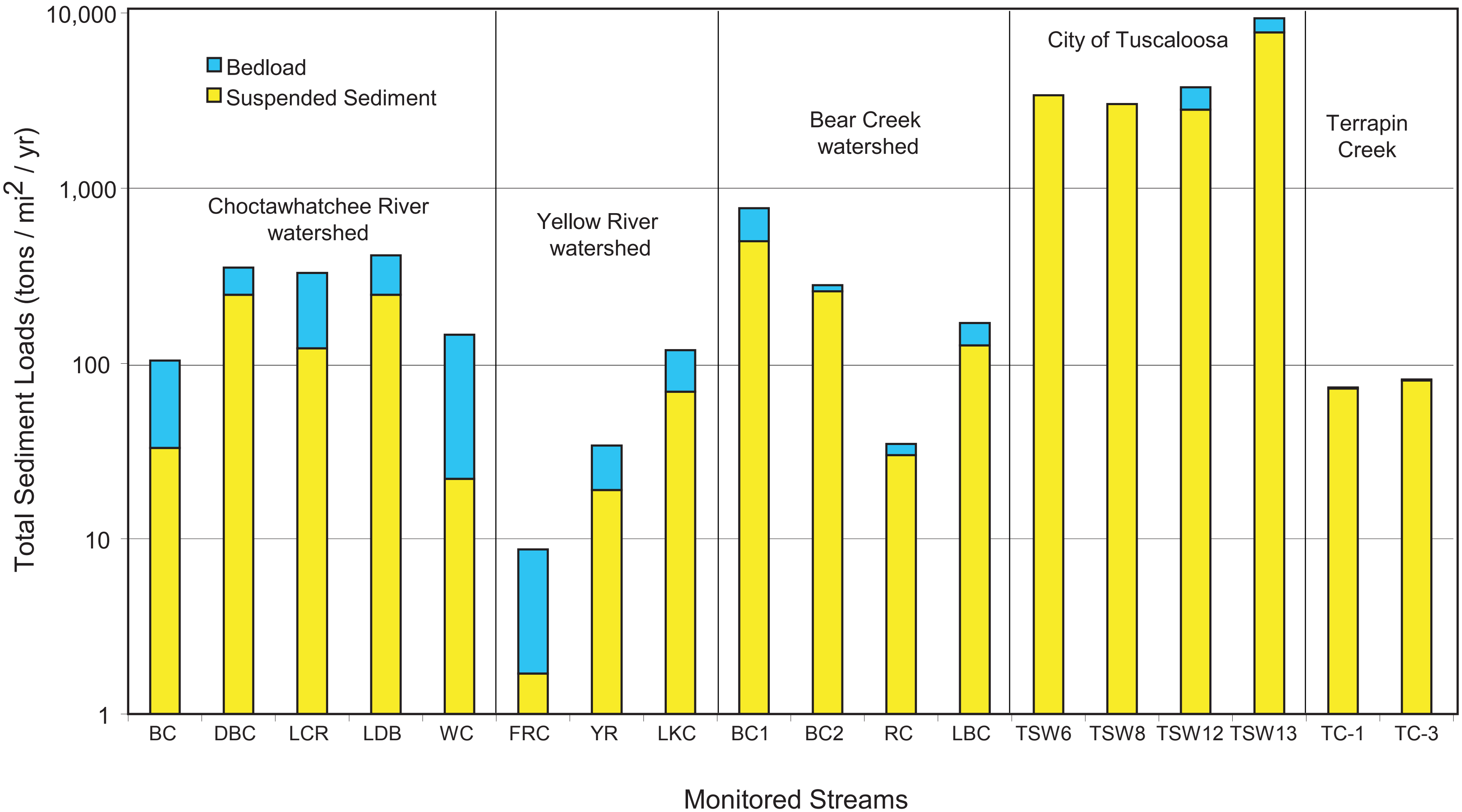


Figure 33. Estimated total annual sediment loads for Terrapin Creek and other selected Alabama streams.



1993). Nitrate concentrations were low in Terrapin Creek and did not exceed 0.5 mg/L in any of the nine samples collected from either site in Terrapin Creek (figs. 34, 35).

Although a limited number of samples were collected for this assessment, stream discharge and corresponding nitrate concentrations at both monitoring sites indicate that an inverse relationship between discharge and nitrate concentrations may exist, especially in summer, in Terrapin Creek. An inverse relationship may generally indicate a limited amount of nitrate in the system, influx of contaminated ground water, or point source contaminants such as wastewater discharged into Terrapin Creek. Estimated nitrate loads for stations TC-1 and TC-3 are included in table 14. Nitrate loads in Terrapin Creek were slightly greater than forested watersheds in south Alabama (Walnut Creek, Five Runs Creek, and Yellow River) but were substantially less than watersheds with heavy agricultural activity (Blackwood Creek, Little Double Bridges Creek) (fig. 36).

PHOSPHORUS

Phosphorus in streams originates from the mineralization of phosphates in soils and rocks, or runoff containing fertilizer or other industrial products. The principal components of the phosphorus cycle involve organic phosphorus and inorganic phosphorus, in the form of orthophosphate (PO_4) (Maidment, 1993). Orthophosphate is soluble and considered to be the only biologically available form of phosphorus. The natural background concentration of total dissolved phosphorus is approximately 0.025 mg/L. Total phosphorus concentrations as low as 0.005 to 0.01 mg/L may cause excessive algae growth, but the critical level of phosphorus necessary for excessive algal growth is around 0.05 mg/L. Although no official water quality criterion has been established in the United States for phosphorus, to prevent the development of biological nuisances, it is recommended that total phosphorus should not exceed 0.05 mg/L in any stream or 0.025 mg/L in a lake or reservoir (Maidment, 1993). In many streams, phosphorus is the primary nutrient that influences biological activity and these streams are termed “phosphorus limited.”

The total phosphorus critical level (0.05 mg/L-total P) was exceeded in four of nine water samples collected from station TC-1 and in two of nine samples collected

Figure 34. Nitrate and discharge measured at station TC-1.

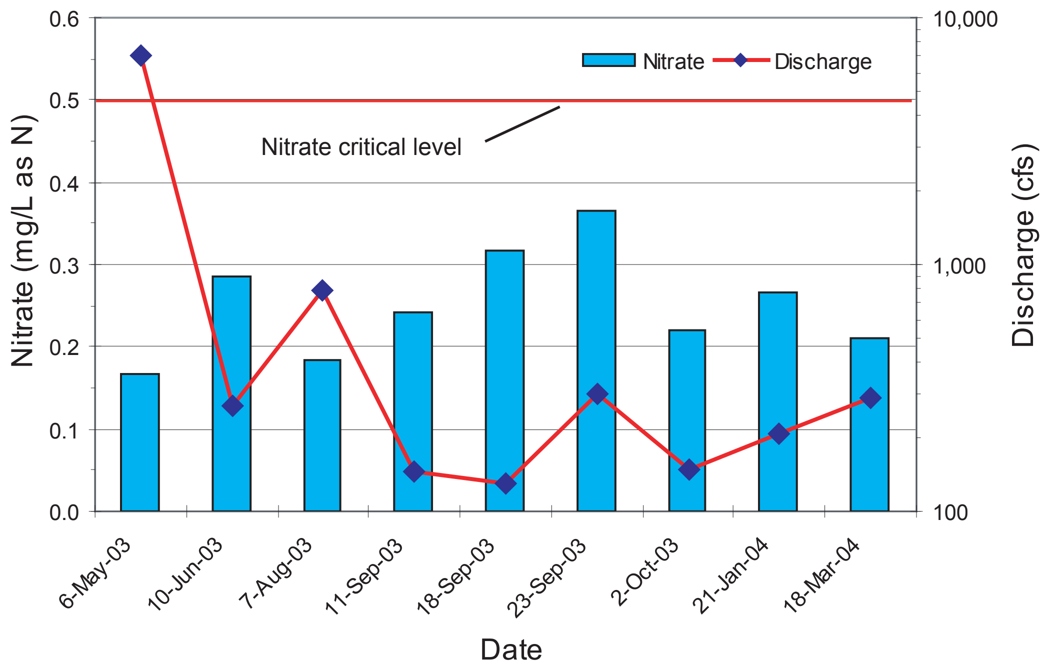


Figure 35. Nitrate and discharge measured at site TC-3.

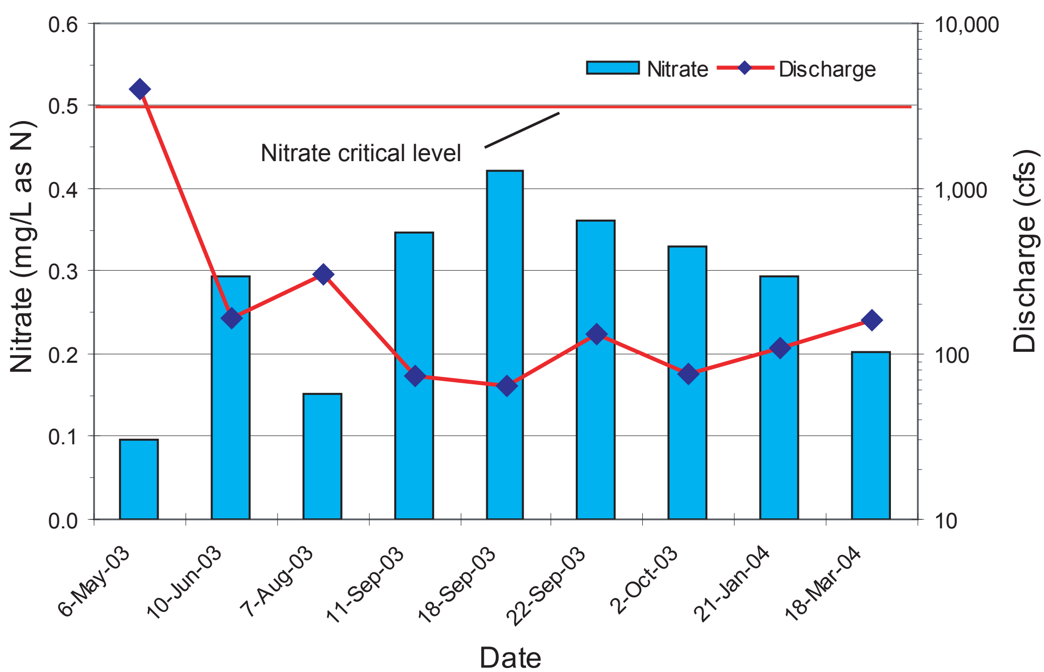
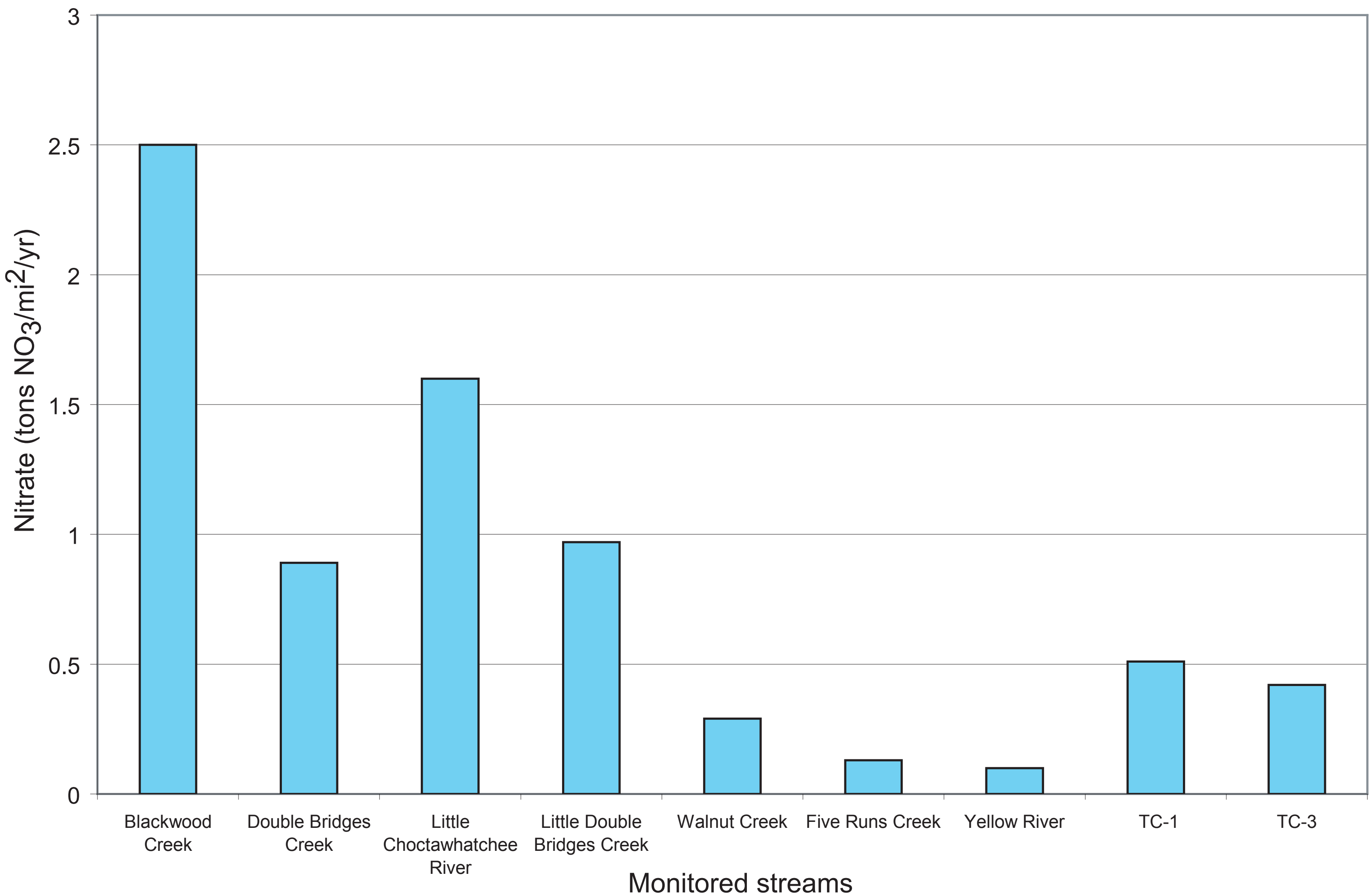


Figure 36. Estimated total annual nitrate loads for Terrapin Creek and other selected streams in Alabama.



from station TC-3 (figs. 37, 38). Total phosphorus concentrations were below detectable limits at both monitoring sites for a high discharge event on May 6, 2003 yet orthophosphate was detected at relatively high concentrations. During a smaller high-discharge event on September 23, total phosphorus and orthophosphate were detected at both sites in relatively high concentrations (figs. 39, 40). This may indicate an acute source of phosphorus related to season and/or land use. Graphs of discharge and orthophosphate indicate that concentrations increase rapidly with increasing discharge to approximately 1,000 cfs at station TC-1 and 400 cfs at station TC-3. At higher discharges, concentrations remain constant or decrease, which may indicate limited sources of phosphorus in the watershed. Orthophosphate concentrations varied from below detection limit (<0.02 mg/L) to 0.08 mg/L at both stations TC-1 and TC-3 (table 14, figs. 39, 40).

CHLOROPHYLL

Phytoplankton, found in most bodies of water, are microscopic one-celled algae and chlorophyll is the green photosynthetic pigment found in phytoplankton, giving lake water its typical green color. Phytoplankton are important not only as primary producers and a major food source for herbivorous fishes, but also because their abundance directly affects water-quality characteristics such as oxygen and water clarity. Analyses of chlorophyll concentrations can help determine the current water-quality conditions and trophic status of a water body.

The trophic state of an impounded water body is another indicator of its water quality. Lakes may be classified into three categories based on their trophic state: oligotrophic, mesotrophic, and eutrophic. These terms define the nutrient and clarity status of a lake or impoundment. Oligotrophic lakes are generally clear, deep, and free of weeds or large algae blooms. They are low in nutrients and do not support abundant fish populations. Eutrophic lakes are high in nutrients and usually support a large biomass (all the plants and animals living in the lake). Eutrophic lakes are usually weedy and are subject to frequent algae blooms. They often support large fish populations but are very susceptible to oxygen depletion because of the high population

Figure 37. Total phosphorus and discharge measured at station TC-1.

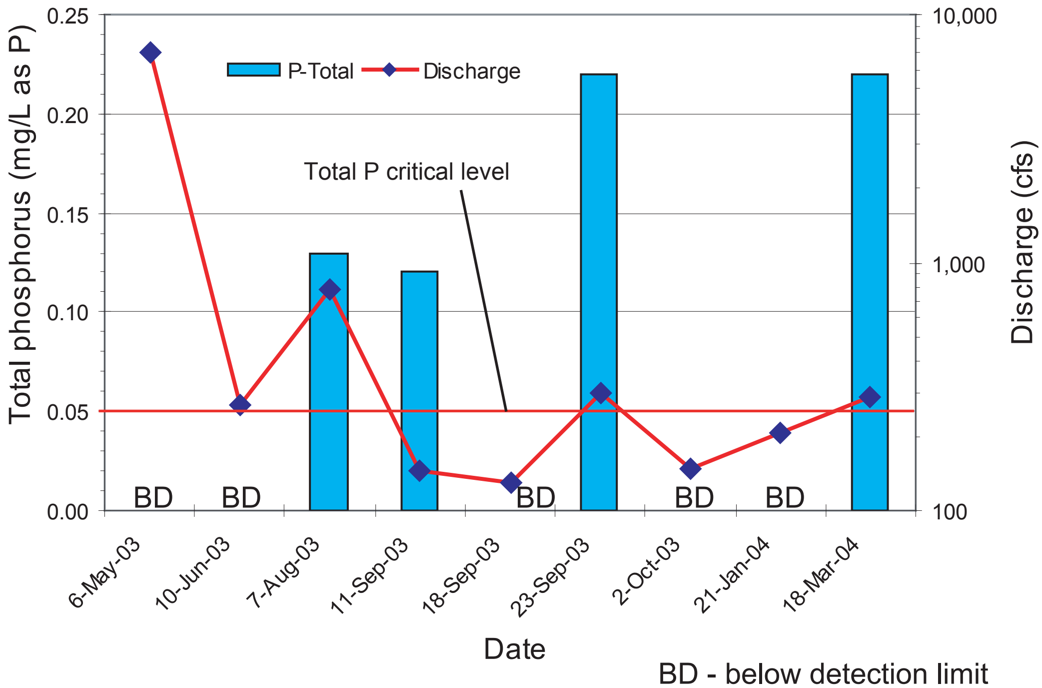


Figure 38. Total phosphorus and discharge measured at station TC-3.

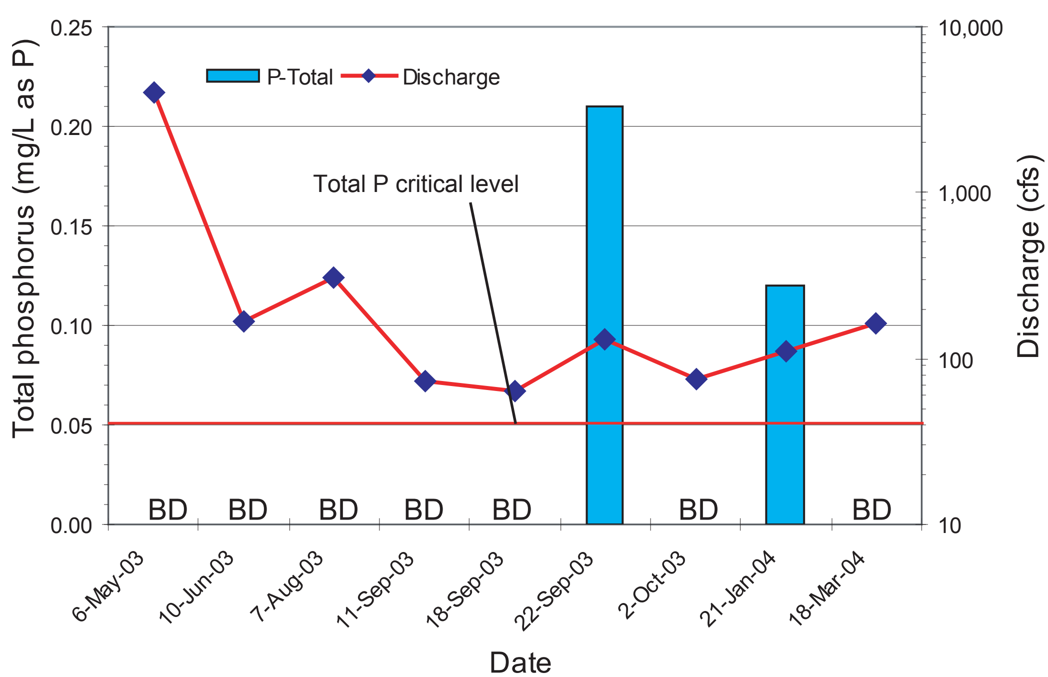


Figure 39. Orthophosphate and discharge measured at station TC-1.

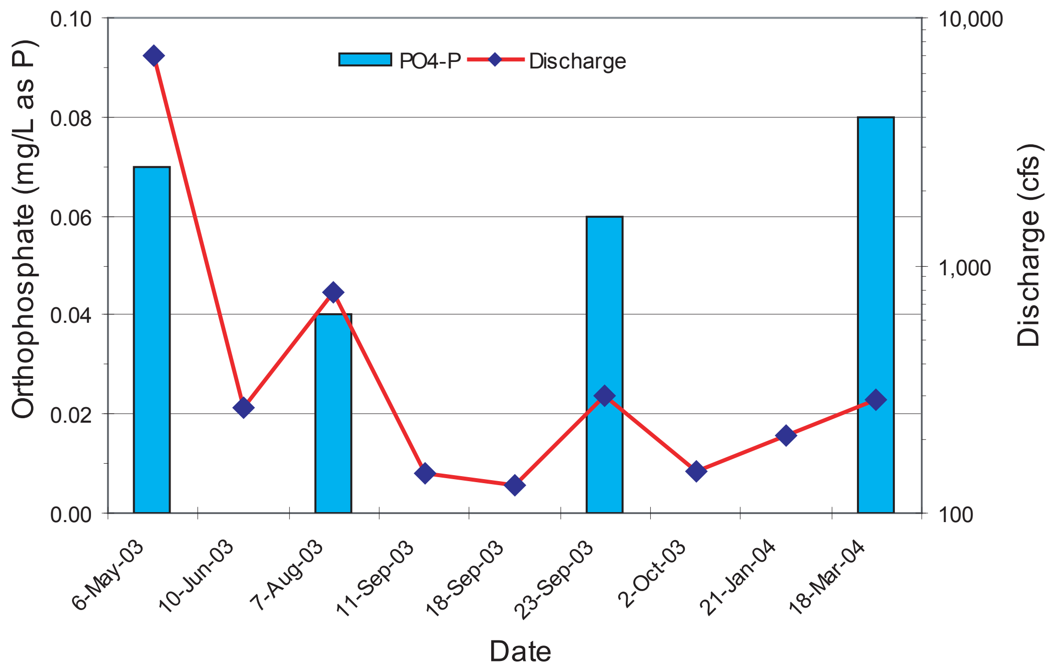
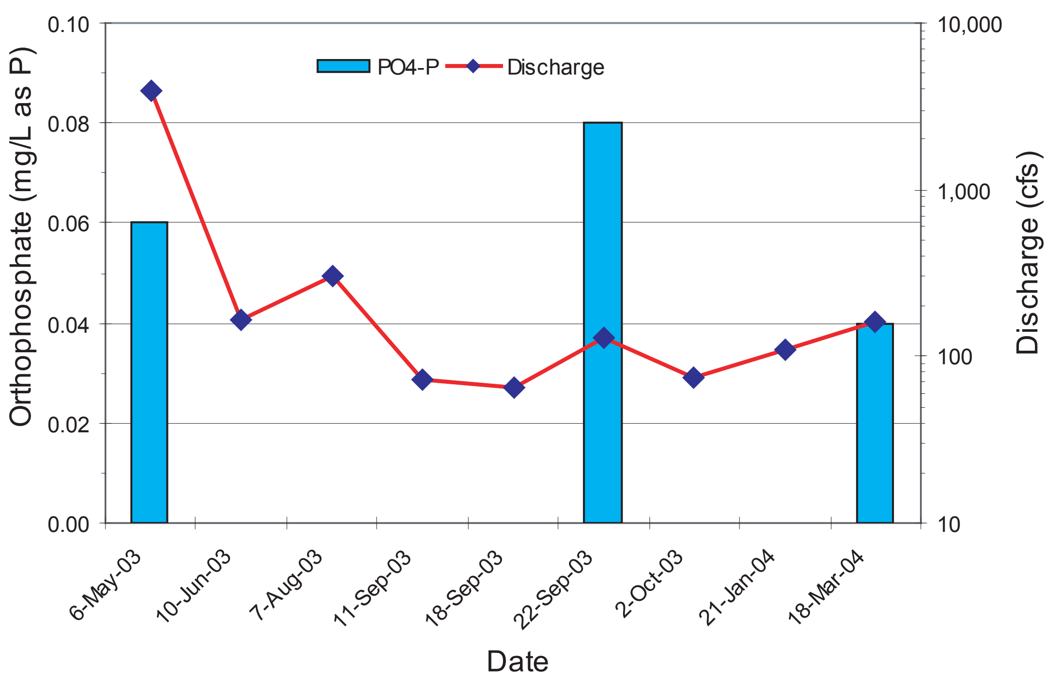


Figure 40. Orthophosphate and discharge measured at station TC-3.



of bacterial decomposers. Mesotrophic lakes lie between the oligotrophic and eutrophic stages and may become oxygen depleted in late summer.

Trophic condition are determined by measuring concentrations of total phosphorus, total nitrogen, chlorophyll *a,* and water clarity. Selected critical constituent concentrations and mean concentrations of critical constituents measured in Terrapin Creek are given in table 15. These data indicate that Terrapin Creek is probably in the upper range of the oligotrophic condition or the lower range of the mesotrophic condition. Figures 41 and 42 portray chlorophyll *a* concentrations for water samples collected from Terrapin Creek and their corresponding trophic classifications.

BACTERIA

Microorganisms are present in all surface waters and include viruses, bacteria, fungi, algae, and protozoa. Analyses of bacteria levels can be used to assess the quality of water and to indicate the presence of human and animal waste in surface and ground water. Fecal coliform and fecal streptococcus groups of bacteria are used as primary indicator organisms of this type of water pollution. The membrane filter procedure as described in the 19th Edition of Standard Methods (Eaton and others, 1995) was used for determining fecal coliform and fecal streptococcus bacteria counts for collected water samples.

Table 15. Selected critical constituent concentrations for general trophic classifications and average concentrations of constituents in Terrapin Creek (modified from Wetzel, 2001)

Constituent	Oligotrophic range (mg/L)	Mesotrophic range (mg/L)	Eutrophic range (mg/L)	Average concentration (mg/L)	
				TC-1	TC-3
Total phosphorus	0.003-0.018	0.011-0.096	0.016-0.386	0.08	0.04
Total nitrogen	0.3-1.6	0.4-1.4	0.4-1.6	0.43	0.29
Chlorophyll-*a*	0.0003-0.005	0.003-0.011	0.003-0.078	0.0019	0.0059

Figure 41. Chlorophyll *a* measured at station TC-1

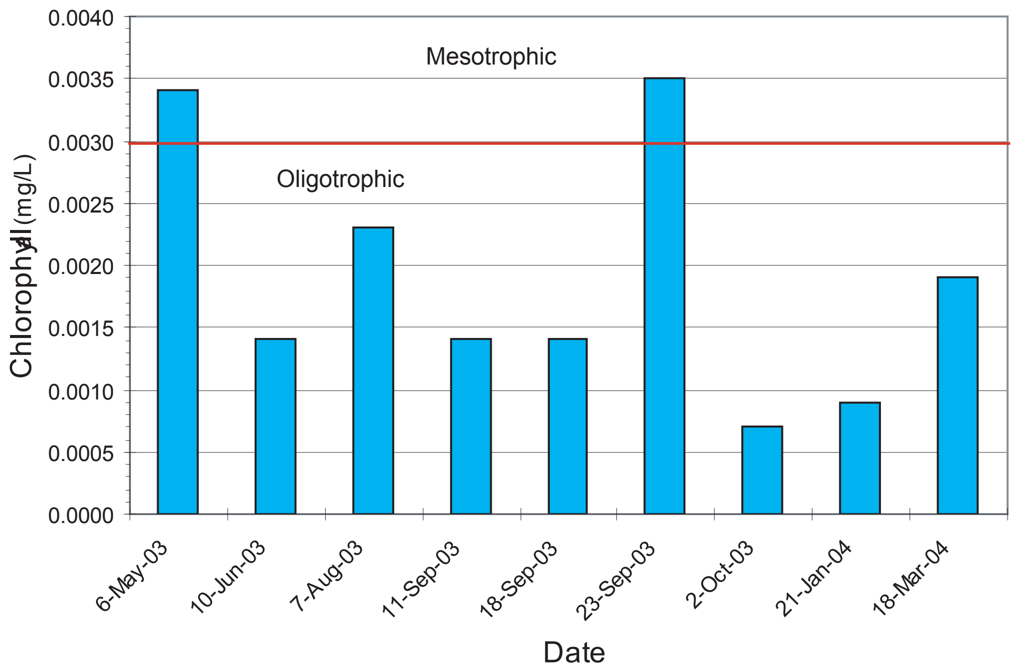


Figure 42. Chlorophyll *a* measured at station TC-3

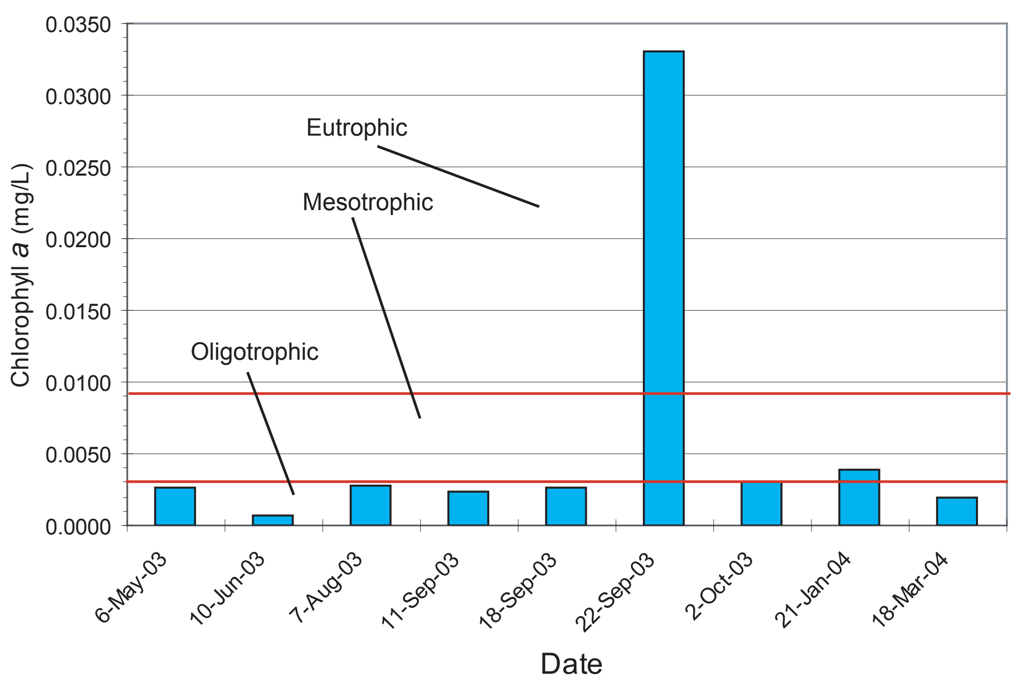


Table 16. Estimated per capita contribution of indicator microorganisms from humans and selected animals (Tchobanoglous and Schroeder, 1985)

Animal	Bacterial indicator organism (average/gram feces)		Ratio of FC/FS
	Fecal coliform (FC) x 10^6	Fecal streptococcus (FS) x 10^6	
Human	13.0	3.0	4.4
Chicken	1.3	3.4	0.4
Cow	0.23	1.3	0.2
Duck	33.0	54.0	0.6
Pig	3.3	84.0	0.04
Sheep	16.0	38.0	0.4
Turkey	0.29	2.8	0.1

The ratio of fecal coliform to fecal streptococcus colonies has been used for many years to differentiate human fecal contamination from that of other warm-blooded animals (table 16). A ratio of 4 was considered indicative of human fecal contamination, whereas a ratio of less than 0.7 was considered to be contamination by nonhuman sources. The 19th Edition of Standard Methods reports that the value of this ratio has been questioned because of variable survival rates of the fecal streptococcus species group in water and the methods for enumerating fecal streptococci. However, a large body of literature is available that documents the differences in bacteria concentrations between humans and animals and the utility of the ratio method as a means to differentiate human and animal contamination of water.

The water-quality criterion for fecal coliform bacteria, established for surface waters classified as Fish and Wildlife, is 2,000 colonies per 100 milliliter sample for any one samples (ADEM, 2005). This limit was exceeded in 3 of 6 samples collected at station TC-1 and in 2 of 6 samples collected at station TC-3 (table 17, figs. 43, 44). Fecal streptococci bacteria were more prevalent than fecal coliform bacteria during the sampling period, as expected, due to the land-use characteristics of the Terrapin Creek watershed (table 17, figs. 45, 46). The average ratio of fecal coliform to fecal streptococci bacteria for the sampling period was 0.49 at station TC-1 and 0.62 for station TC-3. (table 17). This ratio suggests that bacteria in Terrapin likely originates from agricultural sources.

Table 17. Summary data for fecal coliform and fecal streptoccus bacteria at stations TC-1 and TC-3.

Station	Maximum concentration (no./100mL)		Average concentration (no./100mL)		Average ratio (FC/FS)
	FC	FS	FC	FS	
TC-1	8,200	31,600	3,069	10,615	0.49
TC-3	5,200	24,500	1,885	5,783	0.62

Figure 43. Fecal coliform bacteria and discharge measured at station TC-1

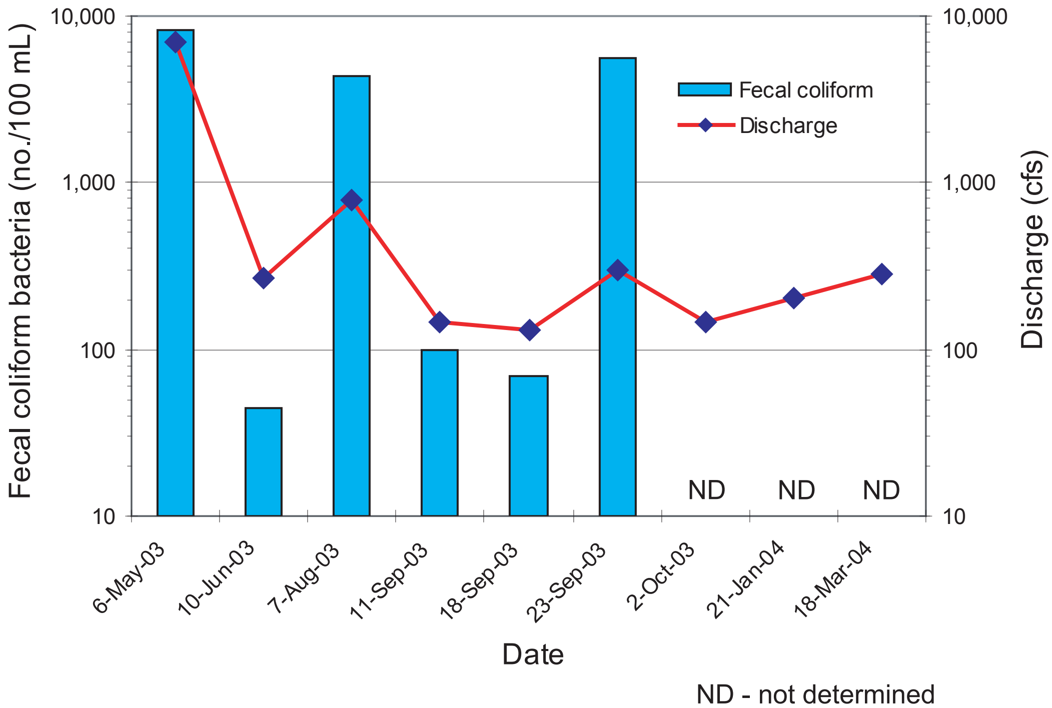


Figure 44. Fecal coliform bacteria and discharge measured at station TC-3

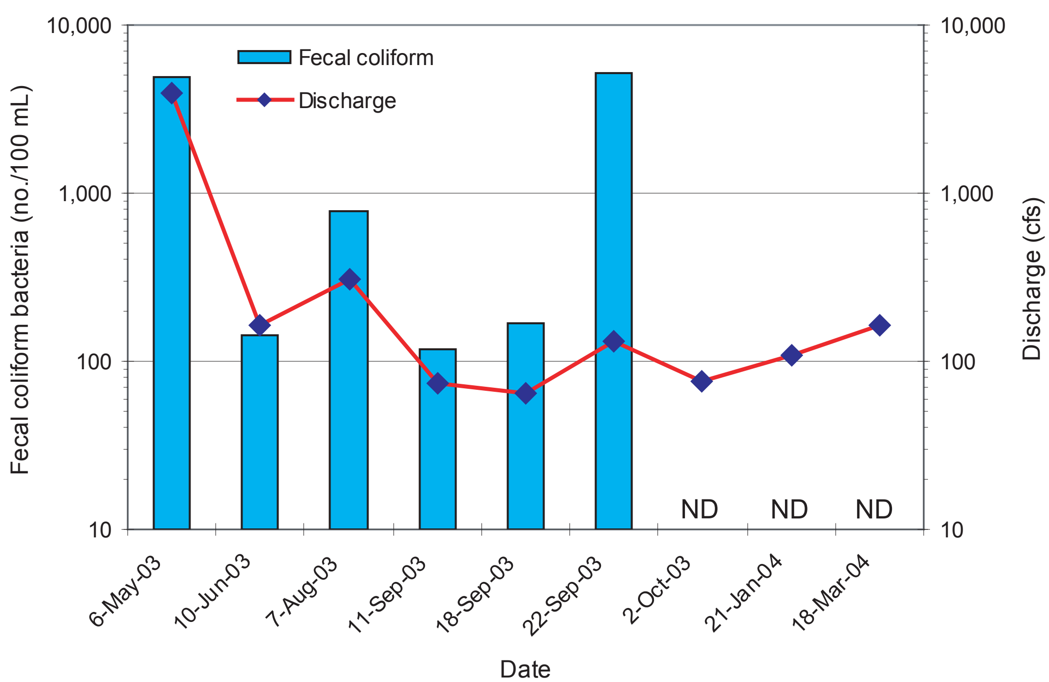


Figure 45. Fecal streptococcus bacteria and discharge measured at station TC-1

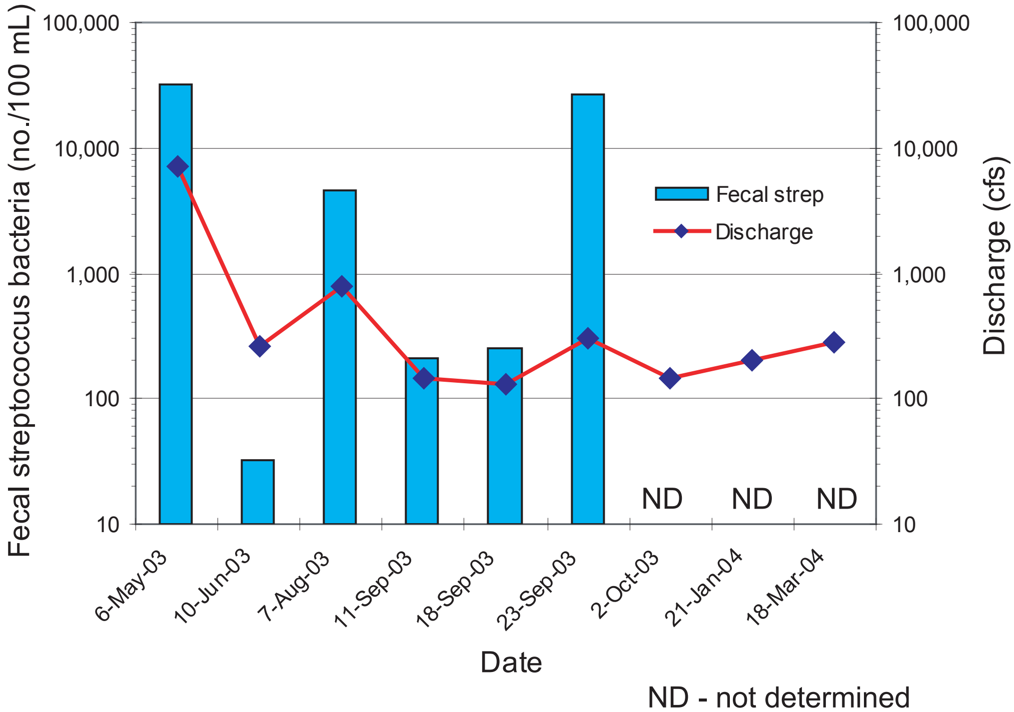
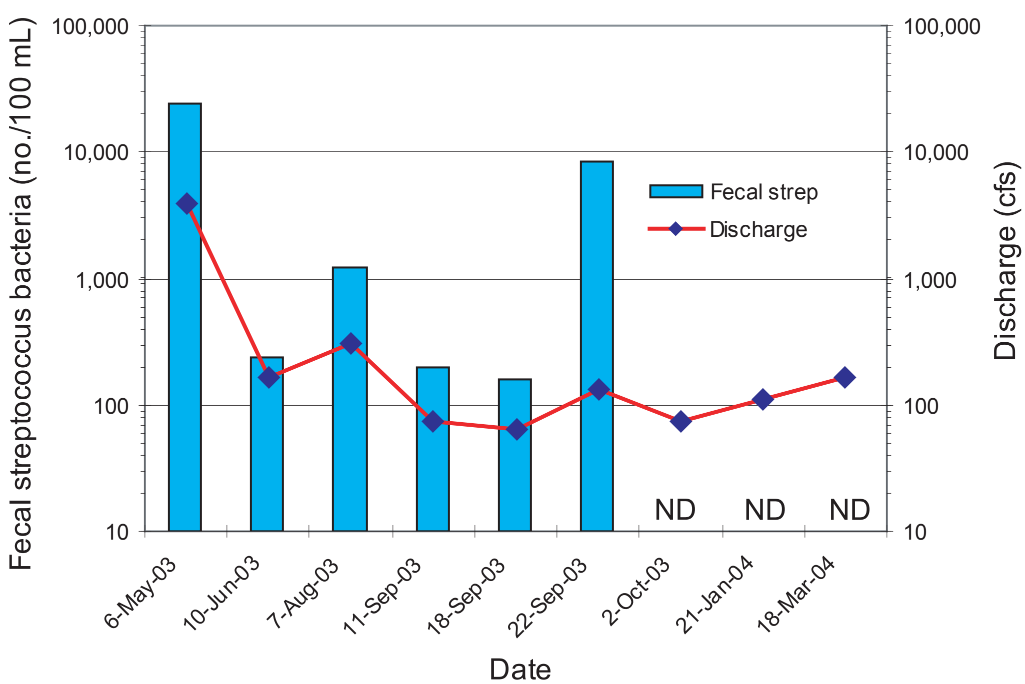


Figure 46. Fecal streptococcus bacteria and discharge measured at station TC-3



OTHER WATER-QUALITY CONSTITUENTS

Water samples were also analyzed for selected metallic constituents. Table 18 contains average concentrations for selected metallic constituents and the number of samples that exceeded ADEM primary and secondary drinking water standards. Water samples were also analyzed for selected inorganic nonmetallic constituents. Table 19 contains concentrations of inorganic nonmetallic constituents. Chloride, fluoride, silica, and sulfate were detected in samples collected at Terrapin Creek stations. These constituents are common in surface water and usually originate, in the observed range of concentrations, from sediments that underlie the watersheds.

Organic compounds are commonly used in our society today and frequently appear in streams and ground-water aquifers due to runoff and discharge of effluents. Many of these compounds have been found to be harmful to human health and the health of the aquatic environment. A limited group of organic constituents were analyzed in water samples collected from the Terrapin Creek monitoring stations. They include total organic carbon (TOC) and total phenolics.

Total organic carbon (TOC) measures the carbon content of dissolved and particulate organic matter present in water. Many water utilities monitor TOC to determine raw water quality or to evaluate the effectiveness of processes designed to remove organic carbon. Some wastewater utilities also employ TOC analysis to monitor the efficiency of the treatment process. In addition to these uses of TOC , measuring changes in TOC concentrations can be an effective "surrogate" for detecting contamination from organic compounds (e.g., petrochemicals, solvents, pesticides). Thus, while TOC analysis does not give specific information about the nature of the threat, identifying changes in TOC can be a good indicator of potential threats to a system by organic constituents (USEPA, 2005b). Typical TOC values for natural waters vary from 1 to 10 mg/L (Mays, 1996). Average TOC values for monitoring stations TC-1 and TC-3 are shown in table 19.

Phenols are used in the production of phenolic resins, germicides, herbicides, fungicides, pharmaceuticals, dyes, plastics, and explosives (USGS, 1998). They may

Table 18. Average concentrations of metallic constituents and number of samples exceeding drinking water standards

Constituent	Drinking water MCL (µg/L)	Site TC-1			Site TC-3		
		Range (µg/L)	Average (µg/L)	Number of samples exceeding drinking water standards	Range (µg/L)	Average (µg/L)	Number of samples exceeding drinking water standards
Aluminum	200	<60 - 313	47.2	1	<60 - 241	41.6	1
Barium	2,000	14.3 - 78.6	29.9	0	17.8 - 40.9	25.5	0
Beryllium	4	all <1	<1	0	all <1	<1	0
Cadmium	5	all <4	<4	0	all <4	<4	0
Chromium	100	<.8 - .8	<.8	0	<.8 - <.8	<.8	0
Copper	1,000	<8 - 8	<8	0	<.8 - 10	<8	0
Iron	300	46.2 - 347	164	1	131 - 415	224	2
Lead	15	<2 - 16.4	2.6	1	<2 - 7.9	<2	0
Manganese	50	12.9 - 43.3	21.4	0	18.6 - 33.9	23.2	0
Mercury	2	all <.06	<.06	0	all <.06	<.06	0
Zinc	5,000	<4 - 24.8	10.1	0	6.1 - 16.7	11.1	0

occur in domestic and industrial waste waters, natural waters, and potable water supplies. They generally are traceable to industrial effluents or landfills (Eaton and others, 1995) and may be acutely and chronically toxic to freshwater aquatic life. Phenol was detected in several samples collected during the study period.

Table 19. Average concentrations of selected inorganic nonmetallic and organic constituents.

Constituent	Station TC-1		Station TC-3	
	Range (mg/L)	Average (mg/L)	Range (mg/L)	Average (mg/L)
Inorganic nonmetallic constituents				
Bromide	all <.05	<.05	All <.05	<.05
Cyanide	<.003 - .004	<.003	all <.003	<.003
Chloride	1.46 - 2.51	2.17	.87 - 2.36	1.98
Fluoride	<.02 - .04	.03	<.02 - .05	.03
Silica	4.26 - 9.04	7.12	5.18 - 11.4	8.85
Sulfate	2.42 - 4.88	3.11	2.62 - 4.85	3.59
Organic constituents				
Total phenolics	<3 - 6.0	<3	<3 - 4.9	<3
Total organic carbon	<.4 - 10.4	2.69	1.69 - 7.77	3.07

CONCLUSIONS AND RECOMMENDATIONS

The IBI protocol fits well into the overall framework of biomonitoring because of its integrative nature, broad regional applicability, and relative ease of calculation. The ability to analyze and assess water-quality degradation due to nonpoint sources is significantly enhanced by including biological parameters in the monitoring program because the causes and effects of nonpoint-source pollution can be difficult or impossible to detect and quantify with traditional physical and chemical analysis techniques. As the emphasis of water resource protection programs shifts to watersheds and nonpoint pollutant sources, biomonitoring should be incorporated more extensively as an assessment, monitoring, and regulatory tool.

Sampling protocols for the IBI vary relative to type of gear used and the sampling endpoints, but two considerations are important to all sampling techniques. The method should be efficient in time and resources devoted to collecting a sample, and the sample should be representative of fish community diversity and abundance patterns. The sampling method presented in this investigation fulfills both of these requirements and is constructed of accepted sampling techniques and gear types that are proven to yield data adequate for IBI calculations. Stratification of sampling effort into four habitat zones–riffles, runs, pools, and shorelines–has ecological meaning relative to the distribution and occurrence of fishes in streams and is a convenient accounting method for tracking sampling effort. The proposed “30+2" minimum sampling effort, with 10 efforts each in riffle, run, and pool habitats plus 2 shoreline efforts, was demonstrated to provide valid data for estimating an IBI and its individual components. With a standardized sampling protocol now in place, natural resource agencies should be better equipped to begin building a statewide fish IBI database.

The Coosa-Tallapoosa IBI presented in this study was built on the original 12-metric concept proposed by Karr (1981) with only slight modifications of either metric type and(or) scoring criteria to reflect regional differences of the fish communities. A few diversity metrics were poorly correlated with watershed area and a few others were poorly correlated with human disturbance, but we have retained them because they have been shown to be robust and important metrics in numerous IBI’s constructed to date. The metrics total native species, number of darter species, number of minnow species, and number of intolerant species were not related to disturbance while the remaining metrics showed discernable responses in relation to disturbance. Our attempt at relating IBI to disturbance can be rated as moderately successful. Much of the classification error of IBI's to the HDG in this investigation is likely related to our method of defining disturbance. Use of HDG calculations not specifically calculated for our sampling stations and the generalized nature of the measure may be sources of error contributing to the poor correlation.

Application of these general HDG values to our sites is likely resulting in disturbance values that either over or under represent the true level of human disturbance in a sampled stream reach. Localized habitat disturbance, such as clear cuts and poorly managed dirt roads, and their proximity to a sampling station can have significant influence on biological condition. Likewise, sampling sites upstream of nonpoint sources can have good or better biological condition while the downstream reaches may be substantially impaired. General HDG assessments over broad areas apparently do not capture these stressors adequately for application to a site-specific IBI. We would tend to error on the side of the IBI as a better reading of disturbance rather than counting solely on GIS-based landscape measures to describe disturbance. If this should hold true, then an important objective for future work becomes continuing research into those habitat and landscape disturbance measures that accurately predict biological response.

The newly formulated Coosa-Tallapoosa IBI is very similar in construction to the original Karr midwestern IBI and to the Black Warrior and Cahaba River IBI's developed by GSA. The substitution of a reproductive metric (proportion as non-lithophilic spawners) for a diversity metric (number of sunfish species) is an attempt to incorporate a measure that is perhaps more sensitive to stressors affecting the reproductive habitats and behaviors of species that are not obligately restricted to lithophilic substrates. Within the Coosa and Tallapoosa system this metric captures species with simple and manipulative spawning behaviors such as *Cyprinella, Pimephales, Noturus, Micropterus, Pomoxis*, and several *Etheostoma*. The net effect is a metric that measures abundance changes of “behaviorally complex” species when their habitats become degraded by disturbance. Whether this change will result in more IBI sensitivity can only be measured by the collection of new watershed assessment data.

Although contaminant concentrations in Terrapin Creek were above natural background levels at the sampling stations, water quality was similar to many other rural/agriculture watersheds in Alabama. Loading rates of nitrogen were substantially less than intensively farmed areas in south Alabama but were greater than streams draining forested areas in the Conecuh National Forest. Nutrient loads in the Terrapin Creek watershed should be reduced, however, to improve water-quality conditions throughout the system downstream of Piedmont and to improve water-quality conditions in the Dead River area. Although water samples were not collected in the upper watershed for this investigation, field observations and selected water-quality measurements made during the biological sampling indicate good conditions in the less disturbed reaches in the Talladega National Forest.

The Terrapin Creek system presents relatively unimpaired habitat and biological conditions in some parts of its watershed in the Talladega National Forest. Notably, the stations in this study with good biological condition ratings were in the forest. Also, the only sizable urban area is the town of Piedmont. Some degree of impairment was noted in a number of tributaries as well as the downstream section of the main channel. For example, the condition of the habitat and the biological community at Mountain Fork was degraded by erosion and sedimentation from a nearby forest clear cut. Another tributary, Frog Creek, was degraded by pasture and crop land adjacent to the stream. On the main stem, stations in the northern part of drainage downstream of Piedmont are degraded by sediment and nutrients from agricultural activities and perhaps nonpoint runoff originating in Piedmont.

The importance of the Terrapin Creek system to the restoration of the Dead River was emphasized by Irwin and others (2001). Terrapin Creek is currently supplying water to the Dead River, downstream of the Terrapin Creek mouth, of acceptable quality and sufficient quantity to support a rare mussel fauna remnant of the original Coosa River. It is extremely important that the Terrapin Creek watershed be protected and managed because of its directly contribution to the support and maintenance of this unique fauna during average to low stream flows. Increased nutrification or sedimentation of Terrapin Creek waters will likely lead to degraded water-quality conditions in the Dead River unless supplemental flows, derived from Weiss Lake, are diverted through the Dead River channel. Creation of a water-quality management plan for the watershed would be an important step in maintaining and improving the biological integrity of the system and assuring that high-quality water will continue to flow to the Dead River. A watershed protection plan addresses known and predicted water-quality issues (Alabama Soil and Water Conservation Committee (ASWCC), 1995) while water-quality management plans provide site-specific information for landowners and resource managers to install, operate and maintain best management practices (BMPs) for activities such as cattle production, agriculture, forestry, suburban development, and sediment control. Implementaiton of such plans could reduce sediment and nutrient loads in the Terrapin Creek system and improve habitat and biological conditions in impaired sections of the watershed. With these thoughts in mind, the following recommendations are offered relative to IBI development in Alabama and for the Terrapin Creek watershed:

- A basic premise of the IBI is that biological communities vary in response to landscape, drainage, and reach-specific factors. A better understanding of the relationship between fish communities and natural classification factors such as drainages, ecoregions, and physiography needs to be developed to guide future IBI calibration studies. This process should be coordinated with all agencies conducting fish biomonitoring in the state.

- Factors that predict and quantify the human disturbance gradient should be researched further to refine their predictability and relationship to biological condition. This is important because measuring human disturbance is one of the major goals of biological assessment.

- ♦ Once IBI regions have been delineated, they should be thoroughly sampled across the gradient of human disturbance and stream sizes, and IBI metrics should be calibrated to account for both the natural faunal variation and the type and intensity of disturbance within each IBI region.

- ♦ A watershed protection and management plan should be developed for the Terrapin Creek system to protect future uses and to assure continued supplies of good quality water to the Dead River. Local, state, and federal stakeholders should be involved and a strong educational component should be integrated with other efforts in the watershed. Faculty and staff at Jacksonville State University could provide excellent support for such a local watershed initiative in Terrapin Creek.

REFERENCES CITED

Alabama Department of Environmental Management (ADEM), 1999a, Standard operating procedures and quality control assurance manual, Volume II, Freshwater macroinvertebrate biological assessment: Alabama Department of Environmental Management, Field Operations Division, Ecological Studies Section, unpublished report.

Alabama Department of Environmental Management, 1999b, Surface water quality screening assessment of the Black Warrior River basin: unpublished report, 221 p.

Alabama Department of Environmental Management, 2002, Surface water quality screening assessment of the Coosa River basin-2000: Montgomery, Alabama, Field Operations Division, unpublished report, 304 p.

Alabama Department of Environmental Management, 2005, Water-quality criteria for surface waters classified Fish and Wildlife: ADEM administrative code, chapter 335-6-10, Water-quality criteria, available online at www.alabamaadministrativecode.state.al.us/docs/adem.

Alabama Soil and Water Conservation Committee, 1995, Protecting water quality on Alabama’s farms: Montgomery, Alabama, Alabama Soil and Water Conservation Committee, 124 p.

Alabama Water Improvement Advisory Commission, 1949, Studies of pollution in streams of Alabama: Montgomery, Alabama, Water Improvement Advisory Commission (currently known as the Alabama Department of Environmental Management), 298 p.

Alabama Water Improvement Commission, 1976, Water quality management plan, Coosa River Basin: Montgomery, Alabama, Water Improvement Advisory Commission (currently known as the Alabama Department of Environmental Management), p. 1- A-24.

Alabama Water Watch Program, 2002, Citizen guide to Alabama rivers: Alabama, Coosa, and Tallapoosa: Citizen guide to Alabama Rivers, Auburn University, v. 2, 16 p.

Angermeier, P.L., and Karr, J.R., 1986, Applying an index of biotic integrity based on stream fish communities: considerations in sampling and interpretation: North American Journal of Fisheries Management, v. 6, p. 418-429.

Angermeier, P.L., and Smoger, R., 1994, Estimating number of species and relative abundance in stream-fish communities: effects of sampling effort and discontinuous spatial distributions: Canadian Journal of Fisheries and Aquatic Science, v. 52, p. 936-949

Barbour, M.T., Gerritsen, J., Snyder, B.D., and Stribling, J.B., 1999, Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates, and fish, second edition: U.S. Environmental Protection Agency, Office of Water, Washington, D.C., EPA 841-B-99-002.

Boschung, H.T., and Mayden R.L., 2004, Fishes of Alabama: Smithsonian Books, 736 p.

Brown, M.T. and Vivas, M.B., 2003, A landscape development intensity index: Tallahassee, Florida, Florida Department of Environmental Protection, 21 p.

Carter, K. W., and Davidian, Jacob, 1968, General procedure for gaging streams: U.S. Geological Survey Techniques of Water Resources Investigations Book 3, Chapter A-6, 13 p.

Cohn, T. A., Caulder, D. L., Gilroy, E. J., Zynjuk, L. D., and Summers, R. M., 1992, The validity of a simple statistical model for estimating fluvial constituent loads: an empirical study involving nutrient loads entering Chesapeake Bay: Water Resources Research, v. 28, p. 2353-2363.

Cook, M.R., and O'Neil, P.E., 2000, Implementation assessment for water resource availability, protection, and utilization for the Choctawhatchee, Pea, and Yellow Rivers watersheds: Alabama Geological Survey contract report for the Choctawhatchee, Pea, Yellow Rivers Watershed Management Authority, 189 p.

Dauwalter, D.C., Pert, E.J., and Keith, W.E., 2003, An index of biotic integrity for fish assemblages in Ozark Highland streams of Arkansas: Southeastern Naturalist, v. 2, no. 3, p. 447-468.

Davenport, L.J., Howell, W.M., Morse, K.J., Yancie, K., and Wood, J.L., 2005, Fishes and macroinvertebrates of the upper Cahaba River: a three-year study: Journal of the Alabama Academy of Science, v. 76, no. 1, p. 1-44.

Eaton, A. D., Clesceri, L. S., and Greenberg, A. E., eds., 1995, Standard Methods for the Examination of Water and Wastewater, 19th edition: Washington, D. C., American Public Health Association, p. 9-53--9-72.

Etnier, D.A., and Starnes, W.C., 1993, The fishes of Tennessee: Knoxville, Tennessee, The University of Tennessee Press, 681 p.

Fore, L.S., 2004, Development and testing of biomonitoring tools for macroinvertebrates in Florida streams: Tallahassee, Florida, Florida Department of Environmental Protection, 70 p.

Fenneman, N.M., 1938, Physiography of the eastern United States: New York, McGraw-Hill Book Company, 714 p.

Georgia Department of Natural Resources, 2005, Part 1: Standard Operating Procedures for conducting biomonitoring on fish communities in wadeable streams in Georgia; Public Document, Georgia Department of Natural Resources.

Goldstein, R.M., and Simon, T.P., 1999, Toward a unified definition of guild structure for feeding ecology of North American freshwater fishes, *in* Simon, T.P., ed., Assessing the sustainability and biological integrity of water resources using fish communities: Boca Raton, Florida, CRC Press, p. 123-202.

Griffith, G.E., Omernik, J.M., Comstock, J.A., Lawrence, S., Martin, G., Goddard, A., Hulcher, V.J., and Foster, T., 2001, Ecoregions of Alabama and Georgia, (color poster with map, descriptive text, summary tables, and photographs): Reston, Virginia, U.S. Geological Survey (map scale 1:1,700,000).

Hayes, E. C., 1978, 7-day low flows and flow duration of Alabama streams: Geological Survey of Alabama Bulletin 113, 21 p.

Herod, J.J., Blalock-Herod, H.D., Ruessler, D.S., and Williams, J.D., 2001, Examination of the freshwater mussel (Bivalvia: Unionidae) community, including the federally endangered southern clubshell, *Pleurobema decisum*, within the old channel of the Coosa River, between Weiss Spillway Dam and Weiss Hydropower Dam, Cherokee County, Alabama: Unpublished report to Alabama Power Company, 54 p.

Hickman, G.H., and McDonough, 1996, Assessing the reservoir fish assembly index - a potential measure of reservoir quality, *in* DeVries, D., ed., Reservoir symposium - multidimensional approaches to reservoir fisheries management: Bethesda, Maryland, American Fisheries Society, Reservoir Committee, Southern Division, p. 85-97.

Hughes, R.M., and Oberdorff, Thierry, 1999, Applications of IBI concepts and metrics to waters outside the United States and Canada, *in* Simon, T.P., ed., Assessing the sustainability and biological integrity of water resources using fish communities: Boca Raton, Florida, CRC Press, p. 79-93.

Irwin, E.R., Freeman, M.C., Belcher, A., Kleiner, K., 2001, Survey of shallow water fish communities in the Dead River and Terrapin Creek: Unpublished report to Alabama Power Company, 23 p.

Karr, J.R., 1981, Assessment of biotic integrity using fish communities: Fisheries, v. 6, no. 6, p. 21-26.

Karr, J.P., and Chu, E.W., 1997, Biological monitoring and assessment using multimetric indexes effectively: Seattle, Washington, EPA 235-297-001.

___1999, Restoring life in running waters: better biological monitoring: Washington D.C., Island Press, 206 p.

Karr, J.R., and Dudley, D.R., 1981, Ecological perspective on water-quality goals: Environmental Management, v. 5, p. 55-68.

Karr, J.R., Fausch, K.D., Angermeier, P.L., Yant, P.R., and Schlosser, I.J., 1986, Assessing biological integrity in running waters, a method and its rationale: Urbana, Illinois, Illinois Natural History Survey Special Publication 5, 28 p.

Karr, J.R., Yant, P.R., Fausch, K.D., and Schlosser, I.J., 1987, Spatial and temporal variability of the index of biotic integrity in three midwestern streams: Transactions of the American Fisheries Society, v. 116, p. 1-11.

Kleinschmidt Associates, 2004, Draft adaptive management plan for the Coosa River-Weiss Bypass: Unpublished report to Alabama Power Company, 35 p.

Leonard, P.M., and Orth, D.J., 1986, Application and testing of an index of biotic integrity in small, coolwater streams: Transactions of the American Fisheries Society, v. 115, p. 401-415.

Lyons, J., Wang, L., and Simonson, T.D., 1996, Development and validation of an index of biotic integrity for coldwater streams in Wisconsin: North American Journal of Fisheries Management, v. 16, p. 241-256.

Maidment, D. R., ed., 1993, Handbook of hydrology: New York, McGraw-Hill Inc., p. 11.37-11.54.

Mays, L. W., ed., 1996, Water resources handbook: New York, McGraw-Hill, p. 8.3-8.49.

Massachusetts Department of Environmental Protection, 1995, Massachusetts DEP preliminary biological mointoring and assessment protocols for wadable rivers and streams: North Grafton, Massachusetts, Massachusetts Department of Environmental Protection.

Mettee, M.F., O’Neil, P.E., and Pierson, J.M., 1996, Fishes of Alabama and the Mobile basin: Oxmoor House, Birmingham, Alabama, 820 p.

Miller, D.L., Leonard, P.M., Hughes, R.M., Karr, J.R. Moyle, P.B., Schrader, L.H., Thompson, B.A., Daniels, R.A., Fausch, K.D., Fitzhugh, G.A., Gammon, J.R., Halliwell, D.B., Angermeier, P.L., and Orth, D.J., 1988, Regional applications of an index of biotic integrity for use in water resource management: Fisheries, v. 13, p. 12-20.

Mirarchi, R.E., ed., 2004, Alabama wildlife. Volume 1. A checklist of vertebrates and selected invertebrates: aquatic mollusks, fishes, amphibians, reptiles, birds, and mammals: Tuscaloosa, Alabama, The University of Alabama Press, 209 p.

Ohio EPA, 1987a, Biological criteria for the protection of aquatic life: volume II: users manual for biological field assessment of Ohio surface waters: State of Ohio Environmental Protection Agency, Division of Water Quality Planning and Assessment, Columbus, Ohio.

Ohio EPA, 1987b, Biological criteria for the protection of aquatic life: volume III: standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities: State of Ohio Environmental Protection Agency, Division of Water Quality Planning and Assessment, Columbus, Ohio.

O’Neil, P.E., and Chandler, R.V., 2005, Water quality and biological monitoring in the Choccolocco Creek watershed, Alabama, 1996-2001: Alabama Geological Survey Bulletin 177, 72 p.

O’Neil, P.E., and Shepard, T.E., 2000a, Water-quality assessment of the lower Cahaba River watershed, Alabama: Alabama Geological Survey Bulletin 167, 135 p.

__2000b, Application of the index of biotic integrity for assessing biological condition of wadeable streams in the Black Warrior River system, Alabama: Alabama Geological Survey Bulletin 169, 71 p.

__2004, Hatchet Creek regional reference watershed study: Alabama Geological Survey Open-File Report 0509, 48 p.

Paller, M.H., Reichert, M.J.M., and Dean, J.M., 1996, Use of fish communities to assess environmental impacts in South Carolina Coastal Plain streams: Transactions of the American Fisheries Society, v. 125, p. 633-644.

Petts, Geoff, and Foster, Ian, 1985, Rivers and landscapes: London, England, Edward Arnold (Publishers) Ltd., 274 p.

Plafkin, J.L., Barbour, M.T., Porter, K.D., Gross, S.K., and Hughes, R.M., 1989, Rapid bioassessment protocols for use in streams and rivers: benthic macroinvertebrates and fish: U.S. Environmental Protection Agency, Office of Water Regulations and Standards, Washington, D.C., EPA 440-4-89-001.

Rankin, E.T., 1989, The Qualitative Habitat Evaluation Index (QHEI); rationale, methods, and application: Columbus, Ohio, State of Ohio EPA, Ecological Assessment Section, Division of Water, 6 p.

Richards, R.P., 1999, Estiamtion of pollutant loads in rivers and streams: a guidance document for NPS programs: Heidelberg College.

Ross, S.T., 2001, The inland fishes of Mississippi: Jackson, Mississippi, Mississippi Department of Wildlife, Fisheries, and Parks, 624 p.

Sapp, C.D., and Emplaincourt, Jacques, 1975, Physiographic regions of Alabama: Alabama Geological Survey Special Map 168.

Saylor, C.F., and Ahlstedt, S.A., 1990, Application of Index of Biotic Integrity (IBI) to fixed station water quality monitoring sites: Norris, Tennessee, Tennessee Valley Authority, Aquatic Biology Department, unpublished report, 94 p.

Schleiger, S.L., 2000, Use of an index of biotic integrity to detect effects of land uses on stream fish communities in West-Central Georgia: Transactions of the American Fisheries Society, v. 129, p. 1118-1133.

Shepard, T.E., O'Neil, P.E., McGregor, S.W., and Henderson, W.P., Jr., 2002, Biomonitoring in the Mulberry Fork watershed, 1999-2002: Alabama Geological Survey unpublished section 6 contract report with the Alabama Department of Conservation of Natural Resources, Wildlife and Freshwater Fisheries Division, 65 p.

Shepard, T.E., O'Neil, P.E., McGregor, S.W., and Mettee, M.F., 2004, Biomonitoring in the Locust Fork watershed, Alabama, 1997-98: Alabama Geological Survey Bulletin 175, 61 p.

Shepard, T.E., O'Neil, P.E., McGregor, S.W., Mettee, M.F., and Harris, S.C.,1997, Biomonitoring and water-quality studies in the upper Cahaba River drainage of Alabama, 1989-94: Alabama Geological Survey Bulletin 165, 255 p.

Simon, T.P., 1999a, Assessment of Balon's reproductive guilds with application to midwestern North American freshwater fishes*, in* Simon, T.P., ed., Assessing the sustainability and biological integrity of water resources using fish communities: Boca Raton, Florida, CRC Press, p. 97-121.

__1999b, Introduction: Biological integrity and use of ecological health concepts for application to water resource characterizations, *in* Simon, T.P., ed., Assessing the sustainability and biological integrity of water resources using fish communities: Boca Raton, Florida, CRC Press, p. 3-16.

Simonson, T., and Lyons, J., 1995, Comparison of catch per effort and removal procedures for sampling stream fish assemblages: North American Journal of Fisheries Management, v. 15, p. 419-427.

Smogor, R.A., and Angermeier, P.L., 1999a, Relations between fish metrics and measures of anthropogenic disturbance in three IBI regions in Virginia, *in* Simon, T.P., ed., Assessing the sustainability and biological integrity of water resources using fish communities: Boca Raton, Florida, CRC Press, p. 585-610.

___1999b, Effects of drainage basin and anthropogenic disturbance on relations between stream size and IBI metrics in Virginia, *in* Simon, T.P., ed., Assessing the sustainability and biological integrity of water resources using fish communities: Boca Raton, Florida, CRC Press, p. 249-272.

Tchobanoglous, G., and Schroeder, E. D., 1985, Water quality: Reading, Massachusetts, Addison-Wesley Publishing, 768 p.

Teels, B.M., and Danielson, T.J., 2001, Using a regional index of biotic integrity (IBI) to characterize the condition of northern Virginia streams, with emphasis on the Occoquan watershed: a case study: Laurel Maryland, U.S. Department of Agriculture, Natural Resources Conservation Service, Wetland Science Center, Technical Note 190-13-1, 92 p.

U.S. Environmental Protection Agency, 1997, Revision to rapid bioassessment protocols for use in streams and rivers: periphyton benthic macroinvertebrates, and fish: Washington, D.C., U.S. Environmental Protection Agency, Office of Water, EPA 841-D-97-002.

___2000, Stressor identification guidance document: Washington D.C., U.S. EPA Office of Water, EPA-822-B-00-025.

___2002, National primary and secondary drinking water standards: USEPA World Wide Web site www.epa.gov/safewater.

___2005a, Use of biological information to better define designated aquatic life uses in state and tribal water quality standards: tiered aquatic life uses, DRAFT: Washington D.C., U.S. EPA Office of Water, EPA-822-R-05-001, August 2005, 188 p.

___2005b, Water and wastewater security product guide: Chemical sensor – Total organic carbon analyzer, http://www.epa.gov/safewater/watersecurity/guide/chemicalsensortotalorganiccarbonanalyzer.html, accessed April 1, 2005.

U.S. Geological Survey, 1998, Water quality in the Las Vegas Valley area and Carson and Truckee River Basins, Nevada and California, 1992-96: U.S. Geological Survey Circular 1170, URL http://water.usgs.gov/pubs/circ/circ1170/gloss.htm

Warren, M.L., Jr., Burr, B.M., Walsh, S.J., Bart, H.L., Jr., Cashner, R.C., Etnier, D.A., Freeman, B.J., Kuhajda, B.R., Mayden, R.L., Robison, H.W., Ross, S.T., and Starnes, W.C., 2000, Diversity, distribution, and conservation status of the native freshwater fishes of the southern United States: Fisheries, vol. 25, no. 10, p. 7-29.

Wetzel, R.G., 2001, Limnology: San Diego, California, Academic Press, 283 p.

Yoder, C.O., and Smith, M.A., 1999, Using fish assemblages in a state biological assessment and criteria program: essential concepts and considerations, *in* Simon, T.P., ed., Assessing the sustainability and biological integrity of water resources using fish communities: Boca Raton, Florida, CRC Press, p. 17-56.

Appendix A

Fish community sampling data

(station numbers referenced in table 2 and depicted in figure 1)

GSA no.	2500	2501	2653	2654	2655	2656
Date	18-Aug-05	19-Aug-05	27-Jul-05	27-Jul-05	28-Jul-05	26-Jul-05
Sample time (min)	90	90	95	85	105	125
Area sampled (sq ft)	5250	5500	5950	5950	7350	6050
Watershed area (sq mi)	35.6	156	172	20.5	18.7	18.3
River system	Coosa	Coosa	Coosa	Coosa	Coosa	Coosa
Ecoregion	67F	67F	67F	67F	67F	45D
Species						
Petromyzontidae						
Ichthyomyzon gagei	--	--	--	--	--	--
Lepisosteidae						
Lepisosteus oculatus	--	--	--	--	--	--
Lepisosteus osseus	--	--	1	--	--	--
Clupeidae						
Dorosoma cepedianum	52	--	--	--	--	--
Cyprinidae						
Campostoma oligolepis	333	151	110	14	1226	53
Cyprinella caerulea	--	--	--	--	--	--
Cyprinella callistia	4	--	29	18	--	68
Cyprinella gibbsi	--	--	--	--	--	--
Cyprinella lutrensis	--	--	--	--	--	--
Cyprinella trichroistia	67	--	47	47	1	98
Cyprinella venusta	7	33	5	1	122	--
Cyprinella hybrid	--	--	--	--	1	--
Cyprinus carpio	--	1	--	--	--	--
Hybopsis lineapunctata	--	--	--	--	--	--
Hybopsis winchelli	--	--	--	--	--	--
Luxilus chrysocephalus	40	26	26	16	142	6
Luxilus zonistius	--	--	--	--	--	--
Lythrurus bellus	--	--	--	--	--	--
Lythrurus lirus	--	--	--	--	--	9
Macrhybopsis aestivalis	--	--	--	--	--	--
Nocomis leptocephalus	--	--	--	--	--	--
Notropis ammophilus	--	--	--	--	--	--
Notropis asperifrons	--	--	--	--	--	22
Notropis atherinoides	--	--	--	--	--	--
Notropis baileyi	--	--	--	--	--	--
Notropis buccatus	--	--	--	--	--	--
Notropis chrosomus	--	--	--	--	--	1
Notropis stilbius	44	1	200	20	11	3
Notropis texanus	--	--	--	--	--	--
Notropis volucellus	--	--	--	--	--	--
Notropis xaenocephalus	--	--	--	--	--	18
Opsopoeodus emiliae	--	--	--	--	--	--
Phenacobius catostomus	--	5	7	15	6	13
Pimephales notatus	--	--	--	--	--	--
Pimephales vigilax	--	7	--	--	--	--
Rhinichthys atratulus	--	--	--	--	1	--
Semotilus atromaculatus	--	--	--	8	--	2

GSA no.	2500	2501	2653	2654	2655	2656
Date	18-Aug-05	19-Aug-05	27-Jul-05	27-Jul-05	28-Jul-05	26-Jul-05
Sample time (min)	90	90	95	85	105	125
Area sampled (sq ft)	5250	5500	5950	5950	7350	6050
Watershed area (sq mi)	35.6	156	172	20.5	18.7	18.3
River system	Coosa	Coosa	Coosa	Coosa	Coosa	Coosa
Ecoregion	67F	67F	67F	67F	67F	45D
Catostomidae						
Erimyzon oblongus	--	--	--	--	--	--
Hypentelium etowanum	96	31	31	50	26	13
Minytrema melanops	--	--	--	--	--	--
Moxostoma duquesnei	17	--	--	--	5	1
Moxostoma erythrurum	--	6	3	--	3	6
Moxostoma poecilurum	2	9	--	--	8	--
Ictaluridae						
Ameiurus natalis	1	2	--	1	16	1
Ictalurus punctatus	--	--	--	--	--	--
Noturus funebris	--	--	--	--	--	--
Noturus leptacanthus	--	--	--	--	--	1
Pylodictis olivaris	--	--	--	--	--	--
Esocidae						
Esox niger	--	--	--	--	--	--
Fundulidae						
Fundulus bifax	--	--	--	--	--	--
Fundulus olivaceus	--	--	--	--	--	--
Fundulus stellifer	--	--	6	--	--	2
Poecilidae						
Gambusia affinis	5	74	4	1	107	2
Centrarchidae						
Ambloplites ariommus	--	--	1	1	--	1
Lepomis auritus	19	17	23	24	6	23
Lepomis cyanellus	1	11	22	30	12	5
Lepomis gulosus	--	--	--	1	1	--
Lepomis macrochirus	22	57	19	30	21	18
Lepomis megalotis	14	1	15	20	16	32
Lepomis microlophus	--	2	--	--	--	--
Lepomis punctatus	--	--	4	2	1	--
Lepomis hybrids	--	--	--	3	--	--
Micropterus coosae	10	2	--	2	--	5
Micropterus punctulatus	--	--	1	1	--	--
Micropterus salmoides	--	1	--	1	10	--
Pomoxis annularis	--	--	--	--	--	--
Pomoxis nigromaculatus	--	--	--	--	--	--

GSA no.	2500	2501	2653	2654	2655	2656
Date	18-Aug-05	19-Aug-05	27-Jul-05	27-Jul-05	28-Jul-05	26-Jul-05
Sample time (min)	90	90	95	85	105	125
Area sampled (sq ft)	5250	5500	5950	5950	7350	6050
Watershed area (sq mi)	35.6	156	172	20.5	18.7	18.3
River system	Coosa	Coosa	Coosa	Coosa	Coosa	Coosa
Ecoregion	67F	67F	67F	67F	67F	45D
Percidae						
Etheostoma brevirostrum	--	--	--	--	--	--
Etheostoma chuckwachatte	--	--	--	--	--	--
Etheostoma coosae	5	--	1	12	--	7
Etheostoma ditrema	--	--	--	--	--	--
Etheostoma jordani	--	--	66	21	--	37
Etheostoma nigrum	--	--	--	--	--	--
Etheostoma parvipinne	--	--	--	--	--	--
Etheostoma rupestre	--	--	--	--	--	--
Etheostoma stigmaeum	4	--	7	13	20	2
Etheostoma swaini	--	--	--	--	--	--
Etheostoma tallapoosae	--	--	--	--	--	--
Etheostoma whipplei	--	--	--	--	--	--
Etheostoma zonifer	--	--	--	--	--	--
Percina kathae	--	--	--	--	--	2
Percina nigrofasciata	12	7	12	15	3	--
Percina palmaris	--	--	15	9	--	6
Percina shumardi	--	--	--	1	--	--
Percina sp.	--	--	--	--	--	--
Elassomatidae						
Elassoma zonatum	--	--	--	--	--	--
Sciaenidae						
Aplodinotus grunniens	--	--	--	--	--	--
Cottidae						
Cottus carolinae	174	170	64	10	2	76
Total specimens	929	614	719	387	1767	533
Total species	21	21	25	28	23	30
IBI	32	32	36	42	22	52

GSA no.	2657	2658	2659	2660	2663	2664
Date	26-Jul-05	27-Jul-05	28-Jul-05	19-Jul-05	20-Jul-05	20-Jul-05
Sample time (min)	115	100	75	110	85	95
Area sampled (sq ft)	5990	5850	5730	5000	5200	4560
Watershed area (sq mi)	2.78	283	94.4	29	26.2	57.9
River system	Coosa	Coosa	Coosa	Tallap.	Tallap.	Tallap.
Ecoregion	45D	67G	67F	45A	45A	45A
Species						
Petromyzontidae						
Ichthyomyzon gagei	--	--	--	--	--	--
Lepisosteidae						
Lepisosteus oculatus	--	2	--	--	--	--
Lepisosteus osseus	--	--	--	--	--	--
Clupeidae						
Dorosoma cepedianum	--	1	--	--	--	--
Cyprinidae						
Campostoma oligolepis	33	83	66	3	--	2
Cyprinella caerulea	--	--	7	--	--	--
Cyprinella callistia	52	20	12	1	15	23
Cyprinella gibbsi	--	--	--	93	92	167
Cyprinella lutrensis	--	11	--	--	--	--
Cyprinella trichroistia	173	2	8	--	--	--
Cyprinella venusta	--	18	4	--	--	1
Cyprinella hybrid	--	--	--	--	--	--
Cyprinus carpio	--	1	--	--	--	--
Hybopsis lineapunctata	--	--	--	3	--	1
Hybopsis winchelli	--	--	--	--	--	--
Luxilus chrysocephalus	13	2	--	18	7	18
Luxilus zonistius	--	--	--	--	--	--
Lythrurus bellus	--	--	--	--	--	6
Lythrurus lirus	--	--	--	--	--	--
Macrhybopsis aestivalis	--	--	--	--	--	2
Nocomis leptocephalus	--	--	--	6	2	--
Notropis ammophilus	--	--	--	--	--	--
Notropis asperifrons	8	--	--	--	--	--
Notropis atherinoides	--	--	--	--	--	--
Notropis baileyi	--	--	--	126	--	2
Notropis buccatus	--	--	--	--	--	--
Notropis chrosomus	183	--	--	--	--	--
Notropis stilbius	--	11	8	1	1	3
Notropis texanus	--	--	--	--	--	--
Notropis volucellus	--	--	--	--	--	--
Notropis xaenocephalus	161	--	--	--	--	--
Opsopoeodus emiliae	--	--	--	--	--	--
Phenacobius catostomus	--	48	6	--	--	1
Pimephales notatus	--	--	--	--	--	--
Pimephales vigilax	--	--	--	--	--	--
Rhinichthys atratulus	1	--	--	--	--	--
Semotilus atromaculatus	30	--	--	--	--	--

GSA no.	2657	2658	2659	2660	2663	2664
Date	26-Jul-05	27-Jul-05	28-Jul-05	19-Jul-05	20-Jul-05	20-Jul-05
Sample time (min)	115	100	75	110	85	95
Area sampled (sq ft)	5990	5850	5730	5000	5200	4560
Watershed area (sq mi)	2.78	283	94.4	29	26.2	57.9
River system	Coosa	Coosa	Coosa	Tallap.	Tallap.	Tallap.
Ecoregion	45D	67G	67F	45A	45A	45A
Catostomidae						
Erimyzon oblongus	--	--	--	--	--	--
Hypentelium etowanum	26	10	27	1	10	8
Minytrema melanops	--	1	--	--	--	--
Moxostoma duquesnei	2	1	1	--	--	--
Moxostoma erythrurum	3	--	17	--	--	--
Moxostoma poecilurum	--	--	1	--	--	--
Ictaluridae						
Ameiurus natalis	--	--	--	--	--	--
Ictalurus punctatus	--	2	1	--	--	--
Noturus funebris	--	--	--	--	14	--
Noturus leptacanthus	1	--	--	2	--	--
Pylodictis olivaris	--	2	--	--	--	--
Esocidae						
Esox niger	--	--	--	--	--	--
Fundulidae						
Fundulus bifax	--	--	--	2	--	3
Fundulus olivaceus	--	6	--	--	--	3
Fundulus stellifer	7	--	1	--	--	--
Poecilidae						
Gambusia affinis	--	2	2	--	--	--
Centrarchidae						
Ambloplites ariommus	--	--	--	--	--	--
Lepomis auritus	15	19	1	2	27	5
Lepomis cyanellus	1	11	10	1	9	1
Lepomis gulosus	--	1	1	--	--	--
Lepomis macrochirus	3	19	14	1	7	2
Lepomis megalotis	5	27	17	--	--	--
Lepomis microlophus	--	--	2	--	--	--
Lepomis punctatus	--	--	--	--	--	--
Lepomis hybrids	--	--	--	--	--	--
Micropterus coosae	24	--	--	3	2	--
Micropterus punctulatus	--	3	4	--	--	1
Micropterus salmoides	--	--	1	--	--	--
Pomoxis annularis	--	--	--	--	--	--
Pomoxis nigromaculatus	--	--	--	--	--	--

GSA no.	2657	2658	2659	2660	2663	2664
Date	26-Jul-05	27-Jul-05	28-Jul-05	19-Jul-05	20-Jul-05	20-Jul-05
Sample time (min)	115	100	75	110	85	95
Area sampled (sq ft)	5990	5850	5730	5000	5200	4560
Watershed area (sq mi)	2.78	283	94.4	29	26.2	57.9
River system	Coosa	Coosa	Coosa	Tallap.	Tallap.	Tallap.
Ecoregion	45D	67G	67F	45A	45A	45A
Percidae						
Etheostoma brevirostrum	--	--	--	--	--	--
Etheostoma chuckwachatte	--	--	--	--	23	16
Etheostoma coosae	38	--	--	--	--	--
Etheostoma ditrema	--	--	--	--	--	--
Etheostoma jordani	--	8	10	--	--	--
Etheostoma nigrum	--	--	--	--	--	--
Etheostoma parvipinne	--	--	--	--	--	--
Etheostoma rupestre	--	--	--	--	--	--
Etheostoma stigmaeum	--	1	8	--	2	1
Etheostoma swaini	--	--	--	--	--	--
Etheostoma tallapoosae	--	--	--	1	5	1
Etheostoma whipplei	--	--	--	--	--	--
Etheostoma zonifer	--	--	--	--	--	--
Percina kathae	8	1	--	--	--	--
Percina nigrofasciata	1	6	12	--	--	--
Percina palmaris	--	9	--	2	10	2
Percina shumardi	--	--	--	--	--	--
Percina sp.	--	--	--	4	10	2
Elassomatidae						
Elassoma zonatum	--	--	--	--	--	--
Sciaenidae						
Aplodinotus grunniens	--	1	--	--	--	--
Cottidae						
Cottus carolinae	51	11	37	12	1	--
Total specimens	840	340	278	282	237	271
Total species	24	31	26	19	17	23
IBI	48	42	40	40	38	42

GSA no.	2667	2668	2669	2670	2693	2698
Date	4-Aug-05	4-Aug-04	4-Aug-05	5-Aug-05	21-Jul-05	18-Aug-05
Sample time (min)	90	75	70	95	70	115
Area sampled (sq ft)	4320	4220	4610	4080	6050	6200
Watershed area (sq mi)	52.7	19.9	20.5	109	16.7	199
River system	Tallap.	Tallap.	Tallap.	Coosa	Coosa	Coosa
Ecoregion	65I	45A	45A	67F	45A	68D
Species						
Petromyzontidae						
Ichthyomyzon gagei	--	--	--	--	--	--
Lepisosteidae						
Lepisosteus oculatus	--	--	--	--	--	--
Lepisosteus osseus	--	--	--	--	--	--
Clupeidae						
Dorosoma cepedianum	--	--	--	--	--	--
Cyprinidae						
Campostoma oligolepis	68	54	25	175	30	88
Cyprinella caerulea	--	--	--	--	--	23
Cyprinella callistia	--	79	--	6	34	32
Cyprinella gibbsi	--	130	9	--	--	--
Cyprinella lutrensis	--	--	--	--	--	--
Cyprinella trichroistia	--	--	--	3	209	1
Cyprinella venusta	34	3	--	--	1	--
Cyprinella hybrid	--	--	--	--	--	--
Cyprinus carpio	--	--	--	--	--	--
Hybopsis lineapunctata	--	11	3	--	--	--
Hybopsis winchelli	--	--	--	--	11	--
Luxilus chrysocephalus	--	1	2	1	--	--
Luxilus zonistius	--	44	--	--	--	--
Lythrurus bellus	25	--	1	--	--	--
Lythrurus lirus	--	--	--	--	--	--
Macrhybopsis aestivalis	--	--	--	--	--	--
Nocomis leptocephalus	--	5	2	--	--	--
Notropis ammophilus	--	--	--	--	--	--
Notropis asperifrons	--	1	--	--	--	--
Notropis atherinoides	--	--	--	--	--	--
Notropis baileyi	--	--	--	--	--	--
Notropis buccatus	--	--	--	--	--	--
Notropis chrosomus	--	--	--	--	3	--
Notropis stilbius	--	--	--	16	1	154
Notropis texanus	--	--	--	--	--	--
Notropis volucellus	46	--	--	--	--	--
Notropis xaenocephalus	--	--	--	2	--	7
Opsopoeodus emiliae	--	--	--	--	--	--
Phenacobius catostomus	--	--	--	17	--	--
Pimephales notatus	--	--	--	--	--	--
Pimephales vigilax	--	--	3	--	--	--
Rhinichthys atratulus	--	--	--	--	--	--
Semotilus atromaculatus	--	--	--	--	1	--

GSA no.	2667	2668	2669	2670	2693	2698
Date	4-Aug-05	4-Aug-04	4-Aug-05	5-Aug-05	21-Jul-05	18-Aug-05
Sample time (min)	90	75	70	95	70	115
Area sampled (sq ft)	4320	4220	4610	4080	6050	6200
Watershed area (sq mi)	52.7	19.9	20.5	109	16.7	199
River system	Tallap.	Tallap.	Tallap.	Coosa	Coosa	Coosa
Ecoregion	65I	45A	45A	67F	45A	68D
Catostomidae						
Erimyzon oblongus	--	--	--	--	--	--
Hypentelium etowanum	10	13	9	13	17	--
Minytrema melanops	--	--	--	--	--	--
Moxostoma duquesnei	--	--	--	--	6	2
Moxostoma erythrurum	4	--	--	--	--	7
Moxostoma poecilurum	10	--	8	--	--	2
Ictaluridae						
Ameiurus natalis	4	--	--	--	1	--
Ictalurus punctatus	1	--	--	--	1	--
Noturus funebris	--	5	2	--	--	--
Noturus leptacanthus	15	--	--	--	8	5
Pylodictis olivaris	--	--	--	--	--	--
Esocidae						
Esox niger	--	--	--	--	--	--
Fundulidae						
Fundulus bifax	--	--	--	--	--	--
Fundulus olivaceus	1	--	1	1	2	--
Fundulus stellifer	--	--	--	1	--	4
Poecilidae						
Gambusia affinis	--	--	--	13	--	--
Centrarchidae						
Ambloplites ariommus	2	--	--	--	--	--
Lepomis auritus	--	1	27	8	3	16
Lepomis cyanellus	2	5	3	5	3	12
Lepomis gulosus	1	--	4	--	--	--
Lepomis macrochirus	28	3	25	6	10	34
Lepomis megalotis	46	--	1	14	16	1
Lepomis microlophus	--	--	--	--	--	--
Lepomis punctatus	1	--	--	2	--	--
Lepomis hybrids	--	--	--	--	--	--
Micropterus coosae	--	5	1	4	4	4
Micropterus punctulatus	5	--	--	--	--	17
Micropterus salmoides	--	--	1	1	3	2
Pomoxis annularis	--	--	--	--	--	--
Pomoxis nigromaculatus	--	--	--	--	--	--

GSA no.	2667	2668	2669	2670	2693	2698
Date	4-Aug-05	4-Aug-04	4-Aug-05	5-Aug-05	21-Jul-05	18-Aug-05
Sample time (min)	90	75	70	95	70	115
Area sampled (sq ft)	4320	4220	4610	4080	6050	6200
Watershed area (sq mi)	52.7	19.9	20.5	109	16.7	199
River system	Tallap.	Tallap.	Tallap.	Coosa	Coosa	Coosa
Ecoregion	65I	45A	45A	67F	45A	68D
Percidae						
Etheostoma brevirostrum	--	--	--	--	--	--
Etheostoma chuckwachatte	--	--	--	--	--	--
Etheostoma coosae	--	--	--	5	5	--
Etheostoma ditrema	--	--	--	--	--	--
Etheostoma jordani	--	--	--	170	33	56
Etheostoma nigrum	--	--	--	--	--	--
Etheostoma parvipinne	--	--	--	--	--	--
Etheostoma rupestre	18	--	--	--	--	--
Etheostoma stigmaeum	6	4	2	16	9	4
Etheostoma swaini	--	--	--	--	--	--
Etheostoma tallapoosae	--	6	17	--	--	--
Etheostoma whipplei	--	--	--	--	--	--
Etheostoma zonifer	--	--	--	--	--	--
Percina kathae	--	3	10	--	5	25
Percina nigrofasciata	51	3	--	7	12	2
Percina palmaris	--	12	1	30	2	44
Percina shumardi	--	--	--	--	--	--
Percina sp.	--	7	8	--	--	--
Elassomatidae						
Elassoma zonatum	--	--	--	--	--	--
Sciaenidae						
Aplodinotus grunniens	--	--	--	--	2	1
Cottidae						
Cottus carolinae	17	46	36	181	--	--
Total specimens	395	441	201	697	432	543
Total species	22	22	24	24	27	24
IBI	38	50	40	34	54	38

GSA no.	2699	2736	2737	2738	2739	2744
Date	18-Aug-05	5-Oct-04	6-Oct-04	6-Oct-04	5-Oct-04	30-Aug-04
Sample time (min)	65	133	102	85	102	97
Area sampled (sq ft)	5250	3940	3900	3990	4060	4711
Watershed area (sq mi)	202	238	125	59.2	46	18.3
River system	Coosa	Coosa	Coosa	Coosa	Coosa	Coosa
Ecoregion	68D	45A	45A	45A	45A	45D
Species						
Petromyzontidae						
Ichthyomyzon gagei	--	--	--	1	--	--
Lepisosteidae						
Lepisosteus oculatus	--	--	--	--	--	--
Lepisosteus osseus	--	1	--	--	--	--
Clupeidae						
Dorosoma cepedianum	--	--	--	--	--	--
Cyprinidae						
Campostoma oligolepis	37	5	2	11	34	131
Cyprinella caerulea	8	--	--	--	--	--
Cyprinella callistia	32	285	73	28	168	60
Cyprinella gibbsi	--	--	--	--	--	--
Cyprinella lutrensis	--	--	--	--	--	--
Cyprinella trichroistia	15	59	137	149	69	87
Cyprinella venusta	--	--	1	--	--	--
Cyprinella hybrid	--	--	--	--	--	--
Cyprinus carpio	--	--	--	--	--	--
Hybopsis lineapunctata	--	--	--	--	--	--
Hybopsis winchelli	--	--	--	1	--	--
Luxilus chrysocephalus	--	--	--	--	--	--
Luxilus zonistius	--	--	--	--	--	--
Lythrurus bellus	--	--	--	--	--	--
Lythrurus lirus	--	--	--	--	--	3
Macrhybopsis aestivalis	--	--	--	--	--	--
Nocomis leptocephalus	--	5	19	--	--	--
Notropis ammophilus	--	--	--	--	--	--
Notropis asperifrons	--	--	2	26	--	32
Notropis atherinoides	--	--	--	--	--	--
Notropis baileyi	--	--	--	--	--	--
Notropis buccatus	--	--	--	--	--	--
Notropis chrosomus	--	--	--	--	--	4
Notropis stilbius	10	26	11	21	14	9
Notropis texanus	--	--	--	--	--	--
Notropis volucellus	--	9	--	--	--	--
Notropis xaenocephalus	2	--	6	4	--	34
Opsopoeodus emiliae	--	--	--	--	--	--
Phenacobius catostomus	--	--	--	--	--	8
Pimephales notatus	--	--	--	--	--	--
Pimephales vigilax	--	--	--	--	--	--
Rhinichthys atratulus	--	--	--	--	--	--
Semotilus atromaculatus	--	--	--	1	--	--

GSA no.	2699	2736	2737	2738	2739	2744
Date	18-Aug-05	5-Oct-04	6-Oct-04	6-Oct-04	5-Oct-04	30-Aug-04
Sample time (min)	65	133	102	85	102	97
Area sampled (sq ft)	5250	3940	3900	3990	4060	4711
Watershed area (sq mi)	202	238	125	59.2	46	18.3
River system	Coosa	Coosa	Coosa	Coosa	Coosa	Coosa
Ecoregion	68D	45A	45A	45A	45A	45D
Catostomidae						
Erimyzon oblongus	--	--	--	--	--	--
Hypentelium etowanum	1	5	8	37	34	15
Minytrema melanops	--	--	--	2	1	--
Moxostoma duquesnei	2	3	1	--	1	--
Moxostoma erythrurum	--	--	--	31	14	7
Moxostoma poecilurum	--	2	--	--	6	--
Ictaluridae						
Ameiurus natalis	--	--	--	--	--	1
Ictalurus punctatus	--	4	--	--	--	--
Noturus funebris	--	--	--	--	--	--
Noturus leptacanthus	26	33	23	4	7	3
Pylodictis olivaris	--	2	--	--	--	--
Esocidae						
Esox niger	--	--	--	--	--	--
Fundulidae						
Fundulus bifax	--	--	--	--	--	--
Fundulus olivaceus	--	--	--	--	--	--
Fundulus stellifer	3	3	--	--	--	3
Poecilidae						
Gambusia affinis	--	1	--	6	--	--
Centrarchidae						
Ambloplites ariommus	--	10	3	--	2	--
Lepomis auritus	20	--	--	--	--	17
Lepomis cyanellus	2	--	--	1	2	3
Lepomis gulosus	--	--	--	--	--	--
Lepomis macrochirus	11	3	1	3	--	9
Lepomis megalotis	--	15	21	43	21	27
Lepomis microlophus	--	--	--	--	--	--
Lepomis punctatus	--	--	--	--	--	--
Lepomis hybrids	--	--	--	--	--	2
Micropterus coosae	--	3	2	3	2	18
Micropterus punctulatus	8	1	1	--	1	--
Micropterus salmoides	--	--	--	1	--	--
Pomoxis annularis	--	--	--	--	--	--
Pomoxis nigromaculatus	--	--	--	--	--	--

GSA no.	2699	2736	2737	2738	2739	2744
Date	18-Aug-05	5-Oct-04	6-Oct-04	6-Oct-04	5-Oct-04	30-Aug-04
Sample time (min)	65	133	102	85	102	97
Area sampled (sq ft)	5250	3940	3900	3990	4060	4711
Watershed area (sq mi)	202	238	125	59.2	46	18.3
River system	Coosa	Coosa	Coosa	Coosa	Coosa	Coosa
Ecoregion	68D	45A	45A	45A	45A	45D
Percidae						
Etheostoma brevirostrum	--	--	4	--	--	--
Etheostoma chuckwachatte	--	--	--	--	--	--
Etheostoma coosae	--	--	--	13	--	8
Etheostoma ditrema	--	--	--	--	--	--
Etheostoma jordani	51	55	161	37	44	58
Etheostoma nigrum	--	--	--	--	--	--
Etheostoma parvipinne	--	--	--	--	--	--
Etheostoma rupestre	--	2	--	1	--	--
Etheostoma stigmaeum	--	3	6	29	--	6
Etheostoma swaini	--	--	--	--	--	--
Etheostoma tallapoosae	--	--	--	--	--	--
Etheostoma whipplei	--	--	--	--	2	--
Etheostoma zonifer	--	--	--	--	--	--
Percina kathae	5	1	--	1	3	8
Percina nigrofasciata	8	13	10	6	15	1
Percina palmaris	26	91	30	11	41	6
Percina shumardi	--	--	--	--	--	--
Percina sp.	--	--	--	--	--	--
Elassomatidae						
Elassoma zonatum	--	--	--	--	--	--
Sciaenidae						
Aplodinotus grunniens	--	--	--	--	--	--
Cottidae						
Cottus carolinae	9	1	1	6	--	102
Total specimens	276	641	523	477	481	662
Total species	19	27	22	27	20	26
IBI	40	50	48	48	50	48

GSA no.	2745	2746	2747	2748	2749	2750
Date	30-Aug-04	31-Aug-04	31-Aug-04	9-Sep-04	9-Sep-04	10-Sep-04
Sample time (min)	61	102	106	115	82	99
Area sampled (sq ft)	2544	5690	4480	4000	3760	3560
Watershed area (sq mi)	2.78	283	172	35	30.3	46.6
River system	Coosa	Coosa	Coosa	Coosa	Coosa	Coosa
Ecoregion	45D	67G	67F	45A	45A	45A
Species						
Petromyzontidae						
Ichthyomyzon gagei	--	--	--	--	--	--
Lepisosteidae						
Lepisosteus oculatus	--	--	--	--	--	--
Lepisosteus osseus	--	--	--	--	--	--
Clupeidae						
Dorosoma cepedianum	--	3	--	--	--	--
Cyprinidae						
Campostoma oligolepis	53	681	634	174	30	86
Cyprinella caerulea	--	--	--	--	--	--
Cyprinella callistia	19	35	58	69	--	21
Cyprinella gibbsi	--	--	--	--	--	--
Cyprinella lutrensis	--	8	--	--	--	--
Cyprinella trichroistia	90	7	52	--	--	--
Cyprinella venusta	--	17	5	14	6	1
Cyprinella hybrid	--	--	--	--	--	--
Cyprinus carpio	--	1	--	--	--	--
Hybopsis lineapunctata	--	--	--	--	--	--
Hybopsis winchelli	--	--	--	--	--	--
Luxilus chrysocephalus	2	--	116	4	12	4
Luxilus zonistius	--	--	--	--	--	--
Lythrurus bellus	--	--	--	--	--	--
Lythrurus lirus	--	--	--	--	1	--
Macrhybopsis aestivalis	--	--	--	--	--	--
Nocomis leptocephalus	--	--	--	--	--	--
Notropis ammophilus	--	--	--	--	--	--
Notropis asperifrons	6	--	--	--	25	--
Notropis atherinoides	--	--	--	--	--	--
Notropis baileyi	--	--	--	--	--	--
Notropis buccatus	--	--	--	--	--	--
Notropis chrosomus	30	--	--	--	--	--
Notropis stilbius	--	8	201	21	49	8
Notropis texanus	--	--	--	--	--	--
Notropis volucellus	--	--	--	--	--	--
Notropis xaenocephalus	64	--	1	113	12	1
Opsopoeodus emiliae	--	--	--	--	--	--
Phenacobius catostomus	--	7	17	--	--	--
Pimephales notatus	--	--	--	--	--	--
Pimephales vigilax	--	1	--	--	--	--
Rhinichthys atratulus	--	--	--	--	--	--
Semotilus atromaculatus	7	--	--	--	--	13

GSA no.	2745	2746	2747	2748	2749	2750
Date	30-Aug-04	31-Aug-04	31-Aug-04	9-Sep-04	9-Sep-04	10-Sep-04
Sample time (min)	61	102	106	115	82	99
Area sampled (sq ft)	2544	5690	4480	4000	3760	3560
Watershed area (sq mi)	2.78	283	172	35	30.3	46.6
River system	Coosa	Coosa	Coosa	Coosa	Coosa	Coosa
Ecoregion	45D	67G	67F	45A	45A	45A
Catostomidae						
Erimyzon oblongus	--	--	--	--	--	--
Hypentelium etowanum	25	72	78	94	19	8
Minytrema melanops	--	--	--	1	--	--
Moxostoma duquesnei	--	--	--	5	--	--
Moxostoma erythrurum	--	2	5	3	1	--
Moxostoma poecilurum	--	2	4	--	--	--
Ictaluridae						
Ameiurus natalis	--	--	--	1	--	3
Ictalurus punctatus	--	3	--	--	--	--
Noturus funebris	--	--	--	--	--	--
Noturus leptacanthus	5	--	1	--	19	3
Pylodictis olivaris	--	1	--	--	--	--
Esocidae						
Esox niger	--	--	--	--	--	--
Fundulidae						
Fundulus bifax	--	--	--	--	--	--
Fundulus olivaceus	--	4	--	9	19	4
Fundulus stellifer	3	--	14	--	10	1
Poecilidae						
Gambusia affinis	--	3	2	1	14	6
Centrarchidae						
Ambloplites ariommus	--	1	1	--	--	--
Lepomis auritus	5	8	3	28	3	3
Lepomis cyanellus	--	5	13	4	18	--
Lepomis gulosus	--	--	--	--	--	--
Lepomis macrochirus	1	29	10	1	21	10
Lepomis megalotis	2	5	13	8	52	48
Lepomis microlophus	--	--	--	--	--	--
Lepomis punctatus	--	3	1	--	--	--
Lepomis hybrids	--	--	--	--	1	--
Micropterus coosae	9	2	2	15	1	9
Micropterus punctulatus	--	5	5	--	--	--
Micropterus salmoides	--	1	--	1	1	--
Pomoxis annularis	--	--	--	--	1	--
Pomoxis nigromaculatus	--	--	--	--	--	--

GSA no.	2745	2746	2747	2748	2749	2750
Date	30-Aug-04	31-Aug-04	31-Aug-04	9-Sep-04	9-Sep-04	10-Sep-04
Sample time (min)	61	102	106	115	82	99
Area sampled (sq ft)	2544	5690	4480	4000	3760	3560
Watershed area (sq mi)	2.78	283	172	35	30.3	46.6
River system	Coosa	Coosa	Coosa	Coosa	Coosa	Coosa
Ecoregion	45D	67G	67F	45A	45A	45A
Percidae						
Etheostoma brevirostrum	--	--	--	--	--	--
Etheostoma chuckwachatte	--	--	--	--	--	--
Etheostoma coosae	23	--	1	19	22	29
Etheostoma ditrema	--	--	--	--	5	--
Etheostoma jordani	--	22	63	--	29	44
Etheostoma nigrum	--	--	--	--	--	--
Etheostoma parvipinne	--	--	--	--	--	--
Etheostoma rupestre	--	--	--	--	--	--
Etheostoma stigmaeum	2	17	21	--	20	9
Etheostoma swaini	--	--	--	--	--	--
Etheostoma tallapoosae	--	--	--	--	--	--
Etheostoma whipplei	--	--	--	--	3	8
Etheostoma zonifer	--	--	--	--	--	--
Percina kathae	3	3	1	--	--	3
Percina nigrofasciata	--	26	17	46	7	11
Percina palmaris	--	10	32	4	--	--
Percina shumardi	--	--	--	--	--	--
Percina sp.	--	--	--	--	--	--
Elassomatidae						
Elassoma zonatum	--	--	--	--	--	--
Sciaenidae						
Aplodinotus grunniens	--	4	--	--	--	--
Cottidae						
Cottus carolinae	56	18	106	--	--	--
Total specimens	405	1014	1477	635	401	333
Total species	19	33	29	22	26	23
IBI	46	34	34	44	44	40

GSA no.	2751	2752	2753	2754	2755	2897
Date	10-Sep-04	29-Sep-04	29-Sep-04	30-Sep-04	30-Sep-04	30-Sep-04
Sample time (min)	71	92	89	112	71	82
Area sampled (sq ft)	3755	4040	3920	3810	5200	4736
Watershed area (sq mi)	77.9	37.3	22.3	21.5	21.0	85.8
River system	Coosa	Coosa	Coosa	Coosa	Coosa	Coosa
Ecoregion	45A	67F	67F	67G	67F	67H
Species						
Petromyzontidae						
Ichthyomyzon gagei	--	--	--	--	--	--
Lepisosteidae						
Lepisosteus oculatus	--	--	--	--	--	--
Lepisosteus osseus	1	--	--	--	--	--
Clupeidae						
Dorosoma cepedianum	--	--	--	--	--	--
Cyprinidae						
Campostoma oligolepis	232	81	32	15	14	39
Cyprinella caerulea	--	--	--	--	--	--
Cyprinella callistia	136	22	3	--	17	60
Cyprinella gibbsi	--	--	--	--	--	--
Cyprinella lutrensis	--	--	--	--	--	--
Cyprinella trichroistia	--	58	52	109	74	1
Cyprinella venusta	4	--	--	1	3	6
Cyprinella hybrid	--	--	--	--	--	--
Cyprinus carpio	--	--	--	--	--	--
Hybopsis lineapunctata	--	--	--	--	--	--
Hybopsis winchelli	--	--	--	--	--	9
Luxilus chrysocephalus	1	--	--	29	3	--
Luxilus zonistius	--	--	--	--	--	--
Lythrurus bellus	--	--	--	--	--	--
Lythrurus lirus	--	--	--	2	1	--
Macrhybopsis aestivalis	--	--	--	--	--	--
Nocomis leptocephalus	--	--	--	--	--	--
Notropis ammophilus	--	--	--	--	--	--
Notropis asperifrons	--	--	--	--	--	--
Notropis atherinoides	--	--	--	--	--	--
Notropis baileyi	--	--	--	--	--	--
Notropis buccatus	--	--	--	--	--	--
Notropis chrosomus	--	--	--	29	--	--
Notropis stilbius	63	1	--	1	71	30
Notropis texanus	--	--	--	--	--	--
Notropis volucellus	--	--	--	--	--	--
Notropis xaenocephalus	2	21	20	10	8	--
Opsopoeodus emiliae	--	--	--	--	--	--
Phenacobius catostomus	--	2	4	6	17	--
Pimephales notatus	--	--	--	--	--	--
Pimephales vigilax	--	--	--	--	--	--
Rhinichthys atratulus	--	--	--	1	--	--
Semotilus atromaculatus	--	--	--	12	3	--

GSA no.	2751	2752	2753	2754	2755	2897
Date	10-Sep-04	29-Sep-04	29-Sep-04	30-Sep-04	30-Sep-04	30-Sep-04
Sample time (min)	71	92	89	112	71	82
Area sampled (sq ft)	3755	4040	3920	3810	5200	4736
Watershed area (sq mi)	77.9	37.3	22.3	21.5	21.0	85.8
River system	Coosa	Coosa	Coosa	Coosa	Coosa	Coosa
Ecoregion	45A	67F	67F	67G	67F	67H
Catostomidae						
Erimyzon oblongus	1	--	--	--	--	--
Hypentelium etowanum	33	19	14	13	33	9
Minytrema melanops	--	--	1	--	--	--
Moxostoma duquesnei	1	--	--	3	3	--
Moxostoma erythrurum	--	3	--	--	--	--
Moxostoma poecilurum	5	--	--	--	--	--
Ictaluridae						
Ameiurus natalis	1	--	--	--	--	--
Ictalurus punctatus	1	--	--	--	--	3
Noturus funebris	--	--	--	--	--	--
Noturus leptacanthus	23	4	--	1	--	11
Pylodictis olivaris	1	--	--	--	--	--
Esocidae						
Esox niger	--	--	--	--	--	--
Fundulidae						
Fundulus bifax	--	--	--	--	--	--
Fundulus olivaceus	13	--	1	--	--	4
Fundulus stellifer	--	3	--	--	--	--
Poecilidae						
Gambusia affinis	--	5	--	7	--	1
Centrarchidae						
Ambloplites ariommus	13	--	--	1	--	--
Lepomis auritus	9	9	9	22	25	9
Lepomis cyanellus	--	7	3	4	20	--
Lepomis gulosus	--	--	--	--	1	--
Lepomis macrochirus	4	4	9	6	5	25
Lepomis megalotis	12	6	18	29	22	4
Lepomis microlophus	--	--	3	--	1	--
Lepomis punctatus	--	--	3	--	1	--
Lepomis hybrids	--	--	--	--	--	--
Micropterus coosae	3	6	6	2	--	--
Micropterus punctulatus	3	--	--	--	--	4
Micropterus salmoides	3	--	--	1	2	--
Pomoxis annularis	--	--	--	--	--	--
Pomoxis nigromaculatus	--	--	--	--	--	--

GSA no.	2751	2752	2753	2754	2755	2897
Date	10-Sep-04	29-Sep-04	29-Sep-04	30-Sep-04	30-Sep-04	30-Sep-04
Sample time (min)	71	92	89	112	71	82
Area sampled (sq ft)	3755	4040	3920	3810	5200	4736
Watershed area (sq mi)	77.9	37.3	22.3	21.5	21.0	85.8
River system	Coosa	Coosa	Coosa	Coosa	Coosa	Coosa
Ecoregion	45A	67F	67F	67G	67F	67H
Percidae						
Etheostoma brevirostrum	--	--	--	--	--	--
Etheostoma chuckwachatte	--	--	--	--	--	--
Etheostoma coosae	15	2	2	5	11	--
Etheostoma ditrema	--	--	--	--	--	--
Etheostoma jordani	43	86	8	--	27	46
Etheostoma nigrum	--	--	--	--	--	--
Etheostoma parvipinne	--	--	--	--	--	--
Etheostoma rupestre	--	--	--	--	--	--
Etheostoma stigmaeum	4	13	--	9	25	10
Etheostoma swaini	--	--	--	--	--	--
Etheostoma tallapoosae	--	--	--	--	--	--
Etheostoma whipplei	--	--	--	--	--	--
Etheostoma zonifer	--	--	--	--	--	--
Percina kathae	1	--	1	1	--	--
Percina nigrofasciata	13	11	11	20	9	32
Percina palmaris	26	--	--	--	4	1
Percina shumardi	--	--	--	--	--	4
Percina sp.	--	--	--	--	--	--
Elassomatidae						
Elassoma zonatum	--	--	--	--	--	--
Sciaenidae						
Aplodinotus grunniens	--	--	--	--	--	--
Cottidae						
Cottus carolinae	--	40	140	13	28	61
Total specimens	668	403	340	352	428	369
Total species	30	21	20	27	26	21
IBI	46	40	40	50	44	38

GSA no.	2898	3940	3941	3942	3943	3944
Date	1-Sep-04	18-Sep-03	12-Aug-03	17-Sep-03	18-Sep-03	18-Aug-03
Sample time (min)	126	83	74	97	53	77
Area sampled (sq ft)	4136	5850	3500	4550	3950	4020
Watershed area (sq mi)	30.6	283	172	245	72.9	41.3
River system	Coosa	Coosa	Coosa	Coosa	Coosa	Coosa
Ecoregion	67F	67G	67F	67F	67H	45D
Species						
Petromyzontidae						
Ichthyomyzon gagei	--	--	--	--	--	--
Lepisosteidae						
Lepisosteus oculatus	--	--	--	--	--	--
Lepisosteus osseus	--	--	--	--	--	--
Clupeidae						
Dorosoma cepedianum	--	--	--	--	--	--
Cyprinidae						
Campostoma oligolepis	516	31	101	150	9	5
Cyprinella caerulea	--	--	--	--	--	--
Cyprinella callistia	2	33	23	83	27	19
Cyprinella gibbsi	--	--	--	--	--	--
Cyprinella lutrensis	--	12	--	--	--	--
Cyprinella trichroistia	--	1	12	59	33	11
Cyprinella venusta	--	9	3	5	--	10
Cyprinella hybrid	--	3	--	--	--	--
Cyprinus carpio	--	--	--	--	--	--
Hybopsis lineapunctata	--	--	--	--	--	--
Hybopsis winchelli	--	--	--	--	--	--
Luxilus chrysocephalus	233	--	34	19	--	--
Luxilus zonistius	--	--	--	--	--	--
Lythrurus bellus	--	--	--	--	--	--
Lythrurus lirus	4	--	--	--	--	--
Macrhybopsis aestivalis	--	--	--	--	--	--
Nocomis leptocephalus	--	--	--	--	--	--
Notropis ammophilus	--	--	--	--	--	--
Notropis asperifrons	--	--	--	--	--	--
Notropis atherinoides	--	--	--	--	--	--
Notropis baileyi	--	--	--	--	--	--
Notropis buccatus	--	--	--	--	--	--
Notropis chrosomus	4	--	--	--	--	--
Notropis stilbius	53	49	76	93	7	14
Notropis texanus	--	--	--	--	--	--
Notropis volucellus	--	--	--	--	--	--
Notropis xaenocephalus	118	1	1	4	30	--
Opsopoeodus emiliae	--	--	--	--	--	--
Phenacobius catostomus	--	10	1	18	--	--
Pimephales notatus	--	--	--	--	--	--
Pimephales vigilax	--	--	--	--	--	--
Rhinichthys atratulus	--	--	--	--	--	--
Semotilus atromaculatus	4	--	--	--	--	--

GSA no.	2898	3940	3941	3942	3943	3944
Date	1-Sep-04	18-Sep-03	12-Aug-03	17-Sep-03	18-Sep-03	18-Aug-03
Sample time (min)	126	83	74	97	53	77
Area sampled (sq ft)	4136	5850	3500	4550	3950	4020
Watershed area (sq mi)	30.6	283	172	245	72.9	41.3
River system	Coosa	Coosa	Coosa	Coosa	Coosa	Coosa
Ecoregion	67F	67G	67F	67F	67H	45D
Catostomidae						
Erimyzon oblongus	--	--	--	--	--	--
Hypentelium etowanum	90	6	8	23	2	4
Minytrema melanops	--	--	--	--	--	--
Moxostoma duquesnei	2	--	--	1	--	--
Moxostoma erythrurum	14	--	--	--	--	1
Moxostoma poecilurum	--	2	--	--	--	--
Ictaluridae						
Ameiurus natalis	--	--	1	--	--	--
Ictalurus punctatus	--	7	--	--	1	2
Noturus funebris	--	--	--	--	--	--
Noturus leptacanthus	--	--	--	--	20	5
Pylodictis olivaris	--	--	--	1	--	--
Esocidae						
Esox niger	--	--	--	--	--	--
Fundulidae						
Fundulus bifax	--	--	--	--	--	--
Fundulus olivaceus	--	2	--	--	--	--
Fundulus stellifer	--	--	1	--	1	2
Poecilidae						
Gambusia affinis	3	8	2	1	--	--
Centrarchidae						
Ambloplites ariommus	--	--	2	5	5	3
Lepomis auritus	--	17	15	12	5	13
Lepomis cyanellus	27	5	22	7	1	2
Lepomis gulosus	--	4	1	--	--	--
Lepomis macrochirus	3	58	14	24	9	8
Lepomis megalotis	52	33	11	3	9	15
Lepomis microlophus	--	2	--	1	--	--
Lepomis punctatus	--	2	7	2	--	--
Lepomis hybrids	--	--	--	--	--	--
Micropterus coosae	11	--	1	8	6	1
Micropterus punctulatus	1	2	--	1	--	--
Micropterus salmoides	1	2	2	1	--	--
Pomoxis annularis	--	--	--	--	--	--
Pomoxis nigromaculatus	--	--	--	--	--	--

GSA no.	2898	3940	3941	3942	3943	3944
Date	1-Sep-04	18-Sep-03	12-Aug-03	17-Sep-03	18-Sep-03	18-Aug-03
Sample time (min)	126	83	74	97	53	77
Area sampled (sq ft)	4136	5850	3500	4550	3950	4020
Watershed area (sq mi)	30.6	283	172	245	72.9	41.3
River system	Coosa	Coosa	Coosa	Coosa	Coosa	Coosa
Ecoregion	67F	67G	67F	67F	67H	45D
Percidae						
Etheostoma brevirostrum	--	--	--	--	--	--
Etheostoma chuckwachatte	--	--	--	--	--	--
Etheostoma coosae	43	--	4	--	--	--
Etheostoma ditrema	--	--	--	--	--	--
Etheostoma jordani	--	11	37	75	18	30
Etheostoma nigrum	--	--	--	--	--	--
Etheostoma parvipinne	--	--	--	--	--	--
Etheostoma rupestre	--	--	--	--	--	--
Etheostoma stigmaeum	5	4	6	6	5	--
Etheostoma swaini	--	--	--	--	--	--
Etheostoma tallapoosae	--	--	--	--	--	--
Etheostoma whipplei	--	--	--	--	--	--
Etheostoma zonifer	--	--	--	--	--	--
Percina kathae	--	5	--	--	--	5
Percina nigrofasciata	33	22	14	16	10	2
Percina palmaris	--	16	17	58	20	6
Percina shumardi	--	--	--	--	--	--
Percina sp.	--	--	--	--	--	--
Elassomatidae						
Elassoma zonatum	--	--	--	--	--	--
Sciaenidae						
Aplodinotus grunniens	--	1	--	1	--	1
Cottidae						
Cottus carolinae	197	5	54	206	25	23
Total specimens	1416	363	470	883	244	183
Total species	22	29	27	28	21	23
IBI	32	40	32	40	44	42

GSA no.	3945	3946	3947	3948	3949	3950
Date	20-Aug-04	6-Aug-03	19-Aug-03	28-Aug-03	12-Aug-03	19-Aug-03
Sample time (min)	75	102	92	69	88	78
Area sampled (sq ft)	3920	6660	3060	2988	3900	4180
Watershed area (sq mi)	5.88	18.3	5.31	19.2	32.6	22.9
River system	Coosa	Coosa	Coosa	Coosa	Coosa	Coosa
Ecoregion	45D	45D	67G	67F	67F	67F
Species						
Petromyzontidae						
Ichthyomyzon gagei	--	--	--	--	--	--
Lepisosteidae						
Lepisosteus oculatus	--	--	--	--	--	--
Lepisosteus osseus	--	--	--	--	--	--
Clupeidae						
Dorosoma cepedianum	--	--	--	--	--	--
Cyprinidae						
Campostoma oligolepis	49	17	288	45	30	155
Cyprinella caerulea	--	--	--	--	--	--
Cyprinella callistia	4	17	--	--	2	4
Cyprinella gibbsi	--	--	--	--	--	--
Cyprinella lutrensis	--	--	--	--	--	--
Cyprinella trichroistia	43	98	3	--	46	67
Cyprinella venusta	--	--	--	--	--	--
Cyprinella hybrid	--	--	--	--	--	--
Cyprinus carpio	--	--	--	--	--	--
Hybopsis lineapunctata	--	--	--	--	--	--
Hybopsis winchelli	--	--	--	--	--	--
Luxilus chrysocephalus	--	--	85	--	16	7
Luxilus zonistius	--	--	--	--	--	--
Lythrurus bellus	--	19	--	--	--	--
Lythrurus lirus	--	13	--	--	--	--
Macrhybopsis aestivalis	--	--	--	--	--	--
Nocomis leptocephalus	--	--	--	--	--	--
Notropis ammophilus	--	--	--	--	--	--
Notropis asperifrons	--	31	--	--	--	--
Notropis atherinoides	--	--	--	--	--	--
Notropis baileyi	--	--	--	--	--	--
Notropis buccatus	--	--	--	--	--	--
Notropis chrosomus	--	3	146	7	--	1
Notropis stilbius	12	14	--	--	34	3
Notropis texanus	--	--	--	--	--	--
Notropis volucellus	--	--	--	--	--	--
Notropis xaenocephalus	7	7	--	--	5	58
Opsopoeodus emiliae	--	--	--	--	--	--
Phenacobius catostomus	--	4	--	--	3	--
Pimephales notatus	--	--	--	--	--	--
Pimephales vigilax	--	--	--	--	--	--
Rhinichthys atratulus	--	--	--	--	--	--
Semotilus atromaculatus	46	--	46	5	--	--

GSA no.	3945	3946	3947	3948	3949	3950
Date	20-Aug-04	6-Aug-03	19-Aug-03	28-Aug-03	12-Aug-03	19-Aug-03
Sample time (min)	75	102	92	69	88	78
Area sampled (sq ft)	3920	6660	3060	2988	3900	4180
Watershed area (sq mi)	5.88	18.3	5.31	19.2	32.6	22.9
River system	Coosa	Coosa	Coosa	Coosa	Coosa	Coosa
Ecoregion	45D	45D	67G	67F	67F	67F
Catostomidae						
Erimyzon oblongus	--	--	--	--	--	--
Hypentelium etowanum	22	5	22	19	10	11
Minytrema melanops	--	--	--	--	--	--
Moxostoma duquesnei	--	1	1	--	--	--
Moxostoma erythrurum	8	1	1	--	--	4
Moxostoma poecilurum	--	--	--	--	--	--
Ictaluridae						
Ameiurus natalis	--	2	6	1	--	--
Ictalurus punctatus	--	--	--	--	--	--
Noturus funebris	--	--	--	--	--	--
Noturus leptacanthus	--	--	--	--	--	--
Pylodictis olivaris	--	--	--	--	--	--
Esocidae						
Esox niger	--	--	--	--	--	--
Fundulidae						
Fundulus bifax	--	--	--	--	--	--
Fundulus olivaceus	--	--	--	--	--	--
Fundulus stellifer	--	9	7	--	2	1
Poecilidae						
Gambusia affinis	--	--	3	--	--	--
Centrarchidae						
Ambloplites ariommus	--	1	1	--	1	1
Lepomis auritus	19	21	14	53	19	13
Lepomis cyanellus	5	2	22	18	10	7
Lepomis gulosus	--	--	--	--	--	1
Lepomis macrochirus	8	23	2	43	10	5
Lepomis megalotis	19	24	--	5	3	--
Lepomis microlophus	--	--	--	--	--	--
Lepomis punctatus	--	--	1	--	10	3
Lepomis hybrids	--	--	--	--	--	--
Micropterus coosae	2	3	3	--	6	4
Micropterus punctulatus	1	--	1	--	--	--
Micropterus salmoides	--	1	--	--	--	--
Pomoxis annularis	--	--	--	--	--	--
Pomoxis nigromaculatus	--	--	--	--	--	--

GSA no.	3945	3946	3947	3948	3949	3950
Date	20-Aug-04	6-Aug-03	19-Aug-03	28-Aug-03	12-Aug-03	19-Aug-03
Sample time (min)	75	102	92	69	88	78
Area sampled (sq ft)	3920	6660	3060	2988	3900	4180
Watershed area (sq mi)	5.88	18.3	5.31	19.2	32.6	22.9
River system	Coosa	Coosa	Coosa	Coosa	Coosa	Coosa
Ecoregion	45D	45D	67G	67F	67F	67F
Percidae						
Etheostoma brevirostrum	--	--	--	--	--	--
Etheostoma chuckwachatte	--	--	--	--	--	--
Etheostoma coosae	46	16	2	3	5	2
Etheostoma ditrema	--	--	--	--	--	--
Etheostoma jordani	--	22	35	--	10	17
Etheostoma nigrum	--	--	--	--	--	--
Etheostoma parvipinne	--	--	--	--	--	--
Etheostoma rupestre	--	--	--	--	--	--
Etheostoma stigmaeum	1	5	9	--	--	--
Etheostoma swaini	--	--	--	--	--	--
Etheostoma tallapoosae	--	--	--	--	--	--
Etheostoma whipplei	--	--	--	--	--	--
Etheostoma zonifer	--	--	--	--	--	--
Percina kathae	1	2	--	3	--	3
Percina nigrofasciata	4	--	9	--	6	3
Percina palmaris	2	2	1	--	6	10
Percina shumardi	--	--	--	--	--	--
Percina sp.	--	--	--	--	--	--
Elassomatidae						
Elassoma zonatum	--	--	--	--	--	--
Sciaenidae						
Aplodinotus grunniens	--	--	--	--	--	--
Cottidae						
Cottus carolinae	3	27	130	118	34	60
Total specimens	302	390	841	320	269	440
Total species	20	28	25	12	22	23
IBI	38	52	38	28	38	46

GSA no.	3951	3952	3953	3954	3955	3956
Date	7-Aug-03	27-Aug-03	28-Aug-03	20-Aug-03	13-Aug-03	18-Aug-03
Sample time (min)	89	67	87	78	61	78
Area sampled (sq ft)	5420	4360	2850	4020	2782	2490
Watershed area (sq mi)	27.4	20.5	7.70	5.87	4.11	1.68
River system	Coosa	Coosa	Coosa	Coosa	Coosa	Coosa
Ecoregion	67F	67F	67F	45D	45D	67H
Species						
Petromyzontidae						
Ichthyomyzon gagei	--	--	--	--	--	--
Lepisosteidae						
Lepisosteus oculatus	--	--	--	--	--	--
Lepisosteus osseus	--	--	--	--	--	--
Clupeidae						
Dorosoma cepedianum	--	--	--	--	--	--
Cyprinidae						
Campostoma oligolepis	61	29	92	18	12	36
Cyprinella caerulea	--	--	--	--	--	--
Cyprinella callistia	6	17	--	11	2	--
Cyprinella gibbsi	--	--	--	--	--	--
Cyprinella lutrensis	--	--	--	--	--	--
Cyprinella trichroistia	16	72	55	9	41	14
Cyprinella venusta	5	2	--	--	--	--
Cyprinella hybrid	--	--	--	--	--	--
Cyprinus carpio	--	--	--	--	--	--
Hybopsis lineapunctata	--	--	--	--	--	--
Hybopsis winchelli	--	--	--	--	--	--
Luxilus chrysocephalus	1	11	19	--	--	--
Luxilus zonistius	--	--	--	--	--	--
Lythrurus bellus	--	--	--	--	--	--
Lythrurus lirus	--	--	--	--	--	--
Macrhybopsis aestivalis	--	--	--	--	--	--
Nocomis leptocephalus	--	--	--	--	--	--
Notropis ammophilus	--	--	--	--	--	--
Notropis asperifrons	--	--	--	1	--	--
Notropis atherinoides	--	--	--	--	--	--
Notropis baileyi	--	--	--	--	--	--
Notropis buccatus	--	--	--	--	--	--
Notropis chrosomus	--	--	5	--	--	--
Notropis stilbius	15	26	--	12	--	--
Notropis texanus	--	--	--	--	--	--
Notropis volucellus	--	--	--	--	--	--
Notropis xaenocephalus	--	6	24	22	5	16
Opsopoeodus emiliae	--	--	--	--	--	--
Phenacobius catostomus	1	11	--	--	--	--
Pimephales notatus	--	--	--	--	--	--
Pimephales vigilax	--	--	--	--	--	--
Rhinichthys atratulus	--	--	--	--	--	--
Semotilus atromaculatus	--	3	11	--	33	12

GSA no.	3951	3952	3953	3954	3955	3956
Date	7-Aug-03	27-Aug-03	28-Aug-03	20-Aug-03	13-Aug-03	18-Aug-03
Sample time (min)	89	67	87	78	61	78
Area sampled (sq ft)	5420	4360	2850	4020	2782	2490
Watershed area (sq mi)	27.4	20.5	7.70	5.87	4.11	1.68
River system	Coosa	Coosa	Coosa	Coosa	Coosa	Coosa
Ecoregion	67F	67F	67F	45D	45D	67H
Catostomidae						
Erimyzon oblongus	--	--	--	--	--	--
Hypentelium etowanum	13	31	24	10	20	4
Minytrema melanops	--	--	--	--	--	--
Moxostoma duquesnei	3	2	--	--	--	--
Moxostoma erythrurum	--	1	1	--	1	--
Moxostoma poecilurum	2	--	--	--	--	--
Ictaluridae						
Ameiurus natalis	--	--	--	1	--	--
Ictalurus punctatus	3	--	--	--	--	--
Noturus funebris	--	--	--	--	--	--
Noturus leptacanthus	--	--	--	3	--	2
Pylodictis olivaris	--	--	--	--	--	--
Esocidae						
Esox niger	--	--	--	--	--	--
Fundulidae						
Fundulus bifax	--	--	--	--	--	--
Fundulus olivaceus	--	--	--	--	--	--
Fundulus stellifer	--	--	--	--	--	--
Poecilidae						
Gambusia affinis	2	--	--	--	--	--
Centrarchidae						
Ambloplites ariommus	1	1	3	--	--	--
Lepomis auritus	19	44	37	28	4	4
Lepomis cyanellus	16	43	37	--	3	2
Lepomis gulosus	2	1	2	--	--	--
Lepomis macrochirus	3	8	7	32	1	--
Lepomis megalotis	10	28	1	9	14	--
Lepomis microlophus	--	--	--	1	--	--
Lepomis punctatus	5	1	--	--	--	--
Lepomis hybrids	--	--	3	1	--	--
Micropterus coosae	3	--	4	2	1	7
Micropterus punctulatus	2	--	1	--	--	--
Micropterus salmoides	--	2	7	1	--	--
Pomoxis annularis	--	--	--	--	--	--
Pomoxis nigromaculatus	--	--	--	--	--	--

GSA no.	3951	3952	3953	3954	3955	3956
Date	7-Aug-03	27-Aug-03	28-Aug-03	20-Aug-03	13-Aug-03	18-Aug-03
Sample time (min)	89	67	87	78	61	78
Area sampled (sq ft)	5420	4360	2850	4020	2782	2490
Watershed area (sq mi)	27.4	20.5	7.70	5.87	4.11	1.68
River system	Coosa	Coosa	Coosa	Coosa	Coosa	Coosa
Ecoregion	67F	67F	67F	45D	45D	67H
Percidae						
Etheostoma brevirostrum	--	--	--	--	--	--
Etheostoma chuckwachatte	--	--	--	--	--	--
Etheostoma coosae	4	3	14	7	9	12
Etheostoma ditrema	--	--	--	--	--	--
Etheostoma jordani	6	33	--	--	--	1
Etheostoma nigrum	--	--	--	--	--	--
Etheostoma parvipinne	--	--	--	--	--	--
Etheostoma rupestre	--	--	--	--	--	--
Etheostoma stigmaeum	5	5	--	8	--	--
Etheostoma swaini	--	--	--	--	--	--
Etheostoma tallapoosae	--	--	--	--	--	--
Etheostoma whipplei	--	--	--	--	--	--
Etheostoma zonifer	--	--	--	--	--	--
Percina kathae	--	--	1	4	--	7
Percina nigrofasciata	7	10	--	8	--	--
Percina palmaris	8	2	--	--	--	1
Percina shumardi	--	--	--	--	--	--
Percina sp.	--	--	--	--	--	--
Elassomatidae						
Elassoma zonatum	--	--	--	--	--	--
Sciaenidae						
Aplodinotus grunniens	3	--	--	--	--	--
Cottidae						
Cottus carolinae	19	34	21	2	4	16
Total specimens	241	426	369	190	150	134
Total species	28	26	20	20	14	14
IBI	42	44	42	38	28	38

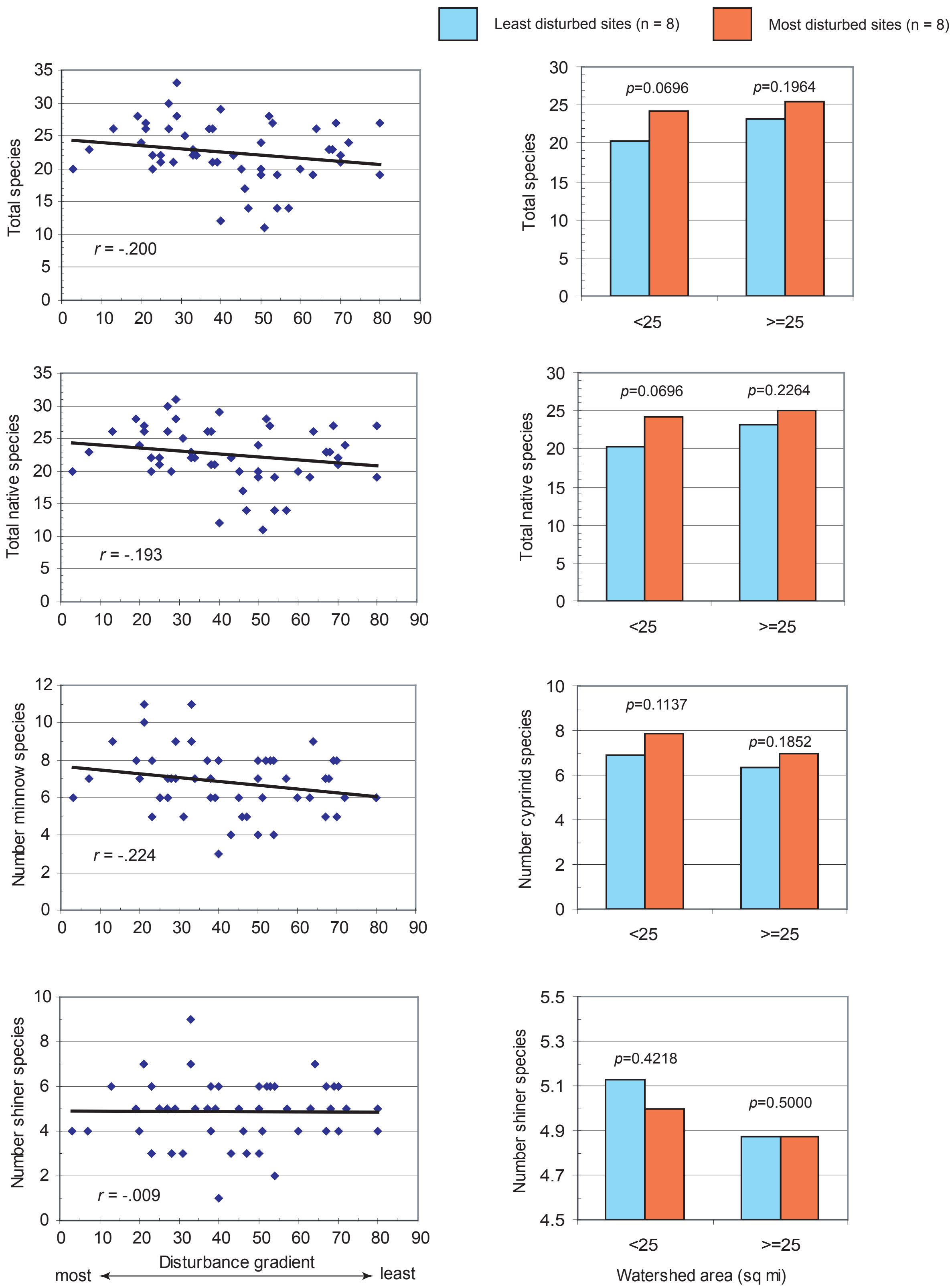
GSA no.	3957	3958	3959	3960	3961
Date	27-Aug-03	19-Sep-03	13-Aug-03	7-Aug-03	8-Aug-03
Sample time (min)	78	62	75	75	99
Area sampled (sq ft)	3160	5100	3460	3900	3420
Watershed area (sq mi)	15.8	53.8	17.9	5.53	2.78
River system	Coosa	Coosa	Coosa	Coosa	Coosa
Ecoregion	67F	45D	45D	45D	45D
Species					
Petromyzontidae					
Ichthyomyzon gagei	--	--	--	--	--
Lepisosteidae					
Lepisosteus oculatus	--	--	--	--	--
Lepisosteus osseus	--	--	--	--	--
Clupeidae					
Dorosoma cepedianum	--	--	--	--	--
Cyprinidae					
Campostoma oligolepis	56	12	5	6	16
Cyprinella caerulea	--	--	--	--	--
Cyprinella callistia	5	19	47	38	25
Cyprinella gibbsi	--	90	--	--	--
Cyprinella lutrensis	--	--	--	--	--
Cyprinella trichroistia	20	--	59	215	101
Cyprinella venusta	2	--	--	--	--
Cyprinella hybrid	--	--	--	--	--
Cyprinus carpio	--	--	--	--	--
Hybopsis lineapunctata	--	--	--	--	--
Hybopsis winchelli	--	--	--	--	--
Luxilus chrysocephalus	--	--	--	--	4
Luxilus zonistius	--	--	--	--	--
Lythrurus bellus	--	--	--	--	--
Lythrurus lirus	--	--	--	--	--
Macrhybopsis aestivalis	--	--	--	--	--
Nocomis leptocephalus	--	--	--	--	--
Notropis ammophilus	--	--	--	--	--
Notropis asperifrons	--	29	4	2	6
Notropis atherinoides	--	--	--	--	--
Notropis baileyi	--	--	--	--	--
Notropis buccatus	--	--	--	--	--
Notropis chrosomus	--	--	--	1	28
Notropis stilbius	10	--	1	--	--
Notropis texanus	--	--	--	--	--
Notropis volucellus	--	--	--	--	--
Notropis xaenocephalus	25	1	12	13	31
Opsopoeodus emiliae	--	--	--	--	--
Phenacobius catostomus	1	--	--	2	--
Pimephales notatus	--	--	--	--	--
Pimephales vigilax	--	--	--	--	--
Rhinichthys atratulus	--	--	--	--	--
Semotilus atromaculatus	2	5	--	--	3

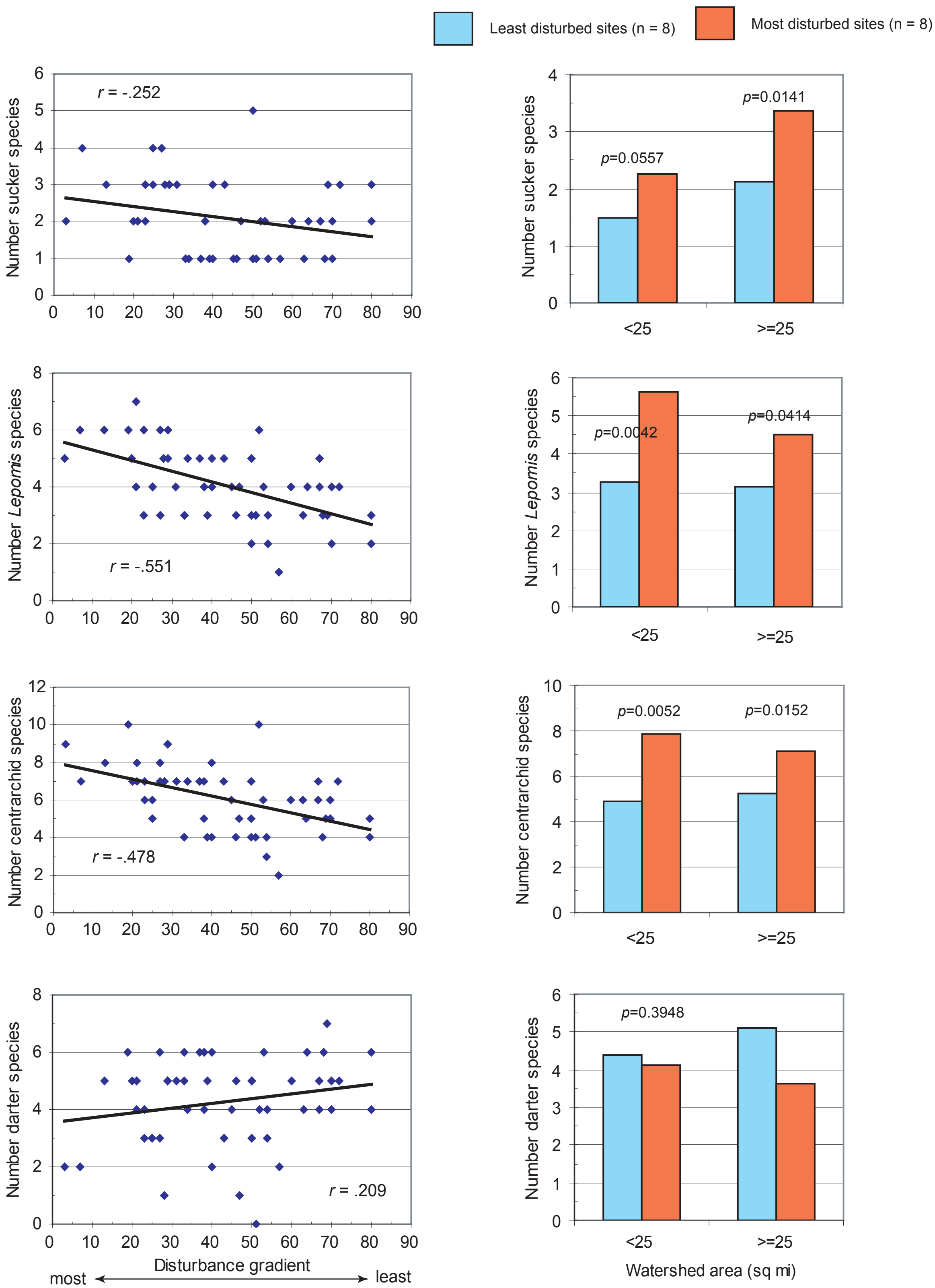
GSA no.	3957	3958	3959	3960	3961
Date	27-Aug-03	19-Sep-03	13-Aug-03	7-Aug-03	8-Aug-03
Sample time (min)	78	62	75	75	99
Area sampled (sq ft)	3160	5100	3460	3900	3420
Watershed area (sq mi)	15.8	53.8	17.9	5.53	2.78
River system	Coosa	Coosa	Coosa	Coosa	Coosa
Ecoregion	67F	45D	45D	45D	45D
Catostomidae					
Erimyzon oblongus	--	--	--	--	--
Hypentelium etowanum	7	5	15	12	12
Minytrema melanops	--	--	--	--	--
Moxostoma duquesnei	--	--	--	--	--
Moxostoma erythrurum	--	--	--	--	--
Moxostoma poecilurum	--	--	--	--	--
Ictaluridae					
Ameiurus natalis	3	--	2	--	--
Ictalurus punctatus	--	--	--	--	--
Noturus funebris	--	--	--	--	--
Noturus leptacanthus	5	--	--	--	2
Pylodictis olivaris	--	--	--	--	--
Esocidae					
Esox niger	--	--	--	--	--
Fundulidae					
Fundulus bifax	--	--	--	--	--
Fundulus olivaceus	--	--	--	--	--
Fundulus stellifer	--	--	--	3	6
Poecilidae					
Gambusia affinis	--	--	--	--	--
Centrarchidae					
Ambloplites ariommus	--	--	2	--	--
Lepomis auritus	22	--	1	--	17
Lepomis cyanellus	5	3	--	--	1
Lepomis gulosus	1	--	--	--	--
Lepomis macrochirus	24	8	16	--	8
Lepomis megalotis	13	14	26	8	11
Lepomis microlophus	--	--	--	--	--
Lepomis punctatus	--	--	--	--	--
Lepomis hybrids	--	--	--	--	--
Micropterus coosae	2	3	12	11	12
Micropterus punctulatus	1	--	--	--	--
Micropterus salmoides	--	--	1	--	--
Pomoxis annularis	--	--	--	--	--
Pomoxis nigromaculatus	--	--	--	--	--

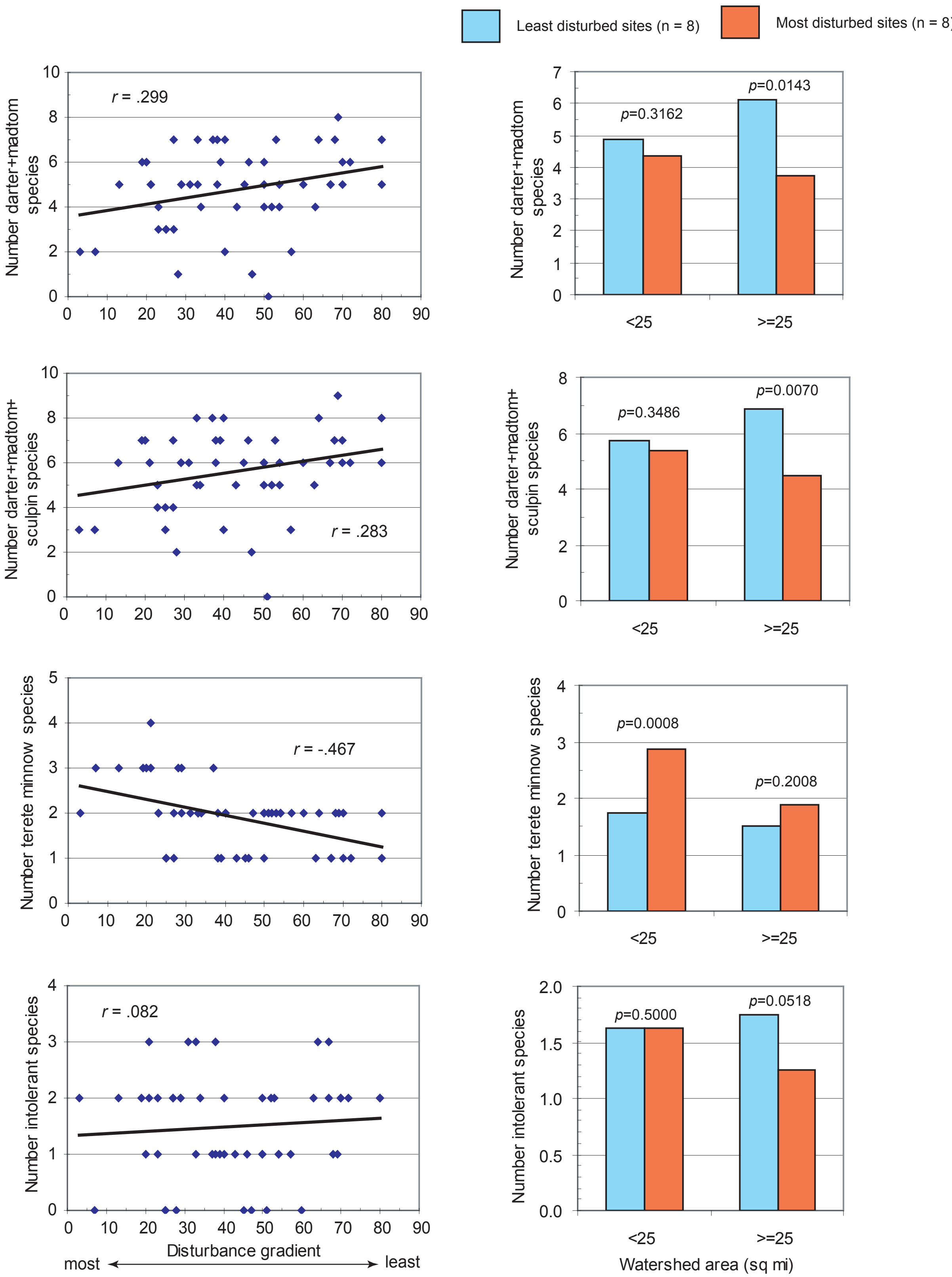
GSA no.	3957	3958	3959	3960	3961
Date	27-Aug-03	19-Sep-03	13-Aug-03	7-Aug-03	8-Aug-03
Sample time (min)	78	62	75	75	99
Area sampled (sq ft)	3160	5100	3460	3900	3420
Watershed area (sq mi)	15.8	53.8	17.9	5.53	2.78
River system	Coosa	Coosa	Coosa	Coosa	Coosa
Ecoregion	67F	45D	45D	45D	45D
Percidae					
Etheostoma brevirostrum	--	--	7	--	--
Etheostoma chuckwachatte	--	--	--	--	--
Etheostoma coosae	1	--	--	2	16
Etheostoma ditrema	--	--	--	--	--
Etheostoma jordani	1	--	11	--	--
Etheostoma nigrum	--	--	--	--	--
Etheostoma parvipinne	--	--	--	--	--
Etheostoma rupestre	--	--	--	--	--
Etheostoma stigmaeum	12	--	--	--	4
Etheostoma swaini	--	--	--	--	--
Etheostoma tallapoosae	--	--	--	--	--
Etheostoma whipplei	--	--	--	--	--
Etheostoma zonifer	--	--	--	--	--
Percina kathae	10	--	3	5	3
Percina nigrofasciata	11	--	3	--	--
Percina palmaris	2	--	--	--	--
Percina shumardi	--	--	--	--	--
Percina sp.	--	--	--	--	--
Elassomatidae					
Elassoma zonatum	--	--	--	--	--
Sciaenidae					
Aplodinotus grunniens	2	--	--	--	--
Cottidae					
Cottus carolinae	4	--	7	38	48
Total specimens	247	189	234	356	354
Total species	26	11	19	14	20
IBI	36	36	42	50	52

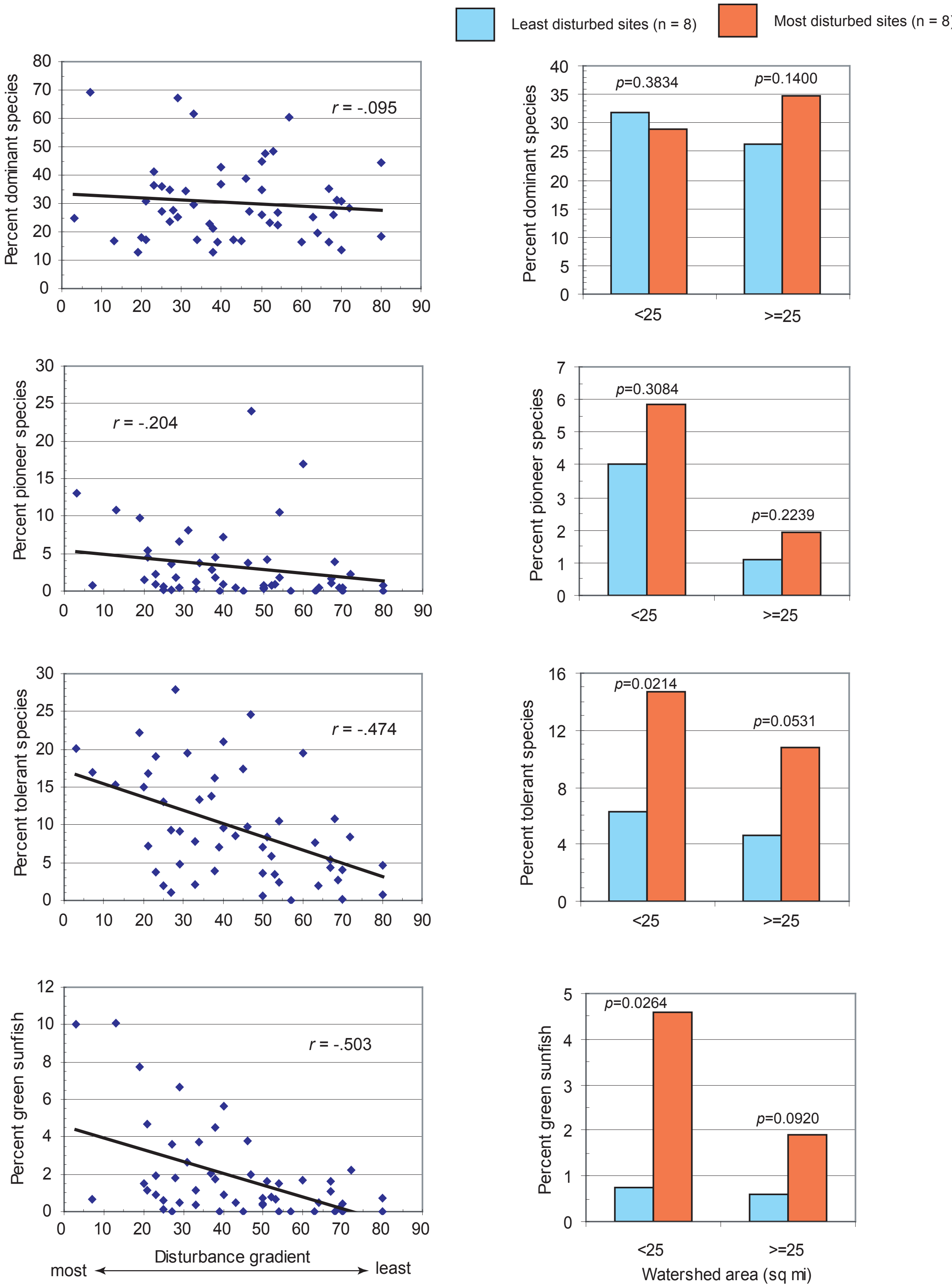
Appendix B

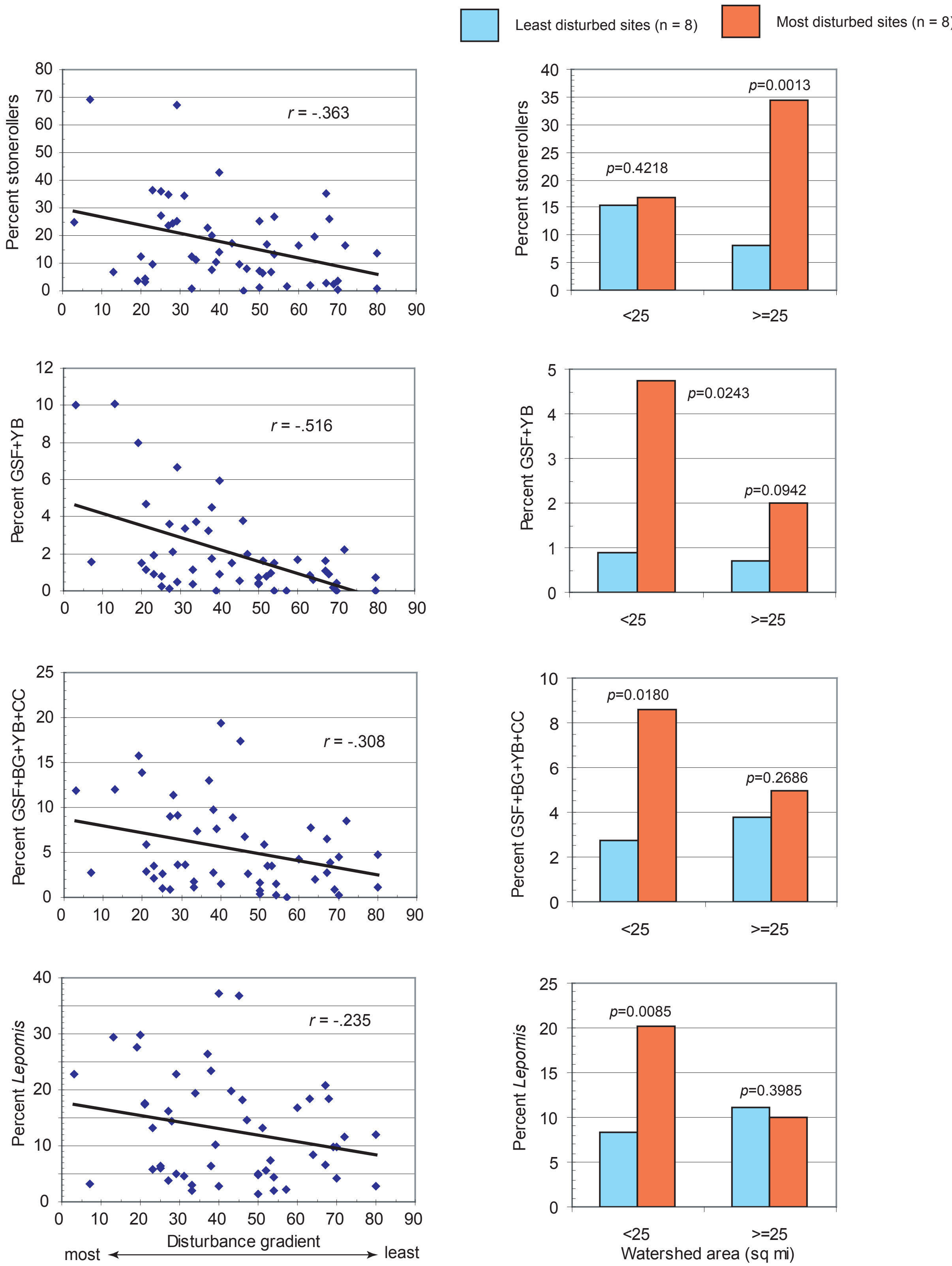
Plots of metric values versus human disturbance gradient and comparison of metric values between least and most disturbed stations for all candidate metrics evaluated

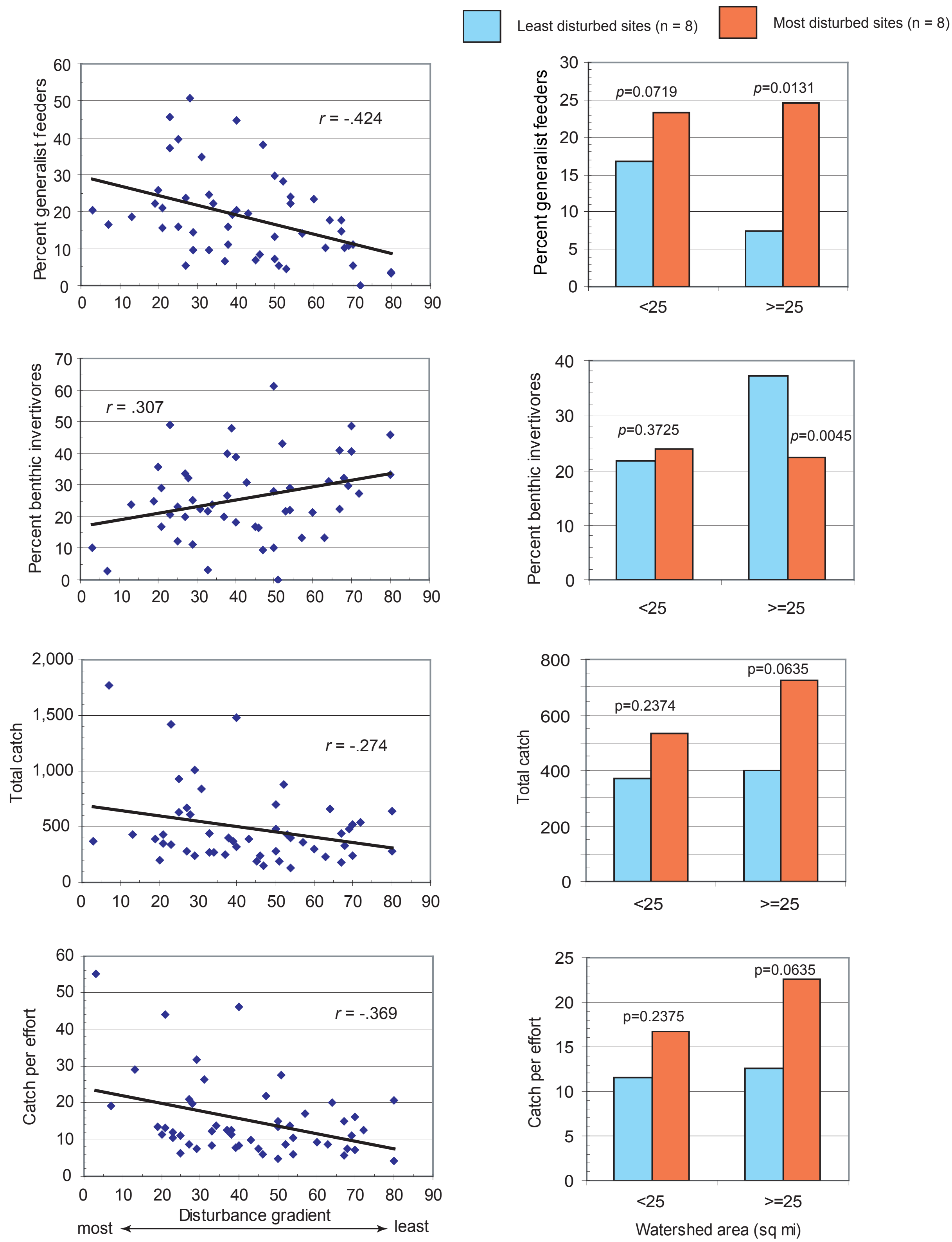

Least disturbed sites (n = 8)
Most disturbed sites (n = 8)
Total species
r = -.200
p=0.0696
p=0.1964
Total native species
r = -.193
p=0.0696
p=0.2264
Number minnow species
r = -.224
Number cyprinid species
p=0.1137
p=0.1852
Number shiner species
r = -.009
p=0.4218
p=0.5000
<25
>=25
Disturbance gradient
most
least
Watershed area (sq mi)

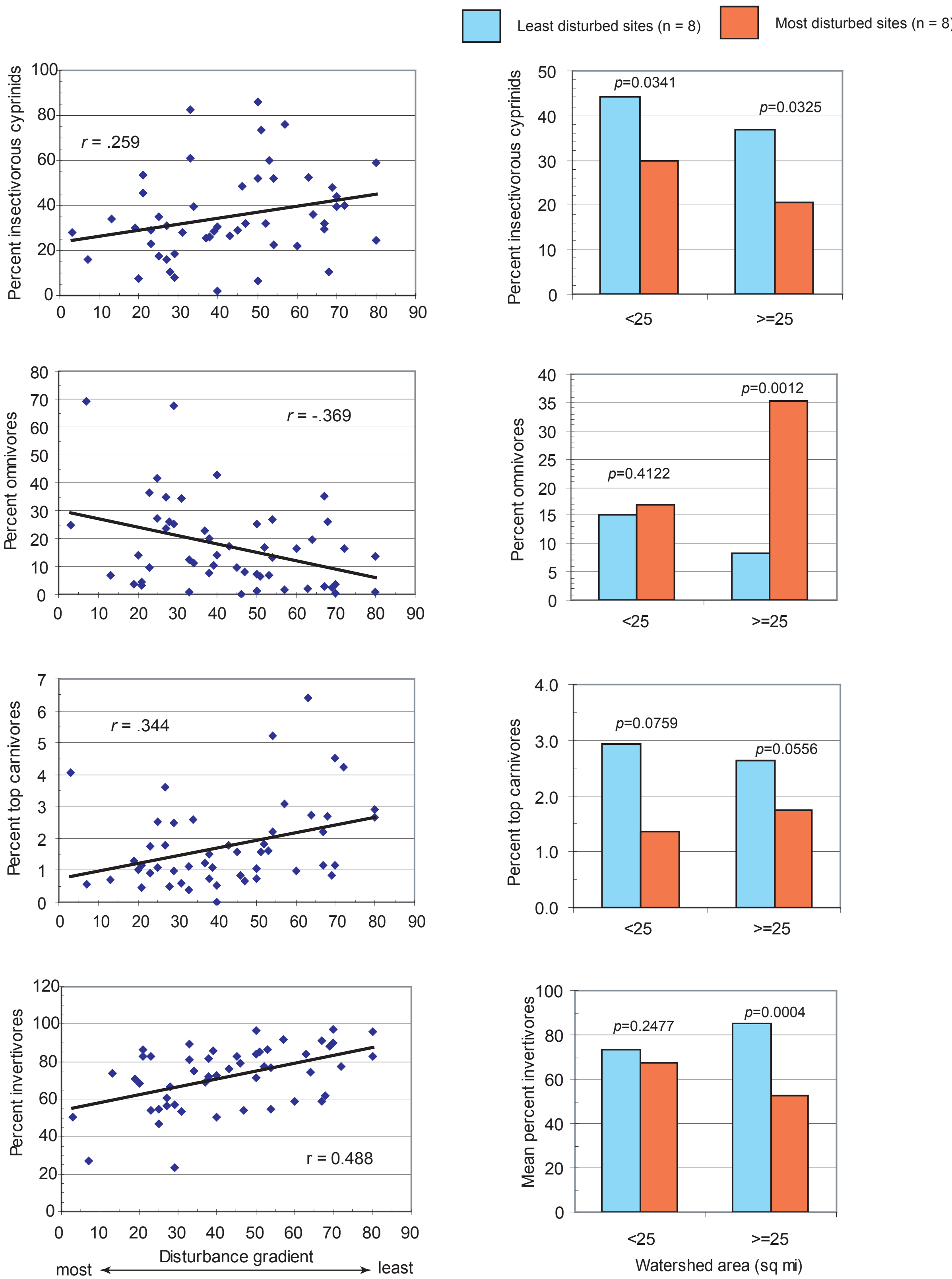

Least disturbed sites (n = 8)
Most disturbed sites (n = 8)
Number sucker species
r = -.252
p=0.0557
p=0.0141
Number Lepomis species
r = -.551
p=0.0042
p=0.0414
Number centrarchid species
r = -.478
p=0.0052
p=0.0152
Number darter species
r = .209
p=0.3948
<25
>=25
Disturbance gradient
most
least
Watershed area (sq mi)


Least disturbed sites (n = 8)
Most disturbed sites (n = 8)
Number darter+madtom species
r = .299
p=0.3162
p=0.0143
Number darter+madtom+ sculpin species
r = .283
p=0.3486
p=0.0070
Number terete minnow species
r = -.467
p=0.0008
p=0.2008
Number intolerant species
r = .082
p=0.5000
p=0.0518
Disturbance gradient
most
least
<25
>=25
Watershed area (sq mi)

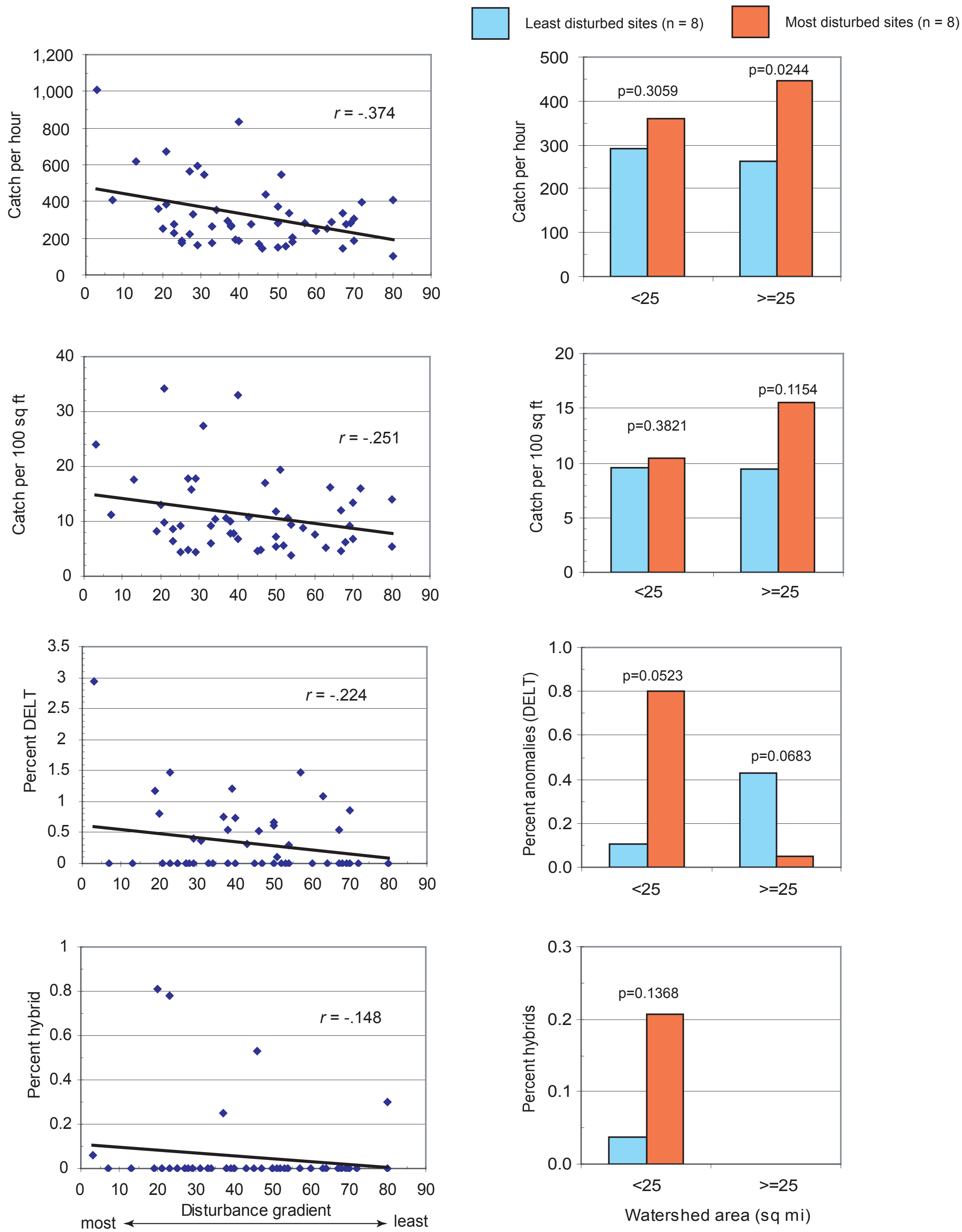

Least disturbed sites (n = 8)
Most disturbed sites (n = 8)
Percent dominant species
r = -.095
p=0.3834
p=0.1400
Percent pioneer species
r = -.204
p=0.3084
p=0.2239
Percent tolerant species
r = -.474
p=0.0214
p=0.0531
Percent green sunfish
r = -.503
p=0.0264
p=0.0920
<25
>=25
Watershed area (sq mi)
Disturbance gradient
most
least

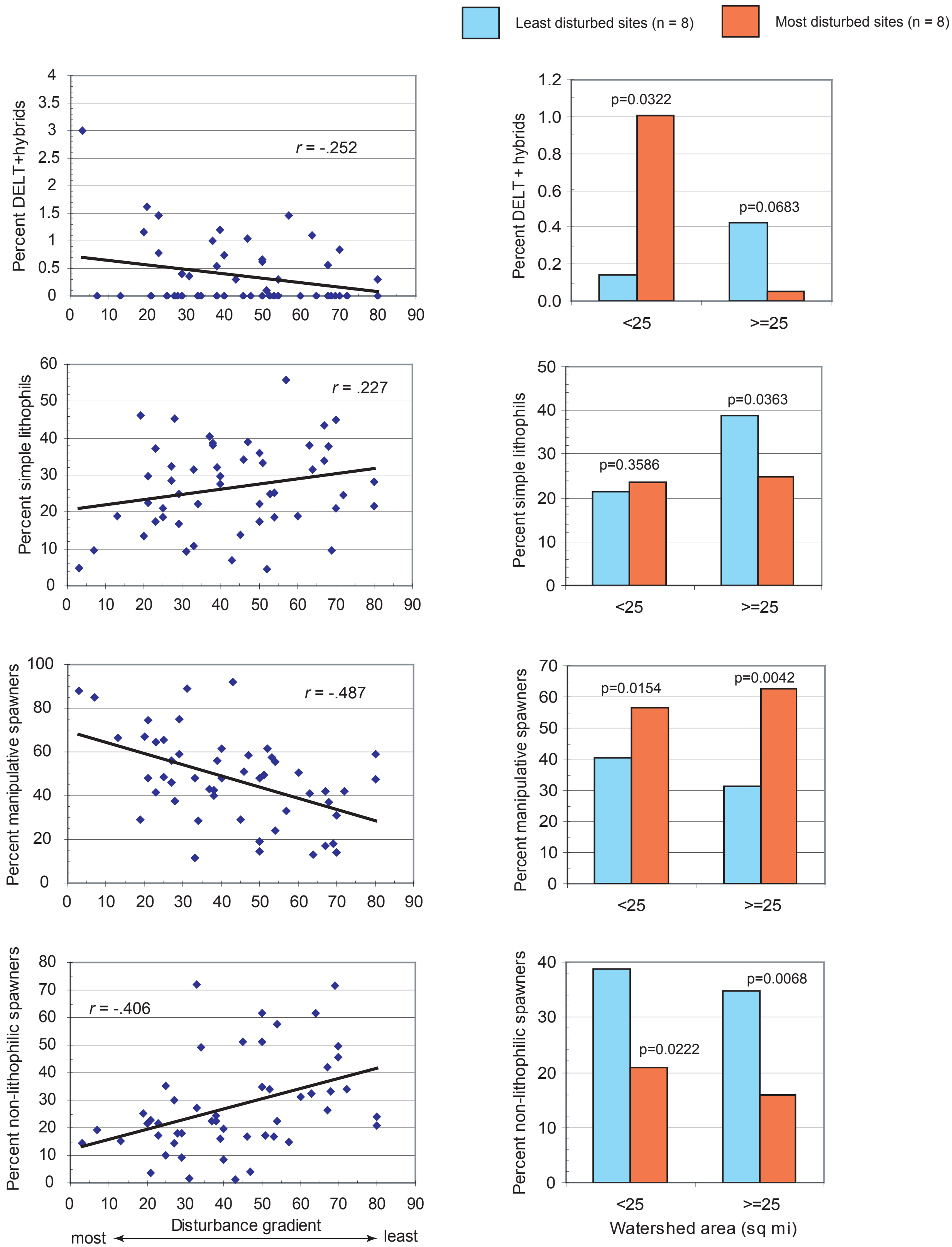

Least disturbed sites (n = 8)
Most disturbed sites (n = 8)
Percent stonerollers
r = -.363
p=0.4218
p=0.0013
Percent GSF+YB
r = -.516
p=0.0243
p=0.0942
Percent GSF+BG+YB+CC
r = -.308
p=0.0180
p=0.2686
Percent Lepomis
r = -.235
p=0.0085
p=0.3985
<25
>=25
Disturbance gradient
most
least
Watershed area (sq mi)


Least disturbed sites (n = 8)
Most disturbed sites (n = 8)
Percent generalist feeders
r = -.424
p=0.0719
p=0.0131
Percent benthic invertivores
r = .307
p=0.3725
p=0.0045
Total catch
r = -.274
p=0.2374
p=0.0635
Catch per effort
r = -.369
p=0.2375
p=0.0635
Disturbance gradient
most
least
<25
>=25
Watershed area (sq mi)

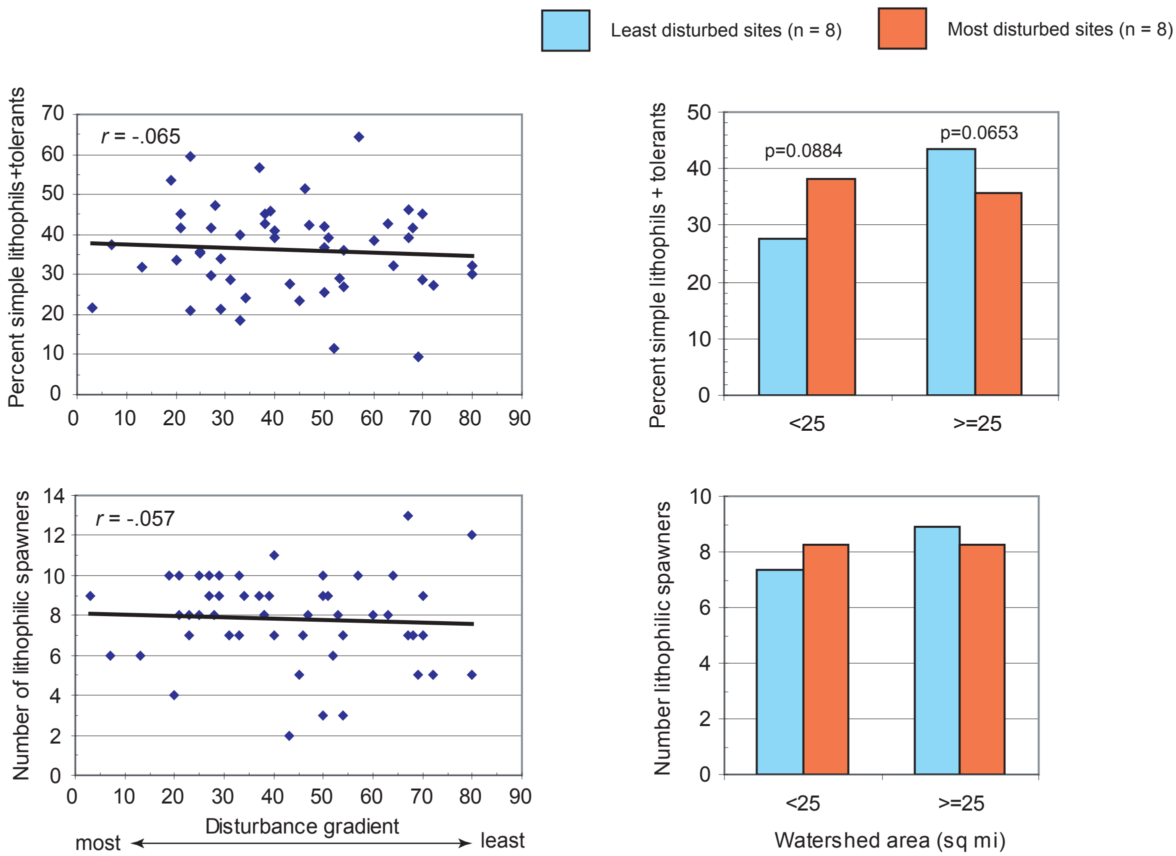


Least disturbed sites (n = 8)
Most disturbed sites (n = 8)
Percent insectivorous cyprinids
r = .259
p=0.0341
p=0.0325
Percent omnivores
r = -.369
p=0.4122
p=0.0012
Percent top carnivores
r = .344
p=0.0759
p=0.0556
Percent invertivores
r = 0.488
Mean percent invertivores
p=0.2477
p=0.0004
<25
>=25
Watershed area (sq mi)
Disturbance gradient
most
least


Least disturbed sites (n = 8)
Most disturbed sites (n = 8)
Catch per hour
r = -.374
p=0.3059
p=0.0244
Catch per 100 sq ft
r = -.251
p=0.3821
p=0.1154
Percent DELT
r = -.224
Percent anomalies (DELT)
p=0.0523
p=0.0683
Percent hybrid
r = -.148
Percent hybrids
p=0.1368
<25
>=25
Disturbance gradient
most
least
Watershed area (sq mi)



Least disturbed sites (n = 8)
Most disturbed sites (n = 8)
Percent DELT+hybrids
r = -.252
Percent DELT + hybrids
p=0.0322
p=0.0683
Percent simple lithophils
r = .227
p=0.3586
p=0.0363
Percent manipulative spawners
r = -.487
p=0.0154
p=0.0042
Percent non-lithophilic spawners
r = -.406
p=0.0068
p=0.0222
<25
>=25
Disturbance gradient
most
least
Watershed area (sq mi)


Least disturbed sites (n = 8)
Most disturbed sites (n = 8)
Percent simple lithophils+tolerants
r = -.065
Percent simple lithophils + tolerants
p=0.0884
p=0.0653
<25
>=25
Number of lithophilic spawners
r = -.057
Disturbance gradient
most
least
Number lithophilic spawners
Watershed area (sq mi)

Appendix C

Ecological and distributional characteristics of freshwater fish species of Alabama

Explanation

Conservation status (Cons. Status)
(from Mirarchi and others, 2004)
- P1-highest concern
- P2-high concern
- P3-moderate concern
- P4-low concern
- P5-lowest concern
- E-endangered
- T-threatened

Vulnerability (Vulner.)
(From Warren and others, 2000)
- CS-currently stable
- V-vulnerable

Habitat
- I-impoundment
- R-river
- S-stream
- H-headwater
- Sp-spring
- Ca-cave
- Sw-swamp
- E-estuarine

Distribution (Dist.)
- W-widespread
- R-restricted
- D-disjunct
- Ex-extirpated
- I-introduced

Abundance (Abund.)
- C-common
- O-occasional
- U-uncommon
- R-rare

Reproduction guild (Repro. guild)
- 1-simple lithophils
- 2-manipulative lithophils
- 3-simple miscellaneous spawners
- 4- manipulative misc. spawners

Feeding guild
- DAH-detritovore-algivore-herbivore
- AHI-algivore-herbivore-invertivore
- INV-invertivore
- INS-insectivore
- PIS-piscivore
- PAR-parasite
- IP-invertivore, piscivore

Tolerance
- INT-intolerant
- TOL-tolerant

FAMILY NAME Scientific name - common name	Cons. status	Vulner. Warren et al	Habitat	Dist.	Abund.	Reprod. guild	Feeding guild	Tolerance
PETROMYZONTIDAE- LAMPREYS								
Ichthyomyzon bdellium- Ohio lamprey	P5	CS	R, S	R	O	2	PAR	
I. castaneus- chestnut lamprey	P5	CS	I, R, S	W	O	2	PAR	
I. gagei- southern brook lamprey	P5	CS	R, S	W	O	2	DAH	
I. greeleyi- mountain brook lamprey	P3	CS	S, H	R	U	2	DAH	INT
Lampetra aepyptera- least brook lamprey	P5	CS	S, H	W	O	2	DAH	
L. appendix- American brook lamprey	P3	CS	S	R	U	2	DAH	
CARCHARHINIDAE- REQUIEM SHARKS								
Carcharhinus leucas- bull shark	P5	CS	E, R	R	R	3	PIS	
ACIPENSERIDAE- STURGEONS								
Acipenser fulvescens- lake sturgeon	Ex	T	R	Ex	--	1	INV	
A. oxyrhinchus desotoi- Atlantic sturgeon	P2, T	T	R	R	U	1	INV	INT
Scaphirhynchus platorynchus- shovelnose sturgeon	Ex	CS	R	Ex	--	1	INV	
S. suttkusi- Alabama sturgeon	P1, E	E	R	R	R	1	INV	INT
POLYODONTIDAE- PADDLEFISH								
Polyodon spathula- paddlefish	P4	V	R, I	W	O	3	AHI	
LEPISOSTEIDAE- GARS								
Atractosteus spatula- alligator gar	P3	V	R	R	O	3	IP	
Lepisosteus oculatus- spotted gar	P5	CS	R, I, Sw	W	C	3	IP	
L. osseus- longnose gar	P5	CS	R, I	W	C	3	IP	TOL
L. platostomus- shortnose gar	Ex	CS	R, I	Ex	--	3	IP	TOL
AMIIDAE- BOWFIN								
Amia calva- bowfin	P5	CS	R, I, Sw	W	O	4	IP	
HIODONTIDAE- MOONEYES								
Hiodon alosoides- goldeye	Ex	CS	R, I	Ex	--	1	IP	
H. tergisus- mooneye	P4	CS	R, I	W	O	1	IP	
ANGUILLIDAE- FRESHWATER EELS								
Anguilla rostrata- American eel	P4	CS	R, I	W	O	3	IP	
CLUPEIDAE-HERRINGS								
Alosa alabamae- Alabama shad	P2	V	R	W	R	3	INV	INT
A. chrysochloris- skipjack herring	P3	CS	R	W	C	3	INV	
Dorosoma cepedianum- gizzard shad	P5	CS	I, R, S	W	C	3	AHI	TOL
D. petenense- threadfin shad	P5	CS	I, R, S	W	C	3	AHI	
ENGRAULIDAE- ANCHOVIES								
Anchoa mitchilli- bay anchovy	P5	CS	E, R	R	C	3	INV	

FAMILY NAME Scientific name - common name	Cons. status	Vulner. Warren et al	Habitat	Dist.	Abund.	Reprod. guild	Feeding guild	Tolerance
CYPRINIDAE- CARPS AND MINNOWS								
Campostoma oligolepis- largescale stoneroller	P5	CS	S, H	W	C	2	DAH	
C. pauciradii- bluefin stoneroller	P3	CS	S, H	R	C	2	DAH	
Carassius auratus- goldfish	P5	CS	I	I, R	U	3	AHI	TOL
Clinostomus funduloides- rosyside dace	P5	CS	S, H	R	O	1	INV	
Ctenopharyngodon idella- grass carp	Exotic	CS	R, I	I, W	U	3	AHI	TOL
Cyprinella caerulea- blue shiner	P2, T	E	S	R, D	R	3	INS	INT
C. callistia- Alabama shiner	P5	CS	R, S	W	C	3	INV	
C. callitaenia- bluestripe shiner	P3	V	R, S	R	U	3	INS	INT
C. galactura- whitetail shiner	P5	CS	S	R	C	3	INS	
C. gibbsi- Tallapoosa shiner	P4	CS	S, H	R	C	3	INS	
C. lutrensis- red shiner	Exotic	CS	I, S	R	R	3	INS	TOL
C. spiloptera- spotfin shiner	P5	CS	I, R, S	R	C	3	INS	
C. trichroistia- tricolor shiner	P5	CS	R, S	R	C	3	INS	
C. venusta- blacktail shiner	P5	CS	I, R, S	W	C	3	INV	
C. whipplei- steelcolor shiner	P5	CS	I, R, S	W	C	3	INV	TOL
Cyprinus carpio- carp	Exotic	CS	I, R	I, W	C	3	INV,DAH	TOL
Erimonax monachus- spotfin chub	T	E	S	Ex	R	3	INS	INT
Erimystax dissimilis- streamline chub	P2	CS	S	R	U	1	INS	INT
E. insignis- blotched chub	P3	CS	S	R	U	1	INS	
Hemitremia flammea- flame chub	P4	V	Sp, H	R	O	3	INV	
Hybognathus hayi- cypress minnow	P4	CS	R, I, Sw	W	U	1	DAH	
H. nuchalis- Mississippi silvery minnow	P4	CS	R, I	W	C	1	DAH	
Hybopsis amblops- bigeye chub	P5	CS	S	R	O	1	INS,INV	INT
H. lineapunctata- lined chub	P5	V	S, H	R	C	1	INS	INT
H. winchelli-clear chub	P5	CS	R, S, I	W	C	1	INS	
H. sp. cf winchelli-	P5	CS	R, S	W	C	1	INS	
Hypophthalmichthys molitrix- silver carp	Exotic	CS	I, R	I	U	3	DAH	TOL
H. nobilis- bighead carp	Exotic	CS	I, R	I	U	3	DAH,INV	TOL
Luxilus chrysocephalus- striped shiner	P5	CS	S, H	W	C	2	INS,DAH	TOL
L. coccogenis- warpaint shiner	P4	CS	S, H	R	O	1	INS,INV	
L. zonistius- bandfin shiner	P5	CS	S, H	R	O	1	INS,DAH	
Lythrurus alegnotus- Warrior shiner	P5	CS	S, H	R	O	1	INS	
L. atrapiculus- blacktip shiner	P5	CS	S, H	R	C	1	INS	
L. bellus- pretty shiner	P5	CS	S, H	W	C	1	INS	

FAMILY NAME Scientific name - common name	Cons. status	Vulner. Warren et al	Habitat	Dist.	Abund.	Reprod. guild	Feeding guild	Tolerance
L. fasciolaris- scarlet shiner	P5	CS	S, H	R	C	1	INS	
L. fumeus- ribbon shiner	P3	CS	S	R	U	1	INS	
L. lirus- mountain shiner	P4	CS	S, H	R	O	1	INS	INT
L. roseipinnis- cherryfin shiner	P5	CS	S, H	R	C	1	INS	
Macrhybopsis a. hyostoma- shoal chub	P2	CS	R, S	R	R	1	INS	INT
M. sp cf aestivalis- undescribed chubs	P4	V	R, S	W	O	1	INS	INT
M. sp. cf aestivalis- Florida chub	P4	V	R, S	W	O	1	INS	INT
M. storeriana- silver chub	P5	CS	I, R, S	W	O	1	INS,INV	
Nocomis leptocephalus- bluehead chub	P5	CS	S, H	W	C	2	INS,AHI	
N. micropogon- river chub	P4	CS	S, C	W	U	2	INV	
Notemigonus crysoleucas- golden shiner	P5	CS	I, R, S	W	O	3	INS,AHI	TOL
Notropis albizonatus- palezone shiner	P1, E	E	S, H	R	R	1	INS,AHI	INT
N. ammophilus- orangefin shiner	P5	CS	R, S	W	C	1	INS,DAH	
N. ariommus- popeye shiner	Ex	V	S	Ex	--	1	INS,DAH	
N. asperifrons- burrhead shiner	P5	CS	S	W, D	O	1	INS,DAH	INT
N. atherinoides- emerald shiner	P5	CS	I, R, S	W	C	1	INS,AHI	
N. baileyi- rough shiner	P5	CS	S, H	W	C	2	INS,DAH	
N. boops- bigeye shiner	P5	CS	S, H	R	U	1	INS,DAH	INT
N. buccatus- silverjaw minnow	P5	CS	R, S	W	C	1	INS,AHI	
N. buchanani- ghost shiner	P2	CS	I, R	R	U	1	INS,DAH	INT
N. cahabae- Cahaba shiner	P1, E	E	R	R	R	3	INS,DAH	INT
N. candidus- silverside shiner	P5	CS	I, R	W	C	1	INS,DAH	
N. chalybaeus- ironcolor shiner	P1	V	S, Sp	W	U	1	INS,DAH	INT
N. chrosomus- rainbow shiner	P5	CS	H	W, D	O	2	INS,DAH	INT
N. cummingsae- dusky shiner	P2	CS	H, Sw	R	U	1	INS,DAH	INT
N. edwardraneyi- fluvial shiner	P5	CS	I, R	W	C	1	INS,AHI	
N. harperi- redeye chub	P5	CS	H, Sp	R	U	1	INS,DAH	INT
N. hypsilepis- highscale shiner	P3	CS	S, H	R	O	1	INS,DAH	INT
N. leuciodus- Tennessee shiner	P4	CS	S, H	R	O	2	INS,DAH	INT
N. longirostris- longnose shiner	P5	CS	R, S	W	C	1	INS,DAH	
N. maculatus- taillight shiner	P4	CS	S, Sw	W	U	3	INS,AHI	
N. melanostomus- blackmouth shiner	P1	V	S	R	R	2	INS	INT
N. micropteryx- highlands shiner	P3	CS	S	R	U	1	INS,DAH	INT
N. petersoni- coastal shiner	P5	CS	S	R	O	1	INS,DAH	
N. photogenis- silver minnow	P3	CS	S	R	U	1	INS,AHI	INT

FAMILY NAME Scientific name - common name	Cons. status	Vulner. Warren et al	Habitat	Dist.	Abund.	Reprod. guild	Feeding guild	Tolerance
N. stilbius- silverstripe shiner	P5	CS	S	W	C	1	INS,DAH	
N. telescopus- telescope shiner	P5	CS	S, H	R	O	1	INS,DAH	
N. texanus- weed shiner	P5	CS	I, R, S	W	C	1	INS,DAH	
N. uranoscopus- skygazer shiner	P3	CS	R	R	C	1	INS,DAH	INT
N. volucellus- mimic shiner	P5	CS	R, S	W	C	3	INS,AHI	
N. sp cf volucellus- Mobile basin form	P5	CS	R, S	W	C	3	INS,AHI	
N. wickliffi- channel shiner	P5	CS	I, R	R	U	3	INS,DAH	
N. xaenocephalus- Coosa shiner	P5	CS	S, H	R	C	1	INS,DAH	
N. sp cf spectrunculus (sawfin shiner)	P4	CS	S, H	R	U	1	INS,DAH	INT
Opsopoeodus emiliae- pugnose minnow	P5	CS	I, R, S	W	O	4	AHI	
Phenacobius catostomus- riffle minnow	P5	CS	R, S	W	O	1	INS	
P. mirabilis- suckermouth minnow	P1	CS	S	R	U	1	INS	INT
P. uranops- stargazing minnow	P2	CS	S	R	U	1	INS	INT
Phoxinus erythrogaster- southern redbelly dace	P5	CS	S, H	R	O	1	AHI	
Pimephales notatus- bluntnose minnow	P5	CS	R, S, H	W	C	4	DAH,INV	TOL
P. promelas- fathead minnow	P5	CS	I, R, S	I	U	4	DAH,INV	TOL
P. vigilax- bullhead minnow	P5	CS	I, R, S	W	C	4	DAH,INV	TOL
Pteronotropis euryzonus- broadstripe shiner	P2	V	S, Sw	R	O	1	INS,DAH	INT
P. grandipinnis- Apalachee shiner	P3	CS	S, H	W	C	1	INS,DAH	
P. hypselopterus- sailfin shiner	P5	CS	S, H	W	C	1	INS,DAH	
P. merlini- orangetail shiner	P4	CS	S, H	W	C	1	INS,DAH	
P. signipinnis- flagfin shiner	P5	CS	S, Sw	R	O	1	INS,DAH	
P. welaka- bluenose shiner	P2	V	S, Sw	W	U	1	INS,DAH	INT
Rhinichthys atratulus- blacknose dace	P5	CS	S, H, Sp	R	O	1	INS	TOL
Semotilus atromaculatus- creek chub	P5	CS	S, H, Sp	W	C	2	IP,INS	TOL
S. thoreauianus- Dixie chub	P5	CS	S, H, Sp	W	O	2	IP,INS	
CATOSTOMIDAE- SUCKERS								
Carpiodes carpio- river carpsucker	P5	CS	I, R	R	O	3	DAH,INV	
C. cyprinus- quillback	P5	CS	I, R	W	C	3	DAH,INV	
C. velifer- highfin carpsucker	P5	CS	I, R	W	C	3	DAH,INV	
Catostomus commersoni- white sucker	P5	CS	S, H, Sp	R	O	1	INV,AH	
Cycleptus elongatus- blue sucker	P3	V	I, R	R	U	1	AHI	INT
Cycleptus meridonalis- southeastern blue	P4	V	I,R	W	C	1	AHI	
Erimyzon oblongus- creek chubsucker	P5	CS	S, H	W	C	2	INV,AH	
E. sucetta- lake chubsucker	P5	CS	S, Sw	W	O	2	AHI	
E. tenuis- sharpfin chubsucker	P5	CS	S, Sw	W	O	2	AHI	

FAMILY NAME Scientific name - common name	Cons. status	Vulner. Warren et al	Habitat	Dist.	Abund.	Reprod. guild	Feeding guild	Tolerance
Hypentelium etowanum- Alabama hog sucker	P5	CS	R, S	W	C	1	AHI	
H. nigricans- northern hog sucker	P5	CS	R, S	R	C	1	AHI	
Ictiobus bubalus- smallmouth buffalo	P5	CS	I, R	W	C	3	INV	
I. cyprinellus- bigmouth buffalo	P5	CS	I, R	R	O	3	INV	
I. niger- black buffalo	P5	CS	I, R	R	O	3	INV	
Minytrema melanops- spotted sucker	P5	CS	I, R, S	W	C	1	INV,DAH	TOL
Moxostoma anisurum- silver redhorse	P5	CS	I, R, S	R	O	1	INV	
M. breviceps- smallmouth redhorse	P5	CS	I, R, S	R	O	1	INV	
M. carinatum- river redhorse	P5	CS	I, R	W	O	1	INV	INT
M. duquesnei- black redhorse	P5	CS	I, R, S	W	C	1	INV	
M. erythrurum- golden redhorse	P5	CS	I, R, S	W	C	1	INV	
M. lacerum- harelip sucker	Extinct	X	--	Extinct	--	1	INV	
M. poecilurum- blacktail redhorse	P5	CS	I, R, S	W	C	1	INV	
M. sp cf poecilurum- Apalachicola redhorse	P4	CS	I, R, S	R	O	1	INV	
Scartomyzon lachneri- greater jumprock	P5	CS	I, R, S	R	C	1	INV	
ICTALURIDAE- BULLHEAD CATFISHES								
Ameiurus brunneus- snail bullhead	P4	V	I, R, S	R	O	4	IP,DAH	
A. catus- white catfish	P4	CS	I, R, S	W	U	4	IP,DAH	
A. melas- black bullhead	P5	CS	R, S	W	O	4	AHI,PIS	TOL
A. natalis- yellow bullhead	P5	CS	I, R, S	W	C	4	AHI,PIS	TOL
A. nebulosus- brown bullhead	P5	CS	I, R, S, Sw	W	U	4	IP,DAH	TOL
A. serracanthus- spotted bullhead	P3	V	I, R	R	U	4	AHI,PIS	
Ictalurus furcatus- blue catfish	P5	CS	I, R	W	C	4	INV	
I. punctatus- channel catfish	P5	CS	I, R, S	W	C	4	INV	
Noturus sp cf elegans- Chucky madtom	Ex	T	R, S	Ex	--	4	INS,INV	INT
N. eleutherus- mountain madtom	P2	CS	R, S	R	R	4	INS,INV	INT
N. exilis- slender madtom	P5	CS	S	R	U	4	INS,AH	
N. funebris- black madtom	P5	CS	S, H	W	C	4	INV	
N. gyrinus- tadpole madtom	P5	CS	S, H	W	C	4	INS,INV	
N. leptacanthus- speckled madtom	P5	CS	S, H	W	C	4	INS	
N. miurus- brindled madtom	P2	CS	S	R	U	4	INS,INV	INT
N. munitus- frecklebelly madtom	P2	T	R, S	D	R	4	INS,INV	INT
N. nocturnus- freckled madtom	P5	CS	S	W	U	4	INS,INV	
N. sp. cf flavus- highlands stonecat	P2	CS	R, S	R	U	4	INS,AH,PIS	INT
Pylodictis olivaris- flathead catfish	P5	CS	I, R	W	O	4	IP	

FAMILY NAME Scientific name - common name	Cons. status	Vulner. Warren et al	Habitat	Dist.	Abund.	Reprod. guild	Feeding guild	Tolerance
ESOCIDAE-PIKES								
Esox americanus- redfin pickerel	P5	CS	S, H, Sw	W	O	3	IP	
E. masquinongy - muskellunge	Exotic	CS	I, R, S	I, R	R	3	IP	
E. niger- chain pickerel	P5	CS	I, R, S, Sw	W	O	3	IP	
SALMONIDAE- TROUTS								
Oncorhynchus mykiss- rainbow trout	Exotic	CS	S	I, R	U	1	IP	INT
Salmo trutta- brown trout	Exotic	CS	S	I, R	R	1	IP	INT
APREDODERIDAE- PIRATE PERCH								
Aphredoderus sayanus- pirate perch	P5	CS	S, H, Sw	W	O	4	INS, PIS	
AMBLYOPSIDAE- CAVEFISHES								
Speoplatyrhinos poulsoni- Alabama cavefish	P1, E	E	Ca	R	R	4	DAH,INV	INT
Typhlichthys subterraneus- southern cavefish	P3	V	Ca	R	U	4	DAH,INV	INT
MUGILIDAE								
Mugil cephalus- striped mullet	P5	CS	E, I, R	W	O	3	DAH,INV	
ATHERINOPSIDAE- NEW WORLD SILVERSIDES								
Labidesthes sicculus- brook silverside	P5	CS	I, R, S	W	C	3	INV	
Menidia audens- Mississippi silverside	P5	CS	E, R	R	O	3	INV	
M. beryllina- inland silverside	P5	CS	E, R	R	O	3	INV	
BELONIDAE- NEEDLEFISHES								
Strongylura marina- Atlantic needlefish	P5	CS	I, R	W	O	3	PIS	
FUNDULIDAE- TOPMINNOWS AND KILLIFISHES								
Fundulus albolineatus- whiteline topminnow	Extinct	X	--	Extinct	--		INV	
F. bifax- stippled topminnow	P3	V	R, S, Sw	R	O	1	INV	
F. blairae- western starhead topminnow	P4	CS	S, Sw	W	U	3	INV	
F. catenatus- northern studfish	P5	CS	S, H	R	O	1	INV	
F. chrysotus- golden topminnow	P4	CS	Sw	R	U	3	INS,INV	
F. cingulatus- banded topminnow	P4	CS	S, Sp, Sw	R	U	3	INV	
F. confluentus- marsh killifish	P3	CS	S, Sw	R	R	3	INV	
F. dispar- starhead topminnow	P3	CS	I, S, Sw	W	O	3	INV	
F. escambiae- russetfin topminnow	P5	CS	R, S, Sw	W	C	3	INV	
F. jenkinsi- saltmarsh topminnow	P3	CS	S, Sw	R	R	3	INV	
F. notatus- blackstripe topminnow	P5	CS	I, R, S, Sw	W	O	3	AHI	
F. nottii- bayou topminnow	P5	CS	I, R, S, Sw	W	C	3	AHI	
F. olivaceus- blackspotted topminnow	P5	CS	R, S, Sw, H	W	C	3	INV	
F. pulvereus- bayou killifish	P3	CS	R, Sw	R	U	3	INV	
F. stellifer- southern studfish	P5	CS	R, S	W	O	1	INV	

FAMILY NAME Scientific name - common name	Cons. status	Vulner. Warren et al	Habitat	Dist.	Abund.	Reprod. guild	Feeding guild	Tolerance
Leptolucania ommata- pygmy killifish	P4	CS	Sw	R	U	3	INS	
Lucania goodei- bluefin killifish	P3	CS	Sw, Sp	R	O	3	INS	
L. parva- rainwater killifish	P4	CS	E, Sw	R	O	3	INS	
POECILIIDAE- LIVEBEARERS								
Gambusia affinis- western mosquitofish	P5	CS	I, R, S, Sw, H	W	C	4	INS,AHI	TOL
G. holbrooki- eastern mosquitofish	P5	CS	I, R, S, Sw	W	C	4	INS,AHI	TOL
Heterandria formosa- least killifish	P4	CS	Sw	R	U	4	INS,AHI	
Poecilia latipinna- sailfin molly	P5	CS	Sw	R	O	4	INV	
CYPRINODONTIDAE- PUPFISHES								
Cyprinodon variegatus	P5	CS	Brackish	R	C	2	INV	
COTTIDAE- SCULPINS								
Cottus bairdi- mottled sculpin	P5	CS	S, H	R	O	2	INS,IP	
C. carolinae- banded sculpin	P5	CS	S, H, Sp	W	C	2	INS,IP	
C. sp. cf carolinae- Tallapoosa sculpin	P3	CS	S, H, Sp	W	C	2	IP	
C. paulus- pygmy sculpin	P1, T	E	Sp	R	R	2	INV	INT
MORONIDAE- TEMPERATE BASSES								
Morone chrysops- white bass	P5	CS	I, R	W	O	3	IP	
M. mississippiensis- yellow bass	P5	CS	I, R	W	O	3	IP	
M. saxatilis- striped bass	P3	CS	I, R	W	O	3	IP	
M. chrysops x saxatilis	--		I, R	W	O		IP	
CENTRARCHIDAE- SUNFISHES								
Ambloplites ariommus- shadow bass	P5	CS	R, S	W	O	2	IP	INT
A. rupestris- rock bass	P5	CS	R, S	R	O	2	IP	INT
Centrarchus macropterus- flier	P5	CS	R, S, Sw	W	U	4	INV	
Enneacanthus gloriosus- bluespotted sunfish	P4	CS	Sw	R	U	4	INV	
E. obesus- banded sunfish	P3	CS	Sw	R	U	4	INV	
Lepomis auritus- redbreast sunfish	P5	CS	I, R, S	W	C	2	INV	
L. cyanellus- green sunfish	P5	CS	R, S, H	W	C	2	IP	TOL
L. gulosus- warmouth	P5	CS	R, S. H	W	O	4	IP	
L. humilis- orangespotted sunfish	P5	CS	R, S	W	O	2	INV	
L. macrochirus- bluegill	P5	CS	I, R, S, H	W	C	2	INV	TOL
L. marginatus- dollar sunfish	P5	CS	R, S	W	O	2	INV	
L. megalotis- longear sunfish	P5	CS	I, R, S, H	W	C	2	INV	
L. microlophus- redear sunfish	P5	CS	I, R, S	W	C	2	INV	
L. miniatus- redspotted sunfish	P5	CS	R, S, H, Sw	W	C	2	INV	

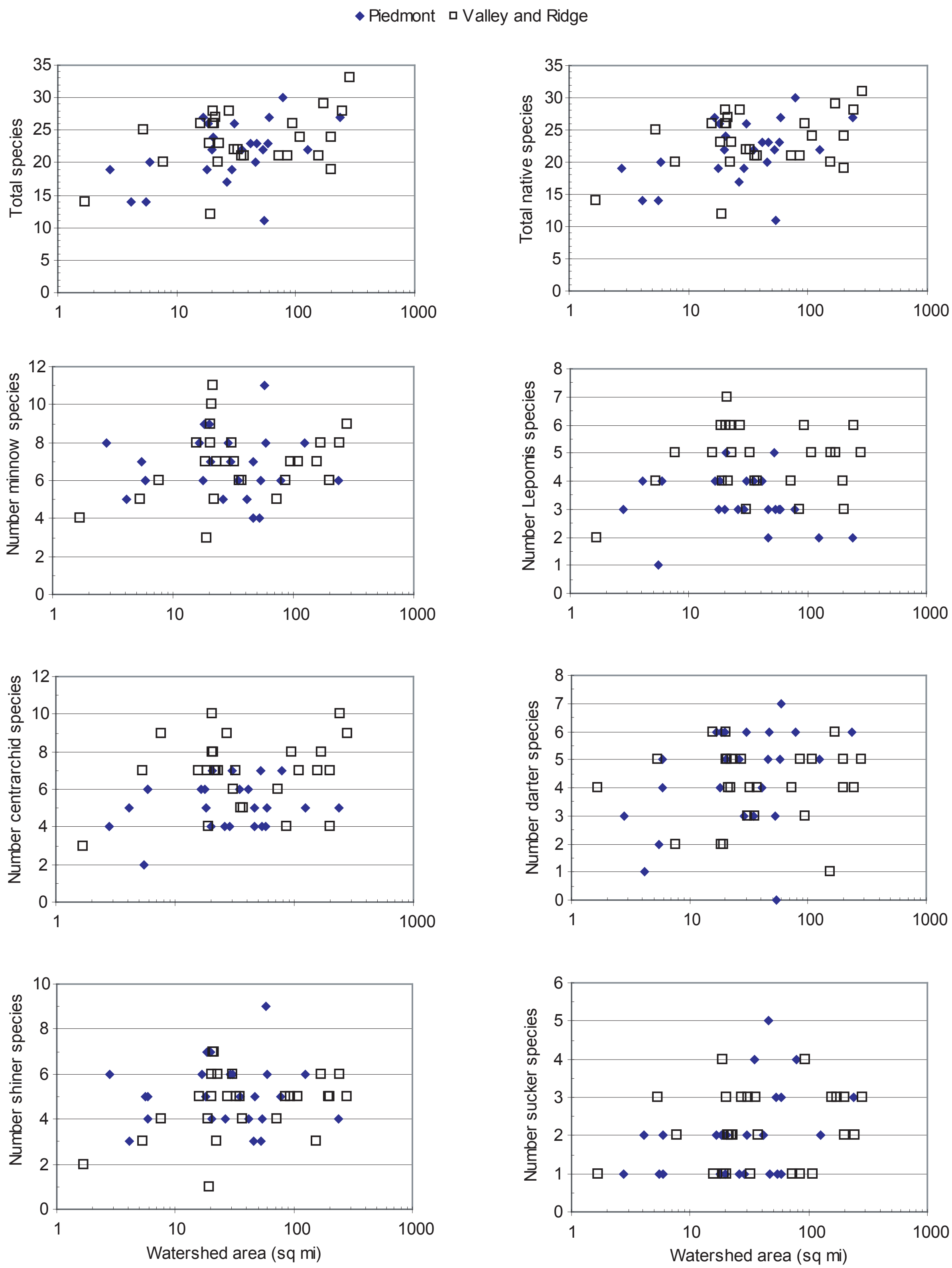
FAMILY NAME Scientific name - common name	Cons. status	Vulner. Warren et al	Habitat	Dist.	Abund.	Reprod. guild	Feeding guild	Tolerance
Micropterus cataractae- shoal bass	P2	V	I, R, S	R	O	2	IP	INT
M. coosae- redeye bass	P5	CS	R, S	R	C	2	IP	
M. dolomieui- smallmouth bass	P5	CS	I, R, S	R	C	2	IP	
M. punctulatus- spotted bass	P5	CS	I, R, S, H	W	C	4	IP	
M. salmoides- largemouth bass	P5	CS	I, R, S, Sw	W	C	4	IP	
Pomoxis annularis- white crappie	P5	CS	I, R, S	W	O	4	IP	
P. nigromaculatus- black crappie	P5	CS	I, R, S	W	O	4	IP	
PERCIDAE- DARTERS AND PERCHES								
Ammocrypta beanii- naked sand darter	P5	CS	R, S	W	O	1	INS	
A. bifascia- Florida sand darter	P5	CS	R, S	R	O	1	INS	
A. meridiana- southern sand darter	P5	CS	R, S	W	O	1	INS	
Crystallaria asprella- crystal darter	P3	V	R	W	U	1	INS	INT
Etheostoma artesiae- redspot darter	P5	CS	S, H	W	C	3	INS	
E. bellator- Warrior darter	P3	CS	S, H	R	U	3	INS	INT
E. sp. cf bellator- Locust Fork darter	P2	T	S, H	R	U	3	INS	INT
E. sp. cf bellator- Sipsey darter	P2	V	S, H	R	U	3	INS	INT
E. blennioides- greenside darter	P5	CS	R, S, H	R	O	3	INS	
E. blennius- blenny darter	P4	CS	S	R	U	1	INS	INT
E. boschungi- slackwater darter	P1, T	T	S, H	R	U	3	INS	INT
E. brevirostrum- holiday darter	P1	T	S, H	R	U	3	INS	INT
E. caeruleum- rainbow darter	P5	CS	S, H, Sp	R	C	1	INS	
E. camurum- bluebreast darter	P2	CS	R, S	R	U	1	INS	INT
E. chermocki- vermilion darter	P1, E	E	S, H, Sp	R	U	3	INS	INT
E. chlorosomum- bluntnose darter	P5	CS	S, H	W	O	3	INS	
E. chuckwachatte- lipstick darter	P2	V	S, H	R	O	1	INS	INT
E. cinereum- ashy darter	Ex	T	S	Ex	--	3	INS	INT
E. colorosum- coastal darter	P5	CS	S, H	R	C	3	INS	
E. coosae- Coosa darter	P5	CS	S, H	R	C	3	INS	
E. corona- crown darter	P5	V	S, H	R	C	4	INS	
E. crossopterum- fringed darter	P3	CS	S, H	R	O	4	INS	
E. davisoni- Choctawhatchee darter	P5	CS	S, H	R	O	4	INS	
E. ditrema- coldwater darter	P2	T	S, H, Sp	R	U	3	INS	INT
E. douglasi- Tuskaloosa darter	P3	CS	S, H	R	O	1	INS	INT
E. duryi- black darter	P5	CS	S, H	R	C	3	INS	
E. edwini- brown darter	P5	CS	S, H, Sw	W	O	3	INS	INT

FAMILY NAME Scientific name - common name	Cons. status	Vulner. Warren et al	Habitat	Dist.	Abund.	Reprod. guild	Feeding guild	Tolerance
E. flabellare- fantail darter	P5	CS	S, H	R	C	4	INS	
E. fusiforme- swamp darter	P5	CS	Sw, H	W	U	3	INS	
E. histrio- harlequin darter	P5	CS	R, S	W	U	3	INS	
E. jessiae- blueside darter	P4	CS	S, H	R	U	1	INS	
E. jordani- greenbreast darter	P5	CS	R, S, H	W	O	1	INS	INT
E. kennicotti- stripetail darter	P5	CS	S, H	R	O	4	INS	
E. lachneri- Tombigbee darter	P5	CS	S, H	W	C	3	INS	
E. lynceum- brighteye darter	P1	CS	S	R	U	3	INS	INT
E. neopterum- lollipop darter	P1	V	H	R	U	4	INS	INT
E. nigripinne- blackfin darter	P5	CS	S, H	R	C	4	INS	
E. nigrum- johnny darter	P5	CS	S, H	W	C	4	INS	
E. nuchale- watercress darter	P1, E	E	Sp	R	R	3	INS	INT
E. parvipinne- goldstripe darter	P5	CS	S, H	W	U	3	INS	
E. phytophilum- rush darter	P1	E	S, H	R	R	3	INS	INT
E. proeliare- cypress darter	P5	CS	H, Sw	W	O	3	INS	
E. ramseyi- Alabama darter	P5	CS	S, H	W	C	3	INS	
E. rufilineatum- redline darter	P5	CS	R, S	R	C	1	INS	
E. rupestre- rock darter	P5	CS	R, S	W	O	1	INS	
E. simoterum- snubnose darter	P5	CS	S, H	R	O	3	INS	
E. stigmaeum- speckled darter	P5	CS	S, H	W	C	1	INS	
E. swaini- gulf darter	P5	CS	S, H	W	O	3	INS	
E. tallapoosae- Tallapoosa darter	P4	CS	S, H	R	C	3	INS	
E. trisella- trispot darter	Ex	E	S,H	Ex	--	3	INS	INT
E. tuscumbia- Tuscumbia darter	P2	V	Sp	R	O	1	INS	INT
E. wapiti- boulder darter	P1, E	E	R, S	R	R	1	INS	INT
E. zonale- banded darter	P4	CS	R, S	R	O	3	INS	
E. zonifer- backwater darter	P5	CS	H, Sw	W	U	3	INS	
E. zonistium- bandfin darter	P2	CS	S, H	R	O	3	INS	INT
E. sp. cf zonistium- blueface darter	P2	T	S, H	R	U	3	INS	INT
Perca flavescens- yellow perch	P4	CS	I, R, S	W	O	3	IP	
P. aurolineata- goldline darter	P1, T	T	R, S	R-D	R	1	INS	INT
P. austroperca- southern logperch	P3	CS	R, S	R	U	1	INS	
P. brevicauda- coal darter	P2	T	R, S	R	U	1	INS	INT
P. burtoni- blotchside logperch	P1	V	R, S	R	R	1	INS	INT
P. caprodes- logperch	P5	CS	R, S	R	C	1	INS	

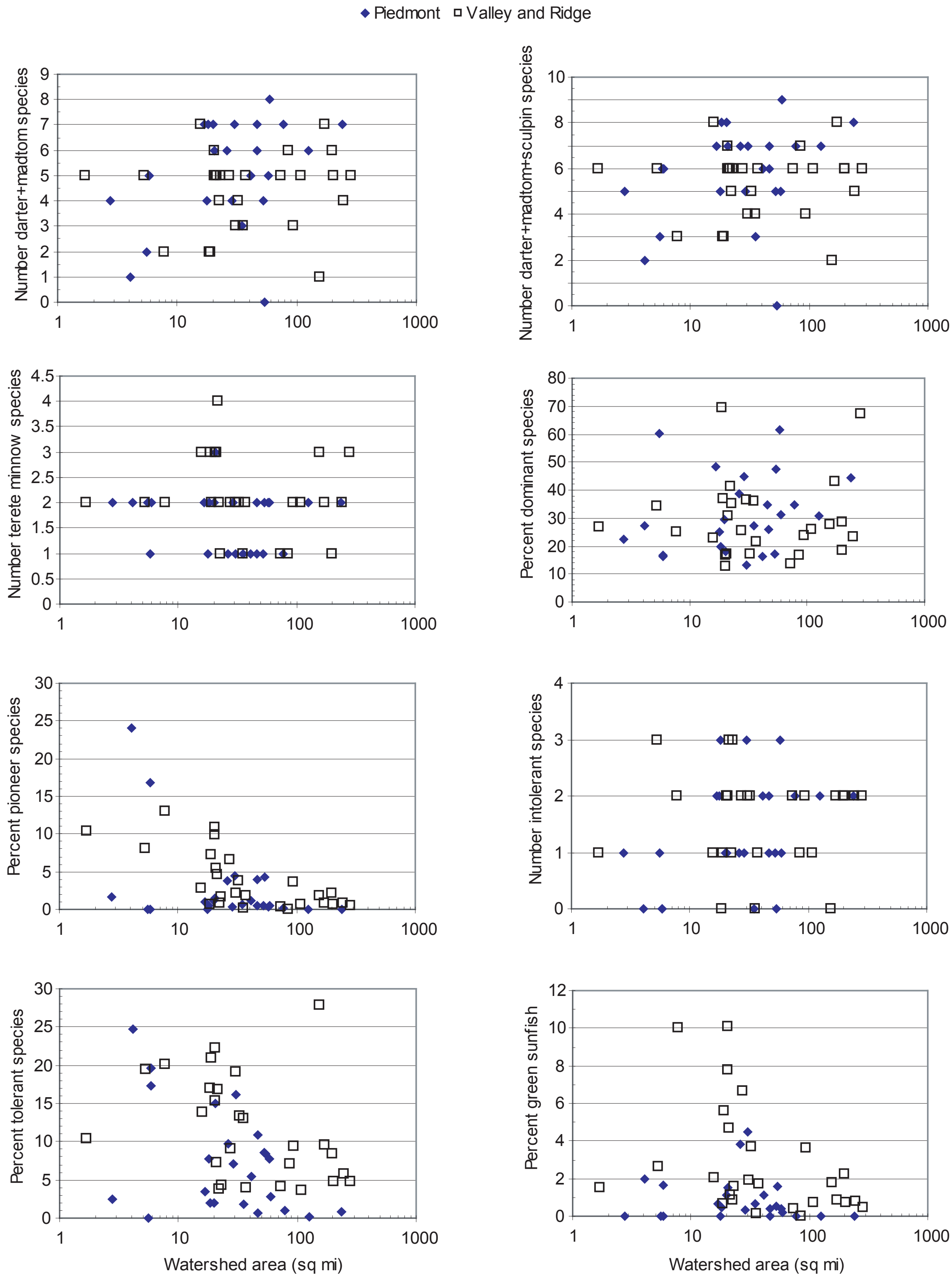
FAMILY NAME Scientific name - common name	Cons. status	Vulner. Warren et al	Habitat	Dist.	Abund.	Reprod. guild	Feeding guild	Tolerance
P. evides- gilt darter	P2	CS	R, S	R	U	1	INS	INT
P. kathae- Mobile logperch	P5	CS	R, S	W	O	1	INS	
P. lenticula- freckled darter	P3	T	R, S	W	U	1	INS	
P. maculata- blackside darter	P5	CS	S, H	W	U	1	INS	INT
P. nigrofasciata- blackbanded darter	P5	CS	R, S, H	W	C	1	INS	
P. palmaris- bronze darter	P5	CS	R, S	R	C	1	INS	
P. phoxocephala- slenderhead darter	P1	CS	R, S	R	U	1	INS	INT
P. sciera- dusky darter	P5	CS	R, S	W	O	1	INS	
P. shumardi- river darter	P5	CS	R, S	W	O	1	INS	
P. suttkusi- Gulf logperch	P5	CS	R, S	W	U	1	INS	
P. tanasi- snail darter	P1, T	T	R, S	R	R	1	INS,INV	INT
P. vigil- saddleback darter	P5	CS	R, S	W	O	1	INS	INT
P. sp cf macrocephala- muscadine darter	P3	V	R, S	R	U	1	INS	
P. sp cf macrocephala- Warrior bridled darter	P1	V	R, S	R	R	1	INS	INT
P. sp.- halloween darter	P1	V	R, S	R	U	1	INS	INT
Sander canadense- sauger	P5	CS	I, R	R	O	1	IP	
S. vitreus- walleye	P3	CS	I, R	W	U	1	IP	
SCIAENIDAE- DRUMS								
Aplodinotus grunniens- freshwater drum	P5	CS	I, R	W	C	3	INV	
ELASSOMATIDAE- PYGMY SUNFISHES								
Elassoma alabamae- spring pygmy sunfish	P1	E	Sw, Sp	R	R	4	INV,INS	INT
E. evergladei- Everglades pygmy sunfish	P4	CS	H, Sp	R	O	4	INV,INS	
E. zonatum- banded pygmy sunfish	P4	CS	S, H, Sw	W	C	4	INV,INS	
PARALICHTHYIDAE- SAND FLOUNDERS								
Paralichthys lethostigma- southern flounder	P5	CS	E, I, R	R	O	1	IP	
ACHIRIDAE- SOLES								
Trinectes maculatus- hogchoker	P5	CS	E, I, R	R	O	1	IP	

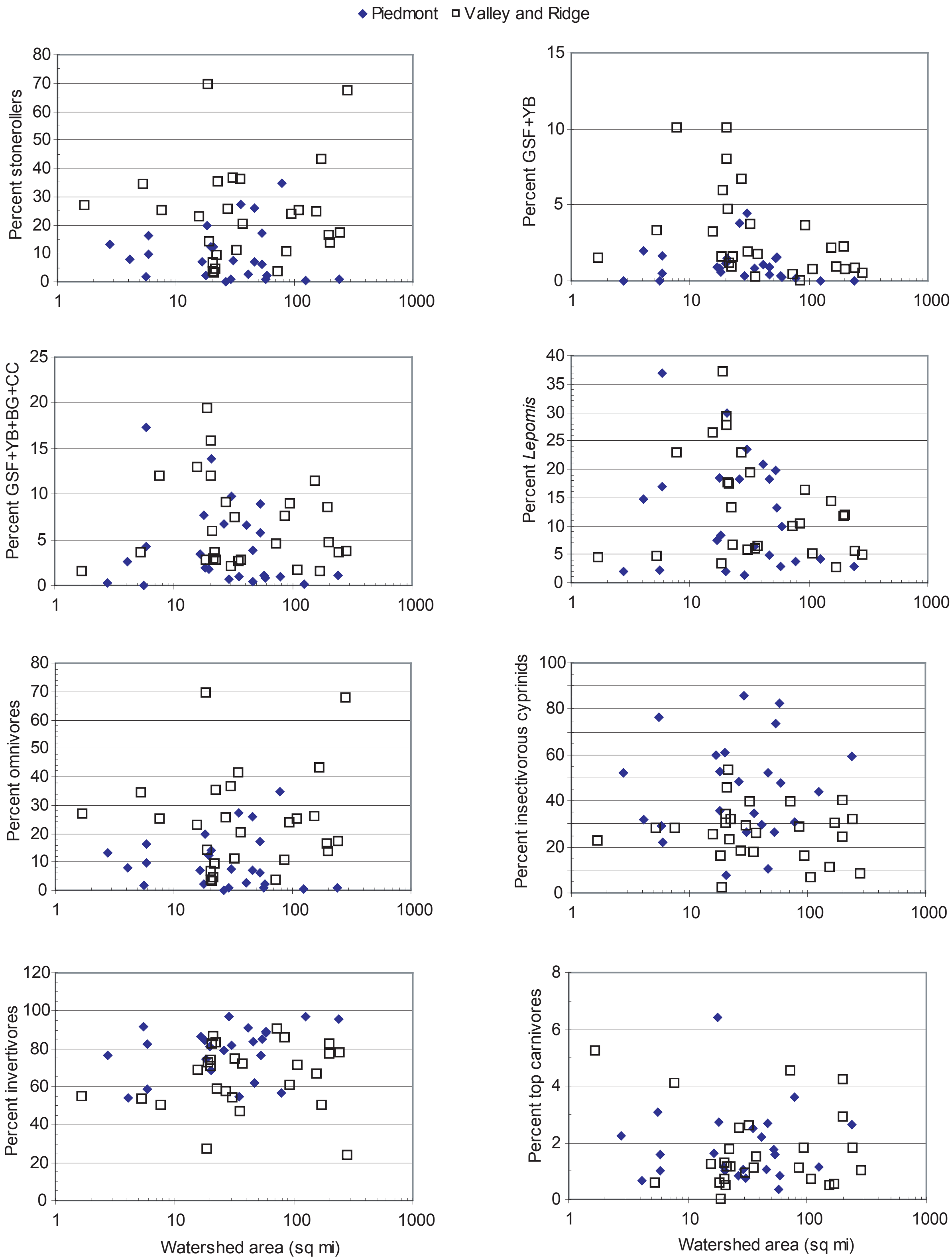
Appendix D

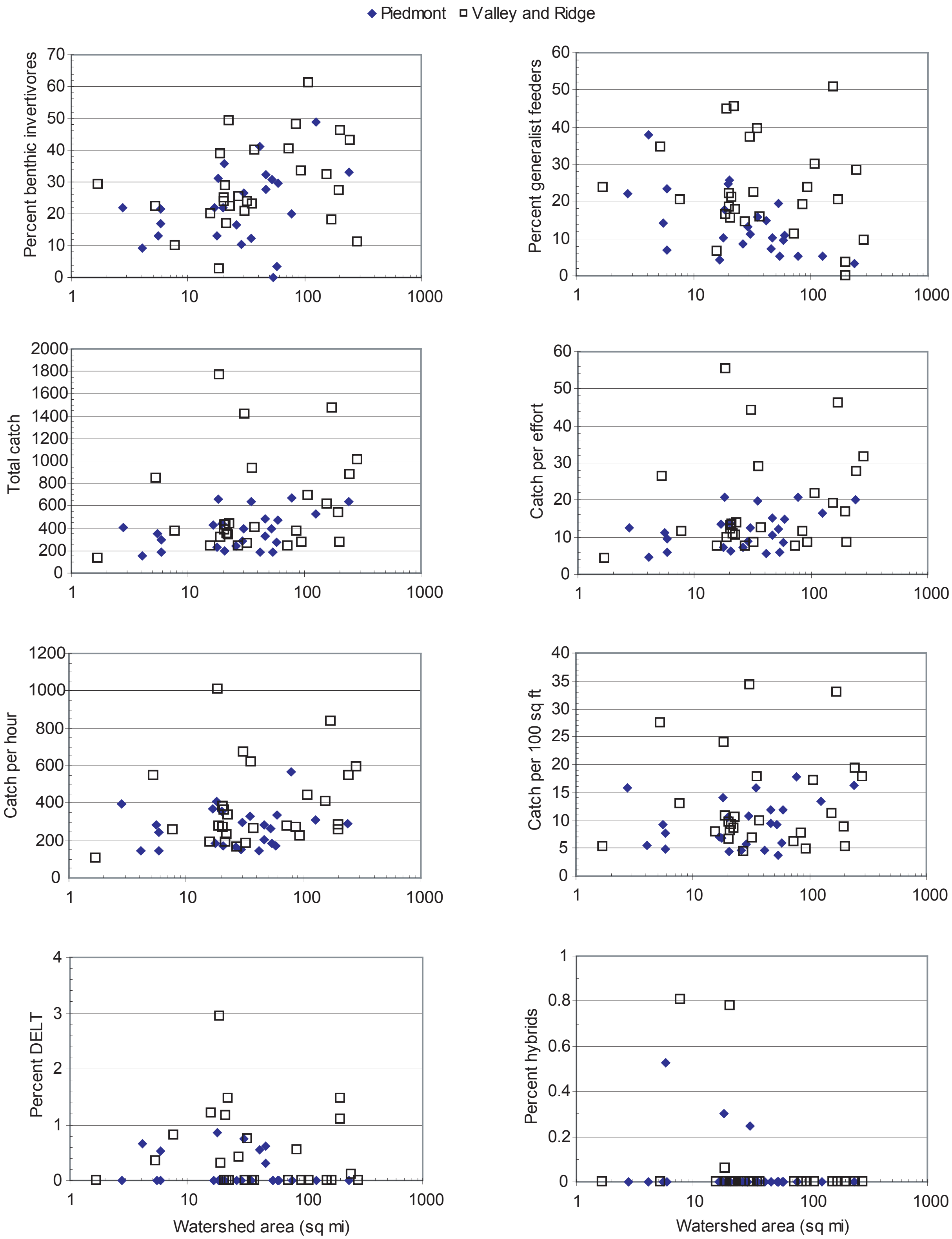
Plots of metric values versus watershed area for all candidate IBI metrics evaluated

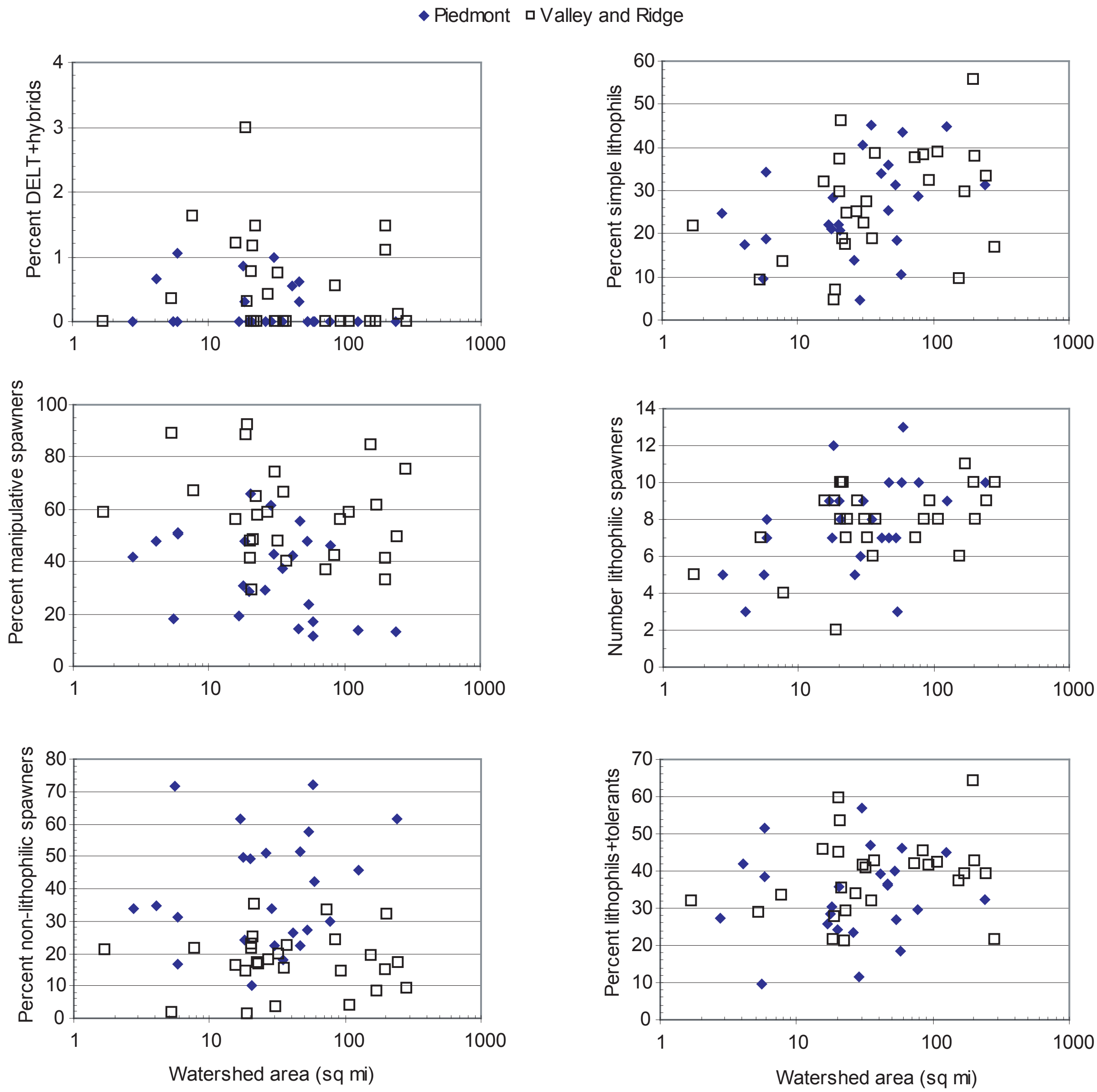


Piedmont
Valley and Ridge
Total species
Total native species
Number minnow species
Number Lepomis species
Number centrarchid species
Number darter species
Number shiner species
Number sucker species
Watershed area (sq mi)
Watershed area (sq mi)


Piedmont
Valley and Ridge
Number darter+madtom species
Number darter+madtom+sculpin species
Number terete minnow species
Percent dominant species
Percent pioneer species
Number intolerant species
Percent tolerant species
Percent green sunfish
Watershed area (sq mi)
Watershed area (sq mi)


◆ Piedmont ▫ Valley and Ridge
Percent stonerollers
0
10
20
30
40
50
60
70
80
Percent GSF+YB
0
5
10
15
Percent GSF+YB+BG+CC
0
5
10
15
20
25
Percent Lepomis
0
5
10
15
20
25
30
35
40
Percent omnivores
0
10
20
30
40
50
60
70
80
Percent insectivorous cyprinids
0
20
40
60
80
100
Percent invertivores
0
20
40
60
80
100
120
Percent top carnivores
0
2
4
6
8
1
10
100
1000
Watershed area (sq mi)
Watershed area (sq mi)


Piedmont
Valley and Ridge
Percent benthic invertivores
Percent generalist feeders
Total catch
Catch per effort
Catch per hour
Catch per 100 sq ft
Percent DELT
Percent hybrids
Watershed area (sq mi)
Watershed area (sq mi)


Piedmont
Valley and Ridge
Percent DELT+hybrids
Percent simple lithophils
Percent manipulative spawners
Number lithophilic spawners
Percent non-lithophilic spawners
Percent lithophils+tolerants
Watershed area (sq mi)
Watershed area (sq mi)
1
10
100
1000

Appendix E

Assessment forms for riffle/run and glide/pool habitats

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

Name of Waterbody ______________________ Date: ____________

Station Number ____________ Investigators ______________________

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

ADEM-FIELD OPERATIONS-MONTGOMERY BRANCH

GLIDE/POOL HABITAT ASSESSMENT FIELD DATA SHEET

Name of Waterbody ______________________________ Date: ______________

Station Number ______________ Investigators ______________________________

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

Appendix F

Collection results for fish samples in the Terrapin Creek system, 2003-05

(station numbers referenced in table 7 and depicted in figure 23)

Species	Common name	Station							
		TC-1a	TC-1b	TC-1c	TC-2	TC-3a	TC-3b	TC-3c	TC-4
Cyprinidae									
Campostoma oligolepis	largescale stoneroller	31	681	83	150	101	634	110	9
Cyprinella callistia	Alabama shiner	33	35	20	83	23	58	29	27
Cyprinella lutrensis	red shiner	12	8	11	--	--	--	--	--
Cyprinella trichroistia	tricolor shiner	1	7	2	59	12	52	47	33
Cyprinella venusta	blacktail shiner	9	17	18	5	3	5	5	--
Cyprinella hybrid	minnow hybrid	3	--	--	--	--	--	--	--
Cyprinus carpio	common carp	--	1	1	--	--	--	--	--
Luxilus chrysocephalus	striped shiner	--	--	2	19	34	116	26	--
Lythrurus bellus	pretty shiner	--	--	--	--	--	--	--	--
Lythrurus lirus	mountain shiner	--	--	--	--	--	--	--	--
Notropis asperifrons	burrhead shiner	--	--	--	--	--	--	--	--
Notropis chrosomus	rainbow shiner	--	--	--	--	--	--	--	--
Notropis stilbius	silverstripe shiner	49	8	11	93	76	201	200	7
Notropis xaenocephalus	Coosa shiner	1	--	--	4	1	1	--	30
Phenacobius catostomus	riffle minnow	10	7	48	18	1	17	7	--
Rhinichthys atratulus	blacknose dace	--	--	--	--	--	--	--	--
Semotilus atromaculatus	creek chub	--	--	--	--	--	--	--	--
Catostomidae									
Hypentelium etowanum	Alabama hog sucker	6	72	10	23	8	78	31	2
Moxostoma duquesnei	black redhorse	--	--	1	1	--	--	--	--
Moxostoma erythrurum	golden redhorse	--	2	--	--	--	5	3	--
Moxostoma poecilurum	blacktail redhorse	2	2	--	--	--	4	--	--
Ictaluridae									
Ameiurus natalis	yellow bullhead	--	--	--	--	1	--	--	--
Ictalurus punctatus	channel catfish	7	3	2	--	--	--	--	1
Noturus leptacanthus	speckled madtom	--	--	--	--	--	1	--	20
Fundulidae									
Fundulus stellifer	southern studfish	--	--	--	--	1	14	6	1
Poecilidae									
Gambusia affinis	western mosquitofish	8	3	2	1	2	2	4	--

Species	Common name	Station							
		TC-1a	TC-1b	TC-1c	TC-2	TC-3a	TC-3b	TC-3c	TC-4
Centrarchidae									
Ambloplites ariommus	shadow bass	--	1	--	5	2	1	1	5
Lepomis auritus	redbreast sunfish	17	8	19	12	15	3	23	5
Lepomis cyanellus	green sunfish	5	5	11	7	22	13	22	1
Lepomis gulosus	warmouth	4	--	1	--	1	--	--	--
Lepomis macrochirus	bluegill	58	29	19	24	14	10	19	9
Lepomis megalotis	longear sunfish	33	5	27	3	11	13	15	9
Lepomis microlophus	redear sunfish	2	--	--	1	--	--	--	--
Lepomis miniatus	redspotted sunfish	2	3	--	2	7	1	4	--
Lepomis hybrids	sunfish hybrids	--	--	--	--	--	--	--	--
Micropterus coosae	redeye bass	--	2	--	8	1	2	--	6
Micropterus punctulatus	spotted bass	2	5	3	1	--	5	1	--
Micropterus salmoides	largemouth bass	2	1	--	1	2	--	--	--
Percidae									
Etheostoma coosae	Coosa darter	--	--	--	--	4	1	1	--
Etheostoma jordani	greenbreast darter	11	22	8	75	37	63	66	18
Etheostoma stigmaeum	speckled darter	4	17	1	6	6	21	7	5
Percina kathae	Mobile logperch	5	3	1	--	--	1	--	--
Percina nigrofasciata	blackbanded darter	22	26	6	16	14	17	12	10
Percina palmaris	bronze darter	16	10	9	58	17	32	15	20
Percina shumardi	river darter	--	--	--	--	--	--	--	--
Sciaenidae									
Aplodinotus grunniens	freshwater drum	1	4	1	1	--	--	--	--
Cottidae									
Cottus carolinae	banded sculpin	5	18	11	206	54	106	64	25
Total specimens		363	1014	340	883	470	1477	719	244
Total species		29	33	31	28	27	29	25	21

Species	Common name	Station							
		TC-5	TC-6	LC-1	HC-1	HC-2	HC-3	LT-1	NC-1
Cyprinidae									
Campostoma oligolepis	largescale stoneroller	5	49	288	30	45	155	56	61
Cyprinella callistia	Alabama shiner	19	4	--	2	--	4	5	6
Cyprinella lutrensis	red shiner	--	--	--	--	--	--	--	--
Cyprinella trichroistia	tricolor shiner	11	43	3	46	--	67	20	16
Cyprinella venusta	blacktail shiner	10	--	--	--	--	--	2	5
Cyprinella hybrid	minnow hybrid	--	--	--	--	--	--	--	--
Cyprinus carpio	common carp	--	--	--	--	--	--	--	--
Luxilus chrysocephalus	striped shiner	--	--	85	16	--	7	--	1
Lythrurus bellus	pretty shiner	--	--	--	--	--	--	--	--
Lythrurus lirus	mountain shiner	--	--	--	--	--	--	--	--
Notropis asperifrons	burrhead shiner	--	--	--	--	--	--	--	--
Notropis chrosomus	rainbow shiner	--	--	146	--	7	1	--	--
Notropis stilbius	silverstripe shiner	14	12	--	34	--	3	10	15
Notropis xaenocephalus	Coosa shiner	--	7	--	5	--	58	25	--
Phenacobius catostomus	riffle minnow	--	--	--	3	--	--	1	1
Rhinichthys atratulus	blacknose dace	--	--	--	--	--	--	--	--
Semotilus atromaculatus	creek chub	--	46	46	--	5	--	2	--
Catostomidae									
Hypentelium etowanum	Alabama hog sucker	4	22	22	10	19	11	7	13
Moxostoma duquesnei	black redhorse	--	--	1	--	--	--	--	3
Moxostoma erythrurum	golden redhorse	1	8	1	--	--	4	--	--
Moxostoma poecilurum	blacktail redhorse	--	--	--	--	--	--	--	2
Ictaluridae									
Ameiurus natalis	yellow bullhead	--	--	6	--	1	--	3	--
Ictalurus punctatus	channel catfish	2	--	--	--	--	--	--	3
Noturus leptacanthus	speckled madtom	5	--	--	--	--	--	5	--
Fundulidae									
Fundulus stellifer	southern studfish	2	--	7	2	--	1	--	--
Poecilidae									
Gambusia affinis	western mosquitofish	--	--	3	--	--	--	--	2

Species	Common name	Station							
		TC-5	TC-6	LC-1	HC-1	HC-2	HC-3	LT-1	NC-1
Centrarchidae									
Ambloplites ariommus	shadow bass	3	--	1	1	--	1	--	1
Lepomis auritus	redbreast sunfish	13	19	14	19	53	13	22	19
Lepomis cyanellus	green sunfish	2	5	22	10	18	7	5	16
Lepomis gulosus	warmouth	--	--	--	--	--	1	1	2
Lepomis macrochirus	bluegill	8	8	2	10	43	5	24	3
Lepomis megalotis	longear sunfish	15	19	--	3	5	--	13	10
Lepomis microlophus	redear sunfish	--	--	--	--	--	--	--	--
Lepomis miniatus	redspotted sunfish	--	--	1	10	--	3	--	5
Lepomis hybrids	sunfish hybrids	--	--	--	--	--	--	--	--
Micropterus coosae	redeye bass	1	2	3	6	--	4	2	3
Micropterus punctulatus	spotted bass	--	1	1	--	--	--	1	2
Micropterus salmoides	largemouth bass	--	--	--	--	--	--	--	--
Percidae									
Etheostoma coosae	Coosa darter	--	46	2	5	3	2	1	4
Etheostoma jordani	greenbreast darter	30	--	35	10	--	17	1	6
Etheostoma stigmaeum	speckled darter	--	1	9	--	--	--	12	5
Percina kathae	Mobile logperch	5	1	--	--	3	3	10	--
Percina nigrofasciata	blackbanded darter	2	4	9	6	--	3	11	7
Percina palmaris	bronze darter	6	2	1	6	--	10	2	8
Percina shumardi	river darter	--	--	--	--	--	--	--	--
Sciaenidae									
Aplodinotus grunniens	freshwater drum	1	--	--	--	--	--	2	3
Cottidae									
Cottus carolinae	banded sculpin	23	3	130	34	118	60	4	19
Total specimens		183	302	841	269	320	440	247	241
Total species		23	20	25	22	12	23	26	28

Species	Common name	Station						
		NC-2a	NC-2b	NC-2c	NC-3	SF-1	SF-2a	SF-2b
Cyprinidae								
Campostoma oligolepis	largescale stoneroller	29	14	14	92	36	17	131
Cyprinella callistia	Alabama shiner	17	17	18	--	--	17	60
Cyprinella lutrensis	red shiner	--	--	--	--	--	--	--
Cyprinella trichroistia	tricolor shiner	72	74	47	55	14	98	87
Cyprinella venusta	blacktail shiner	2	3	1	--	--	--	--
Cyprinella hybrid	minnow hybrid	--	--	--	--	--	--	--
Cyprinus carpio	common carp	--	--	--	--	--	--	--
Luxilus chrysocephalus	striped shiner	11	3	16	19	--	--	--
Lythrurus bellus	pretty shiner	--	--	--	--	--	19	--
Lythrurus lirus	mountain shiner	--	1	--	--	--	13	3
Notropis asperifrons	burrhead shiner	--	--	--	--	--	31	32
Notropis chrosomus	rainbow shiner	--	--	--	5	--	3	4
Notropis stilbius	silverstripe shiner	26	71	20	--	--	14	9
Notropis xaenocephalus	Coosa shiner	6	8	--	24	16	7	34
Phenacobius catostomus	riffle minnow	11	17	15	--	--	4	8
Rhinichthys atratulus	blacknose dace	--	--	--	--	--	--	--
Semotilus atromaculatus	creek chub	3	3	8	11	12	--	--
Catostomidae								
Hypentelium etowanum	Alabama hog sucker	31	33	50	24	4	5	15
Moxostoma duquesnei	black redhorse	2	3	--	--	--	1	--
Moxostoma erythrurum	golden redhorse	1	--	--	1	--	1	7
Moxostoma poecilurum	blacktail redhorse	--	--	--	--	--	--	--
Ictaluridae								
Ameiurus natalis	yellow bullhead	--	--	1	--	--	2	1
Ictalurus punctatus	channel catfish	--	--	--	--	--	--	--
Noturus leptacanthus	speckled madtom	--	--	--	--	2	--	3
Fundulidae								
Fundulus stellifer	southern studfish	--	--	--	--	--	9	3
Poecilidae								
Gambusia affinis	western mosquitofish	--	--	1	--	--	--	--

Species	Common name	Station						
		NC-2a	NC-2b	NC-2c	NC-3	SF-1	SF-2a	SF-2b
Centrarchidae								
Ambloplites ariommus	shadow bass	1	--	1	3	--	1	--
Lepomis auritus	redbreast sunfish	44	25	24	37	4	21	17
Lepomis cyanellus	green sunfish	43	20	30	37	2	2	3
Lepomis gulosus	warmouth	1	1	1	2	--	--	--
Lepomis macrochirus	bluegill	8	5	30	7	--	23	9
Lepomis megalotis	longear sunfish	28	22	20	1	--	24	27
Lepomis microlophus	redear sunfish	--	1	--	--	--	--	--
Lepomis miniatus	redspotted sunfish	1	1	2	--	--	--	--
Lepomis hybrids	sunfish hybrids	--	--	3	3	--	--	2
Micropterus coosae	redeye bass	--	--	2	4	7	3	18
Micropterus punctulatus	spotted bass	--	--	1	1	--	--	--
Micropterus salmoides	largemouth bass	2	2	1	7	--	1	--
Percidae								
Etheostoma coosae	Coosa darter	3	11	12	14	12	16	8
Etheostoma jordani	greenbreast darter	33	27	21	--	1	22	58
Etheostoma stigmaeum	speckled darter	5	25	13	--	--	5	6
Percina kathae	Mobile logperch	--	--	--	1	7	2	8
Percina nigrofasciata	blackbanded darter	10	9	15	--	--	--	1
Percina palmaris	bronze darter	2	4	9	--	1	2	6
Percina shumardi	river darter	--	--	1	--	--	--	--
Sciaenidae								
Aplodinotus grunniens	freshwater drum	--	--	--	--	--	--	--
Cottidae								
Cottus carolinae	banded sculpin	34	28	10	21	16	27	102
Total specimens		426	428	387	369	134	390	662
Total species		26	26	28	20	14	28	26

Species	Common name	Station					
		SF-2c	SF-3a	SF-3b	SF-3c	CC-1	MC-1
Cyprinidae							
Campostoma oligolepis	largescale stoneroller	53	16	53	33	18	12
Cyprinella callistia	Alabama shiner	68	25	19	52	11	2
Cyprinella lutrensis	red shiner	--	--	--	--	--	--
Cyprinella trichroistia	tricolor shiner	98	101	90	173	9	41
Cyprinella venusta	blacktail shiner	--	--	--	--	--	--
Cyprinella hybrid	minnow hybrid	--	--	--	--	--	--
Cyprinus carpio	common carp	--	--	--	--	--	--
Luxilus chrysocephalus	striped shiner	6	4	2	13	--	--
Lythrurus bellus	pretty shiner	--	--	--	--	--	--
Lythrurus lirus	mountain shiner	9	--	--	--	--	--
Notropis asperifrons	burrhead shiner	22	6	6	8	1	--
Notropis chrosomus	rainbow shiner	1	28	30	183	--	--
Notropis stilbius	silverstripe shiner	3	--	--	--	12	--
Notropis xaenocephalus	Coosa shiner	18	31	64	161	22	5
Phenacobius catostomus	riffle minnow	13	--	--	--	--	--
Rhinichthys atratulus	blacknose dace	--	--	--	1	--	--
Semotilus atromaculatus	creek chub	2	3	7	30	--	33
Catostomidae							
Hypentelium etowanum	Alabama hog sucker	13	12	25	26	10	20
Moxostoma duquesnei	black redhorse	1	--	--	2	--	--
Moxostoma erythrurum	golden redhorse	6	--	--	3	--	1
Moxostoma poecilurum	blacktail redhorse	--	--	--	--	--	--
Ictaluridae							
Ameiurus natalis	yellow bullhead	1	--	--	--	1	--
Ictalurus punctatus	channel catfish	--	--	--	--	--	--
Noturus leptacanthus	speckled madtom	1	2	5	1	3	--
Fundulidae							
Fundulus stellifer	southern studfish	2	6	3	7	--	--
Poecilidae							
Gambusia affinis	western mosquitofish	2	--	--	--	--	--

Species	Common name	Station					
		SF-2c	SF-3a	SF-3b	SF-3c	CC-1	MC-1
Centrarchidae							
Ambloplites ariommus	shadow bass	1	--	--	--	--	--
Lepomis auritus	redbreast sunfish	23	17	5	15	28	4
Lepomis cyanellus	green sunfish	5	1	--	1	--	3
Lepomis gulosus	warmouth	--	--	--	--	--	--
Lepomis macrochirus	bluegill	18	8	1	3	32	1
Lepomis megalotis	longear sunfish	32	11	2	5	9	14
Lepomis microlophus	redear sunfish	--	--	--	--	1	--
Lepomis miniatus	redspotted sunfish	--	--	--	--	--	--
Lepomis hybrids	sunfish hybrids	--	--	--	--	1	--
Micropterus coosae	redeye bass	5	12	9	24	2	1
Micropterus punctulatus	spotted bass	--	--	--	--	--	--
Micropterus salmoides	largemouth bass	--	--	--	--	1	--
Percidae							
Etheostoma coosae	Coosa darter	7	16	23	38	7	9
Etheostoma jordani	greenbreast darter	37	--	--	--	--	--
Etheostoma stigmaeum	speckled darter	2	4	2	--	8	--
Percina kathae	Mobile logperch	2	3	3	8	4	--
Percina nigrofasciata	blackbanded darter	--	--	--	1	8	--
Percina palmaris	bronze darter	6	--	--	--	--	--
Percina shumardi	river darter	--	--	--	--	--	--
Sciaenidae							
Aplodinotus grunniens	freshwater drum	--	--	--	--	--	--
Cottidae							
Cottus carolinae	banded sculpin	76	48	56	51	2	4
Total specimens		533	354	405	840	190	150
Total species		30	20	19	24	20	14

Appendix G

Water-quality data collected in Terrapin Creek, 2003-05

Parameter	Units	LLD	Terrapin Creek at Co. Hwy. 71 (TC-1)								
Date			6-May-03	10-Jun-03	7-Aug-03	11-Sep-03	18-Sep-03	23-Sep-03	2-Oct-03	21-Jan-04	18-Mar-04
Time	24hr		11:30	12:00	14:45	11:40	8:30	11:30	11:30	13:30	14:00
Stream discharge	cfs		7,000	266	781	144	130	300	147	206	286
Temperature	°C		19	24	24	23	21	20	17	7	15
Dissolved oxygen	mg/L		8.7	8.3	7.7	8.8	8.0	7.9	9.5	12.1	9.9
BOD 5-day	mg/L		5.5	0.6	1.6	0.5	0.9	1.3	0.9	1.6	0.8
Specific conductance	µS/cm	1	35	129	85	185	167	176	170	144	133
Turbidity	NTU	1	357	10	90	9	2	39	4	2	14
TSS	mg/L	4	nd	9	30	8	5	43	5	7	11
Bedload	tons/day										
pH	s.u.		6.5	7.8	7.4	7.9	7.8	7.7	8.1	7.0	7.9
Carbonate	mg/L	1	<1	<1	<1	1	<1	<1	1	<1	<1
TDS	mg/L		24	69	55	97	101	98	90	83	67
Hardness	mg/L $CaCO_3$		17	63	44	86	90	87	80	79	64
Alkalinity	mg/L $CaCO_3$	3	9	54	37	86	91	86	78	63	51
Ammonia	mg/L as N	0.02	0.06	0.04	0.06	<.02	<.02	0.02	<.02	<.02	<.02
Nitrite	mg/L as N	0.010	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Nitrate	mg/L as N	0.020	0.166	0.285	0.185	0.242	0.318	0.366	0.219	0.265	0.210
Nitrite+Nitrate	mg/L as N	0.020	0.166	0.285	0.185	0.242	0.318	0.366	0.219	0.265	0.210
TKN	mg/L	0.10	1.60	0.19	0.51	<.1	<.1	0.28	0.20	0.23	<.1
Total phosphorus	mg/L as P	0.120	<.12	<.12	0.130	0.120	<.12	0.220	<.12	<.12	0.220
Orthopsosphate	mg/L as P	0.02	0.07	<.02	0.04	<.02	<.02	0.06	<.02	<.02	0.08
Silica	mg/L	0.05	4.26	7.31	9.04	7.27	7.86	7.40	8.39	6.83	5.70
Calcium	mg/L	0.0	4.40	14.7	10.6	20.5	21.3	20.6	18.9	19.1	15.6
Magnesium	mg/L	0.04	1.39	6.33	4.17	8.46	9.02	8.50	7.98	7.47	6.18
Sodium	mg/L	0.05	1.07	1.62	1.59	1.53	1.53	1.37	1.50	1.97	1.66
Potassium	mg/L	0.50	2.00	0.70	1.58	0.75	0.75	1.45	0.77	1.09	0.71
Sulfate	mg/L	0.00	3.18	3.02	2.77	2.50	2.42	2.99	2.43	4.88	3.79
Chloride	mg/L	0.05	1.46	2.02	2.34	2.21	2.28	2.48	1.96	2.51	2.23
Bromide	mg/L	0.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
Fluoride	mg/L	0.02	0.03	0.03	0.03	0.03	0.03	0.04	0.03	<.02	0.02
Aluminum	µg/L	60	313	<60	112	<60	<60	<60	<60	<60	<60
Arsenic	µg/L	3	<3	<3	<3	<3	<3	<3	<3	<3	<3
Boron	µg/L	10	25	<10	<10	<10	<10	<10	<10	<10	<10
Barium	µg/L	2.0	78.6	21.2	22.7	25.8	19.2	24.7	37.8	14.3	24.7
Beryllium	µg/L	1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cadmium	µg/L	4	<4	<4	<4	<4	<4	<4	<4	<4	<4
Cobalt	µg/L	7	<7	<7	<7	<7	<7	<7	<7	<7	<7
Chromium	µg/L	0.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	8
Copper	µg/L	8	<8	<8	<8	<8	<8	<8	<8	8	<8
Iron	µg/L		347	292	256	165	46.2	71.3	69	104	121
Mercury	µg/L	0.06	<.06	<.06	<.06	<.06	<.06	<.06	<.06	<.06	<.06
Lithium	µg/L	5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Manganese	µg/L	2.0	43.3	22.5	14.4	22.7	17.7	12.9	15.2	16.8	27.4
Molybdenum	µg/L	20	<20	<20	<20	<20	<20	<20	<20	<20	<20
Nickel	µg/L	10	18	<10	39	<10	<10	<10	<10	<10	<10
Lead	µg/L	2.0	2.7	<2	4.7	<2	16.4	<2	<2	<2	<2
Sb	µg/L	3.0	<3	<3	<3	<3	<3	<3	<3	<3	<3
Selenium	µg/L	3.0	<3	<3	<3	<3	<3	<3	<3	<3	<3
Silver	µg/L	10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Tin	µg/L	50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Strontium	µg/L	1.0	8.2	34.1	23.9	38.8	40.9	39.4	37.0	42.7	34.6
Titanium	µg/L	4	<4	<4	<4	<4	<4	<4	<4	<4	<4
Thallium	µg/L	2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Vanadium	µg/L	4	<4	<4	<4	<4	<4	<4	<4	<4	<4
Zinc	µg/L	4.0	24.8	6.5	20.5	19.6	<4	5.8	5.6	<4	7.7
COD	mg/L	30	235	52	135	146	130	320	110	68	362
Cyanide	mg/L	0.003	<.003	<.003	<.003	<.003	<.003	<.003	<.003	0.004	<.003
Total phenolics	mg/L	3.0	<3	<3	6.0	<3	<3	3.2	<3	<3	<3
Total organic carbon	mg/L	0.40	10.40	1.07	4.33	0.85	2.38	4.04	0.00	0.00	1.15
Chlorophyll *a*	mg/L	0.0002	0.0034	0.0014	0.0023	0.0014	0.0014	0.0035	0.0007	0.0009	0.0019
Fecal coliform	no./100 mL		8,200	44	4,400	100	70	5,600	nd	nd	nd
Fecal streptococcus	no./100 mL		31,600	32	4,600	210	250	27,000	nd	nd	nd

Parameter	Units	LLD	Terrapin Creek at Co. Hwy. 8 (TC-3)								
Date			6-May-03	10-Jun-03	7-Aug-03	11-Sep-03	18-Sep-03	22-Sep-03	2-Oct-03	21-Jan-04	18-Mar-04
Time	24hr		10:30	10:30	13:30	10:30	9:10	16:10	10:45	11:00	12:30
Stream discharge	cfs		4,130	165	304	73	64	156	75	110	162
Temperature	°C		18	21	24	21	19	21	15	5	15
Dissolved oxygen	mg/L		8.3	8.2	7.9	8.6	8.2	7.0	9.5	12.4	11.3
BOD 5-day	mg/L		2.9	0.5	1.0	0.6	0.8	4.1	0.8	2.6	0.8
Specific conductance	µS/cm	1	25	101	56	147	143	171	137	113	109
Turbidity	NTU	1	200	3	30	2	2	91	1	4	6
TSS	mg/L	4	nd	5	22	0	0	119	4	0	6
Bedload	tons/day										
pH	s.u.		6.3	7.4	7.0	7.5	7.7	7.6	7.7	6.8	7.9
Carbonate	mg/L	1	<1	<1	<1	<1	<1	<1	<1	<1	<1
TDS	mg/L		20	57	43	81	88	93	76	67	58
Hardness	mg/L $CaCO_3$		12	46	28	65	71	78	62	61	51
Alkalinity	mg/L $CaCO_3$	3	5	39	24	66	73	79	58	44	40
Ammonia	mg/L as N	0.02	0.03	0.03	0.03	0.02	<.02	<.02	<.02	0.02	0.02
Nitrite	mg/L as N	0.010	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Nitrate	mg/L as N	0.020	0.096	0.294	0.153	0.348	0.422	0.362	0.331	0.293	0.203
Nitrite+Nitrate	mg/L as N	0.020	0.096	0.294	0.153	0.348	0.422	0.362	0.331	0.293	0.203
TKN	mg/L	0.10	0.79	0.23	0.15	0.13	0.20	0.98	0.17	0.33	<.1
Total phosphorus	mg/L as P	0.120	<.12	<.12	<.12	<.12	<.12	0.210	<.12	0.120	<.12
Orthopsosphate	mg/L as P	0.02	0.06	<.02	<.02	<.02	<.02	0.08	<.02	<.02	0.04
Silica	mg/L	0.05	5.18	9.32	11.40	9.56	9.62	7.86	10.50	8.45	7.76
Calcium	mg/L	0.0	2.80	10.6	6.58	14.7	16.3	18.7	14.1	14.4	11.9
Magnesium	mg/L	0.04	1.21	4.84	2.87	6.75	7.37	7.55	6.46	6.07	5.15
Sodium	mg/L	0.05	0.86	1.91	1.67	2.13	2.15	1.62	2.10	2.35	1.98
Potassium	mg/L	0.50	1.30	0.69	0.59	0.97	0.95	1.96	1.07	0.86	0.68
Sulfate	mg/L	0.00	3.80	3.27	2.62	3.33	3.24	3.75	3.39	4.85	4.02
Chloride	mg/L	0.05	0.87	1.86	1.44	2.36	2.35	2.36	2.19	2.32	2.08
Bromide	mg/L	0.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
Fluoride	mg/L	0.02	<.02	0.03	0.04	0.04	0.04	0.05	0.04	0.03	0.03
Aluminum	µg/L	60	241	66	<60	<60	<60	67	<60	<60	<60
Arsenic	µg/L	3	<3	<3	<3	<3	<3	<3	<3	<3	<3
Boron	µg/L	10	16	<10	<10	<10	<10	<10	10	<10	<10
Barium	µg/L	2.0	40.9	18.6	21.8	21.4	17.8	23.0	22.5	22.5	40.8
Beryllium	µg/L	1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cadmium	µg/L	4	<4	<4	<4	<4	<4	<4	<4	<4	<4
Cobalt	µg/L	7	<7	<7	<7	<7	<7	<7	<7	<7	<7
Chromium	µg/L	0.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Copper	µg/L	8	<8	<8	<8	<8	10	<8	<8	<8	<8
Iron	µg/L		235	333	415	228	131	135	206	166	165
Mercury	µg/L	0.06	<.06	<.06	<.06	<.06	<.06	<.06	<.06	<.06	<.06
Lithium	µg/L	5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Manganese	µg/L	2.0	33.9	26.0	21.1	22.6	18.6	24.5	21.5	19.4	21.1
Molybdenum	µg/L	20	<20	<20	<20	<20	<20	<20	<20	<20	<20
Nickel	µg/L	10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Lead	µg/L	2.0	<2	<2	7.6	<2	7.9	<2	<2	<2	<2
Sb	µg/L	3.0	<3	<3	<3	<3	<3	<3	<3	<3	<3
Selenium	µg/L	3.0	<3	<3	<3	<3	<3	<3	<3	<3	<3
Silver	µg/L	10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Tin	µg/L	50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Strontium	µg/L	1.0	6.8	49.0	25.7	56.6	59.6	56.9	51.8	49.4	39.8
Titanium	µg/L	4	<4	<4	<4	<4	<4	<4	<4	<4	<4
Thallium	µg/L	2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Vanadium	µg/L	4	<4	<4	<4	<4	<4	<4	<4	<4	<4
Zinc	µg/L	4.0	8.1	8.2	16.7	13.2	11.9	12.1	6.1	9.4	14.2
COD	mg/L	30	197	48	854	182	165	421	119	75	302
Cyanide	mg/L	0.003	<.003	<.003	<.003	<.003	<.003	<.003	<.003	<.003	<.003
Total phenolics	mg/L	3.0	<3	<3	4.9	<3	<3	<3	<3	<3	<3
Total organic carbon	mg/L	0.40	7.77	1.69	3.63	2.18	2.40	4.52	1.77	1.70	1.96
Chlorophyll *a*	mg/L	0.0002	0.0027	0.0007	0.0028	0.0024	0.0026	0.0331	0.0030	0.0039	0.0019
Fecal coliform	no./100 mL		4,900	144	780	118	170	5,200	nd	nd	nd
Fecal streptococcus	no./100 mL		24,500	240	1,200	200	160	8,400	nd	nd	nd

GEOLOGICAL SURVEY OF ALABAMA
P.O. Box 869999
420 Hackberry Lane
Tuscaloosa, Alabama 35486-6999
205/349-2852

Berry H. (Nick) Tew, Jr., State Geologist

A list of the printed publications by the Geological Survey of Alabama can be obtained from the Publications Sales Office (205/247-3636) or through our web site at http://www.gsa.state.al.us/.

E-mail: info@gsa.state.al.us