GEOLOGICAL SURVEY OF ALABAMA

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STATUS SURVEY OF THE TUSCUMBIA DARTER (*Etheostoma tuscumbia*) ON AND NEAR REDSTONE ARSENAL, ALABAMA
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By

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With assistance from
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CONTENTS

FIGURES

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ABSTRACT

During this study qualitative collections for presence/absence were made at 98 locations within and peripheral to the historic range of the Tuscumbia Darter in an effort to document its current status and to locate new populations. Approximately 120 person hours were spent sampling, with techniques and gear appropriate for personnel available and conditions present. Sampling effort for long-term quantitative sampling at one location, Williams Spring on Redstone Arsenal, and a single sampling event of unknown effort by several workers from different agencies at another location, Byrd Spring, is not included in that total. Collections were made at historic collection locations and at other locations that appeared to have appropriate habitat for the species. The darter was found to be present at 18 of 33 historic locations visited and was found at 8 of 61 new locations visited. Four historic locations visited were not sampled as they have been inundated by the Tennessee River. All new collection locations were on Redstone Arsenal, mostly at the foot of low ridges along the margins of backwaters of Wheeler Reservoir. These locations were found where pre-impoundment springs were located but maintain sufficient characteristics of spring environments, including temperature regimes and vegetation, to permit this habitat-specific species to persist.

INTRODUCTION

The Tuscumbia Darter, *Etheostoma tuscumbia*, was described by Gilbert and Swain in 1887 and named for the type locality, Tuscumbia (Big) Spring, in Tuscumbia, Colbert County, Alabama. It is potentially sympatric with members of the *Etheostoma squamiceps* species complex (*E. crossopterum*, *E. neopterum*, and *E. nigripinne*) based on pigmentation patterns and body form, but is in the monotypic subgenus *Psychromaster* (Boschung and Mayden, 2004). It is also possibly sympatric with *E. parvipinne* in the area adjacent to Pickwick Reservoir (Etnier and Starnes, 1993; Mettee and others, 1996).

The Tuscumbia Darter is restricted to valley floor springs in the Highland Rim Physiographic Section of northern Alabama and southern middle Tennessee. However, the only known populations in Tennessee were single collections from springs now inundated by Pickwick Reservoir (impounded since 1938) and it may be extirpated from that state (Bailey and Richards, 1963; Etnier and Starnes, 1993; Mettee and others, 1996; Boschung and Mayden, 2004). The Tuscumbia Darter was considered a species of special concern by Ramsey (1986) and recently was listed as a priority 2 species (High Conservation Concern) in Alabama (Kuhajda, 2004). The latter determination was due to the loss of many of the known historic localities due to impoundment of the Tennessee River and degradation of other spring habitats by removal of aquatic vegetation, dewatering, excessive sedimentation, agricultural use of springs, and small impoundments (Mettee and others, 1996; Kuhajda, 2004). Boschung and Mayden (2004) recommended a status of Threatened due to the species' restriction to spring environments and the extreme vulnerability of springs to developmental degradation.

Tuscumbia Darters live among aquatic vegetation in ponded areas of limestone springs under mats of vegetation such as milfoil, watercress, and algae. Adult Tuscumbia Darters attain lengths of about 67 mm. Their diet consists of physid snails, amphipods, midge larvae, isopods, and crayfishes (Koch, 1978; Etnier and Starnes, 1993; Mettee and others, 1996; Boschung and Mayden, 2004). In some springs both males and females burrow into gravel during spawning and eggs are deposited in the substratum, while in other springs eggs are attached to vegetation (Boschung and Mayden, 2004). Koch (1978) reported the species to be diurnal in Buffler (King) Spring, Lauderdale County. He reported gravid females and ripe males year-round, with no well-defined spawning peak. However, he reported increased spawning activity from January to March. Boyce (1997) studied Tuscumbia Darters from several populations across the range of the species and found it to be a composite of two distinct life history strategies varying among allopatric populations, and that it may represent a complex of different evolutionary lineages with divergent life history strategies. She suggested that divergence be considered for any future management plans for the species.

During 1966-1967 personnel from the University of Alabama (UA) Department of Biological Sciences surveyed 68 springs in the southern bend of the Tennessee River in Alabama and Tennessee using minnow seines, in order to evaluate the compositions of their fish faunas (Armstrong and Williams, 1971). They reported a total of 47 species of fish including the Tuscumbia Darter. The Tuscumbia Darter was found in six of the springs sampled.

A Tuscumbia Darter survey across its range coupled with a monitoring effort among several known populations therein was executed from May 1993 to May 1995 (Jones and others, 1995). Their study included 10 standard (previously documented) populations, which were monitored, and 9 new (previously undocumented) populations that were discovered during their study. They reported that four of the standard populations were stable and six were in various states of conservation concern, based on observed habitat degradation and evaluations of catch per unit effort (CPUE) and catch per unit time (CPUT). With less vigorous sampling of the new populations, they were only able to offer limited comments on their respective statuses and found that two appeared stable and three were moderately healthy.

The Alabama Natural Heritage Program conducted a study of the Tuscumbia Darter population in Williams Spring on Redstone Arsenal, one of the new populations reported by Jones and others (1995) (Godwin, 1999). That study consisted of four seasonal sampling efforts to determine percentage of substrate types, composition of fish and aquatic invertebrate faunas, and information on habitats within and around the spring. The Tuscumbia Darter was the most abundant of six fish species encountered, yielding 13 of the 32 (41%) fish collected. The estimated density of Tuscumbia Darters was found to be 4.0/ft^2 (0.37/m^2).

In 1999 the Geological Survey of Alabama (GSA) entered into a single-year contract with the Cultural and Environmental Resources Directorate at the U.S. Army Garrison at Redstone Arsenal (RSA) to assess the fish fauna in Williams Spring and to attempt to document other Tuscumbia Darter populations on RSA property. No additional populations were encountered (McGregor and others, 2000). Since that time GSA has monitored the Williams Spring population annually and has made recommendations to protect the species based on potential threats to the population as indicated by the results of those monitoring efforts. Over the ensuing 15 years that effort has provided a very informative data set reflecting the ebb and flow of species presence and abundance in reaction to changes in the spring environment due to a variety of factors (McGregor and others, 2015). Williams Spring is a south-flowing limestone spring located in level hardwood bottomland on National Aeronautical and Space Administration (NASA) property within the boundaries of RSA. The spring, which is up to 6 feet (2 m) deep at its source, wells up through a series of vents and flows for a short distance in a shallow channel near the forest floor to a ditch, which is entrenched as much as 5 feet (1.5 m) below the forest floor in some places. The substratum of the spring is composed of silt, sand, gravel, woody debris, and rooted aquatic vegetation. The channelized ditch has a similar composition near its confluence with the spring run and contains areas of hard clay substrate, cobble, gravel, sand, silt, and woody debris. The complex is 563 feet (171.6 m) in length from its source to its confluence with Indian Creek, and varies from 14 to 18 feet (4.3-5.5 m) in width. A direct ground water connection to the spring from a drainage well and open sinkholes approximately 4.7 miles (7.6 km) to the north was found using tracer dye media during a previous, unrelated study (Rheams and others, 1994) and little if any recharge is provided by Indian Creek (Godwin, 1999).

Fluker and others (2011) included the Tuscumbia Darter in a report summarizing a three-year study on the conservation genetics of spring associated darters in Alabama and found that it is likely that the impoundment of the Tennessee River has acted to isolate Tuscumbia Darter populations on the margins of its range in the recent past. For example, their data indicate that most, if not all, populations of the Tuscumbia Darter were intermittently connected throughout the species' history. However, the presence of recent bottlenecks and low genetic diversity in marginal populations indicates the possibility that migration routes between central and marginal populations may now be blocked by inundated waters. This situation will likely lead to gene suppression through genetic isolation, further stressing the importance of protecting extant populations where they exist and, possibly, recovering populations lost to habitat degradation, provided those habitats can be restored.

In October 2009 a previously unknown population of Tuscumbia Darters was found in an upstream tributary of Indian Creek on RSA during an unrelated study. Based on that discovery and in an effort to be proactive in protecting a state protected species known to easily succumb to environmental perturbations, GSA subsequently entered into a multi-year contract with RSA to delineate the Tuscumbia Darter population in the Indian Creek system on RSA and to attempt to document additional populations on RSA property. After this study began the Center for Biological Diversity (CBD) petitioned the U.S. Fish and Wildlife Service (USFWS) to list 404 aquatic, riparian, and wetland species in the Southeastern U.S., including the Tuscumbia Darter, as either threatened or endangered (CBD, 2010) under the Endangered Species Act of 1973, as amended (ESA). A requirement of the ESA dictates that the USFWS address any species petitioned. In an effort to assist USFWS to satisfy that requirement for the Tuscumbia Darter, RSA agreed that GSA could expand the scope of the project to include locations off post. This report summarizes both the recent qualitative sampling for the Tuscumbia Darter species across its range and the long-term quantitative efforts to monitor the population in Williams Spring, as well as documenting water quality at a few known Tuscumbia Darter locations on RSA.

ACKNOWLEDGMENTS

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STUDY AREA

The Tuscumbia Darter is known from large valley floor springs that flow into the Tennessee River in the Highland Rim Physiographic Section in Alabama and Tennessee (fig. 1). The Highland Rim extends from the Tennessee River in northwest Alabama northward to the glacial boundary in Indiana. The Highland Rim in Alabama is located in the northwest portion of the state and is drained exclusively by the Tennessee River. Valley floors are predominantly limestone at elevations of 500 feet (152 m) while ridges are typically composed of sandstone and are near 1,000 feet (305 m). Three districts are delineated within the Highland Rim section—the Tennessee Valley, Little Mountain, and Moulton Valley—all sloping to the west and plunging beneath Coastal Plain deposits. Streams in the southern portion of the Highland Rim usually originate in the Pottsville escarpment of the Warrior Basin, flow north through the Moulton Valley, and bisect Little Mountain in narrow, deep valleys through sandstone beds.

The Tennessee Valley, comprised of red-clay lands on both sides of the Tennessee River, is the largest district in the Highland Rim. In the level parts of the valley are numerous karst features such as springs, ponds, lime sinks, and caves formed by solution of the underlying limestone. Tuscumbia Darter distribution is limited to this district.

Water discharge from springs often sustains stream flows during droughts and some large springs, such as Brahan Spring in Huntsville, Madison County, and Tuscumbia Spring in Tuscumbia, Colbert County, serve as municipal drinking water supplies. Small headwater streams flowing north through the Little Mountain and Moulton Valley districts have reduced flows during late summer. Some receive nonpoint agricultural runoff and permitted wastewater discharges which often lead to water-quality problems during low stream flows. Streams draining south to the Tennessee River generally flow year round and many have exceptionally good water quality. The Tennessee Valley, Little Mountain, and Moulton Valley districts are drained by the Tennessee River and its larger tributaries, including Elk River and Cypress, Shoal, Bluewater, and Limestone Creeks to the north and Town, Spring, Big Nance, and Flint Creeks to the south of the Tennessee River. Collections during this project were focused on those spring habitats and in related stream and swamp habitats from the most downstream historic collection in Hardin County, Tennessee, upstream to selected springs in the Paint Rock River system in Marshall County, Alabama, peripheral to and upstream of the historic range of the Tuscumbia Darter.

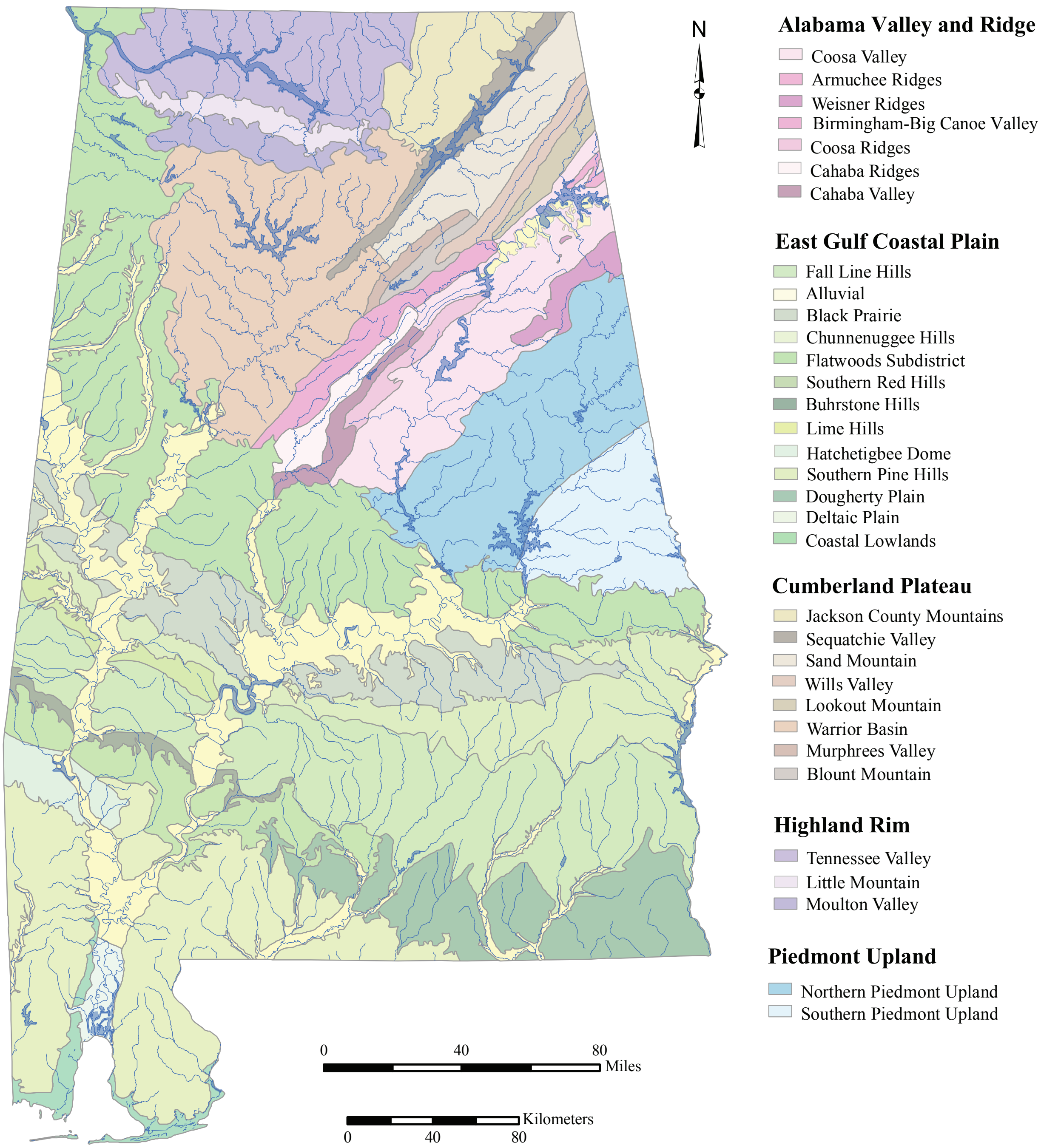

Figure 1. Map of Alabama showing general physiographic sections and districts.

METHODS

FISH SAMPLING

The range of the Tuscumbia Darter covers a linear distance of about 125 miles (200 km) from west to east (fig. 2) in Alabama and Tennessee. Within that range are numerous springs and the Tuscumbia Darter, due to its very specific life history requirements, is known from only a small percentage of springs. In an effort to find new populations within and peripheral to that range, visits were made to many springs found via topographic maps, according to first-hand knowledge of the area, by driving surveys, and, on and near RSA, with the aid of thermal imagery. Numerous collections were made during unrelated projects within the range and in habitats appropriate for Tuscumbia Darters, and those records are included in the report as well. Locations sampled were enumerated from most downstream to most upstream, and within that context were loosely grouped into lower, middle, and upper study areas for discussion purposes based on geographic range and density of collection records (figs. 3, 4, 5, 6, and 7).

Mostly qualitative sampling was employed using either dipnets or seines, or a combination thereof, as conditions, time, and personnel permitted. Time of effort expended sampling, method employed, personnel involved, fishes encountered, and pertinent habitat notes were recorded. Map coordinates were determined using a Garmin GPSmap 60Cx or similar hand-held global positioning system device. As this was primarily a qualitative survey, if Tuscumbia Darters were encountered soon after sampling began, effort generally continued to the next quarter hour, for example 0.25 hour, 0.5 hour, etc. If Tuscumbia Darters were not encountered soon after sampling commenced, effort continued until it was deemed that reasonable effort had been expended searching suitable habitat, and that effort was recorded. All Tuscumbia Darter encounters were recorded in a field notebook and individuals were returned to the stream.

At most locations sampled a running tally of fish species encountered and numbers of each were recorded. From some locations a few specimens whose identifications proved difficult to verify in the field were retained and later identified in the lab and added to the list. Locations sampled were categorized as follows: historic collection locations with Tuscumbia Darters extant; historic locations where Tuscumbia Darters were not found; new locations where Tuscumbia Darters were collected; and new locations where Tuscumbia Darters were not collected. No collection effort was made at four historic locations visited that are now inundated by the Tennessee River.

As noted earlier, the population of Tuscumbia Darters in Williams Spring on RSA is quantitatively monitored annually. For that project, fish are sampled by setting a seine in the stream channel and kicking downstream through habitat into the seine or by dragging the seine

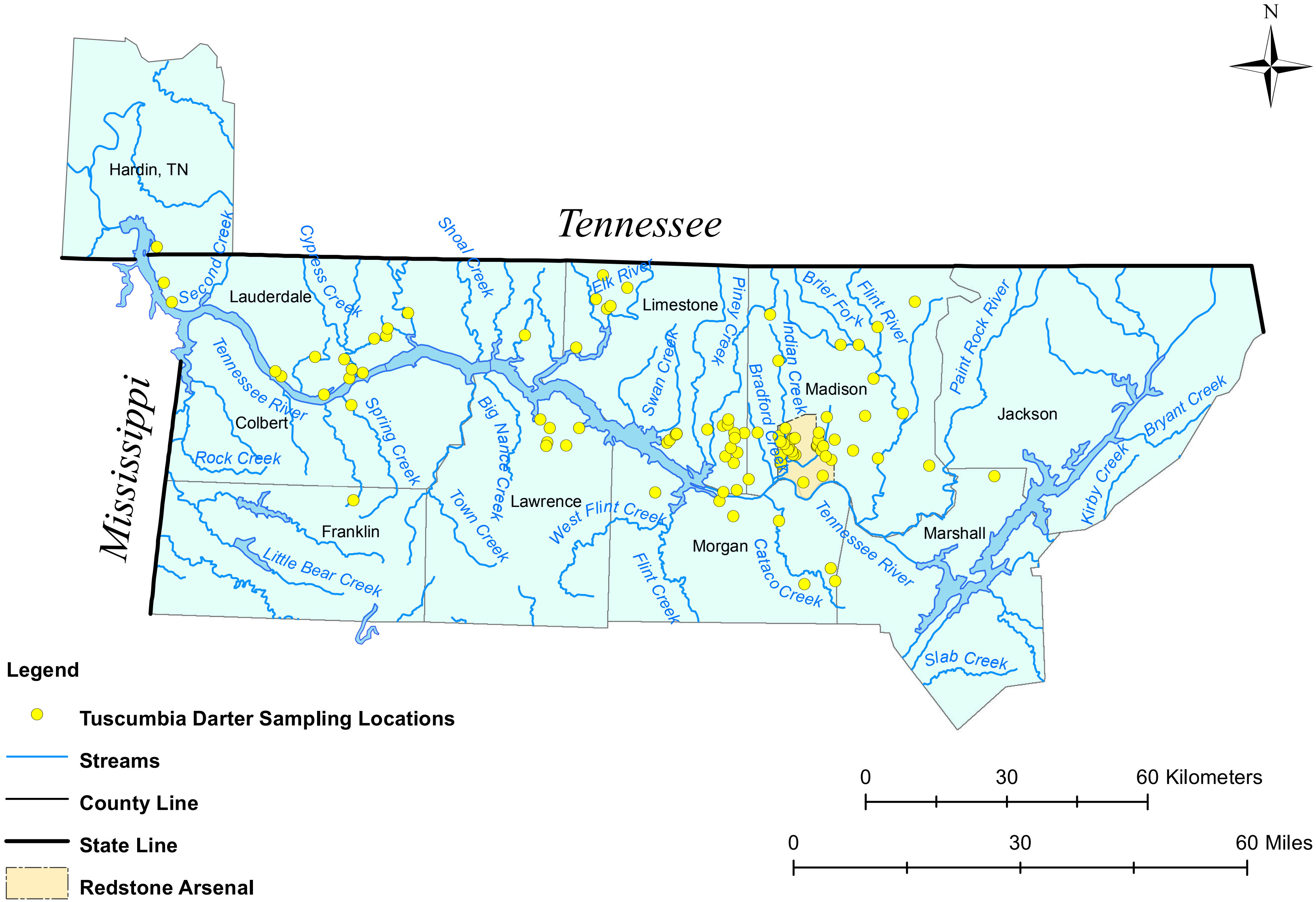

Figure 2. Map of north Alabama and Hardin County, Tennessee, showing collection locations.

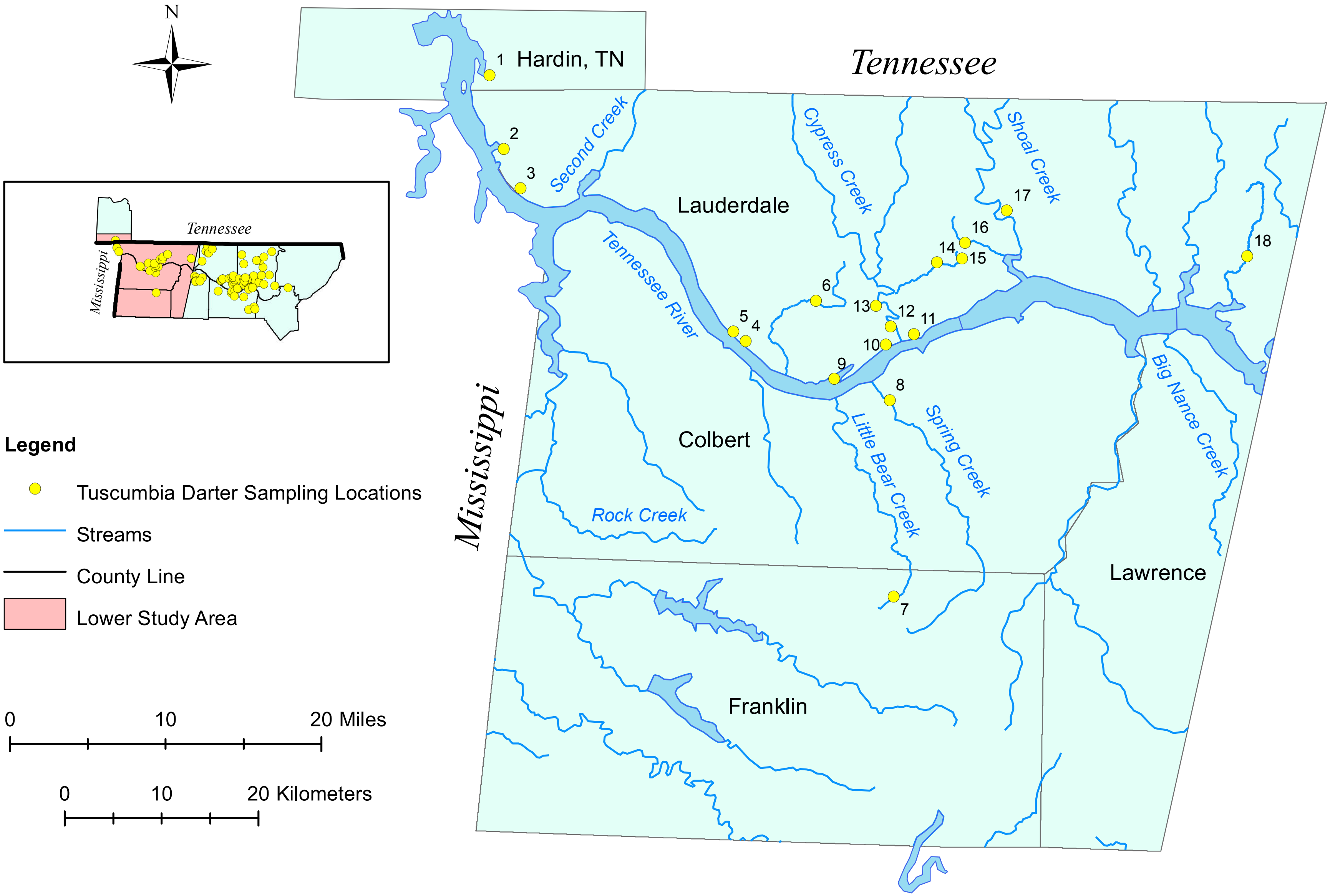

Figure 3. Map of collection locations in the lower study area.

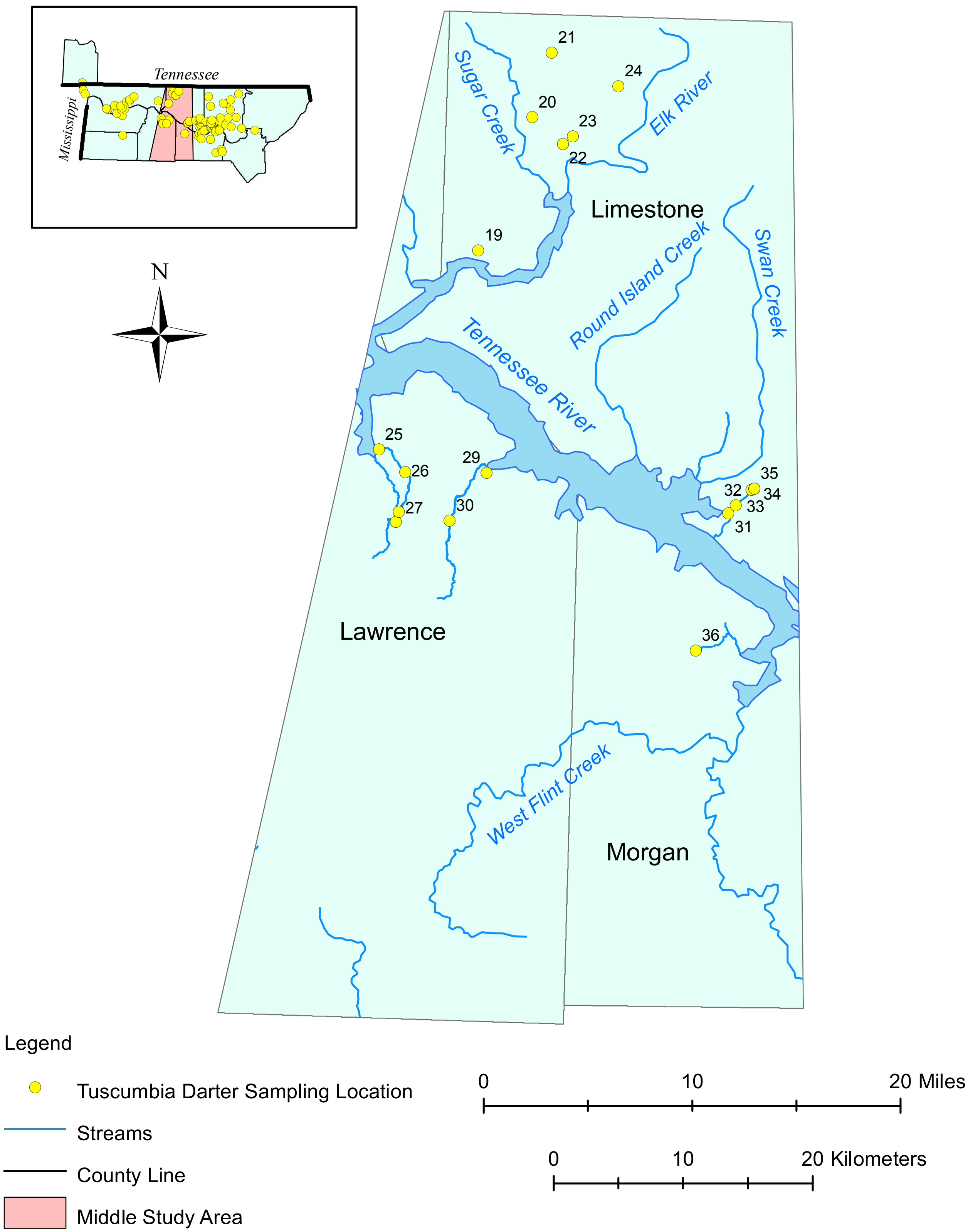

Figure 4. Map of collection locations in the middle study area.

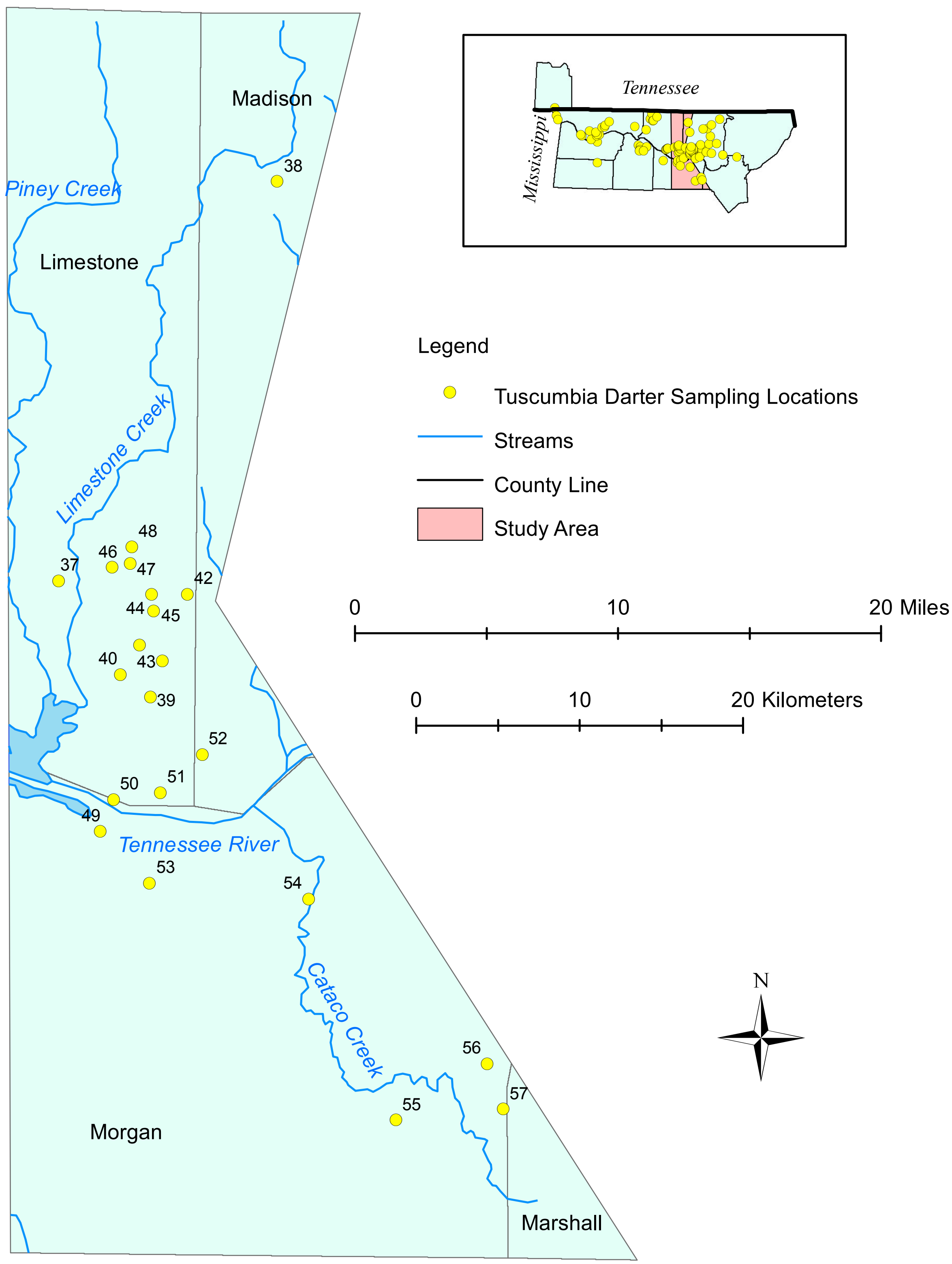

Figure 5. Map of collections in locations in upper study area 1.

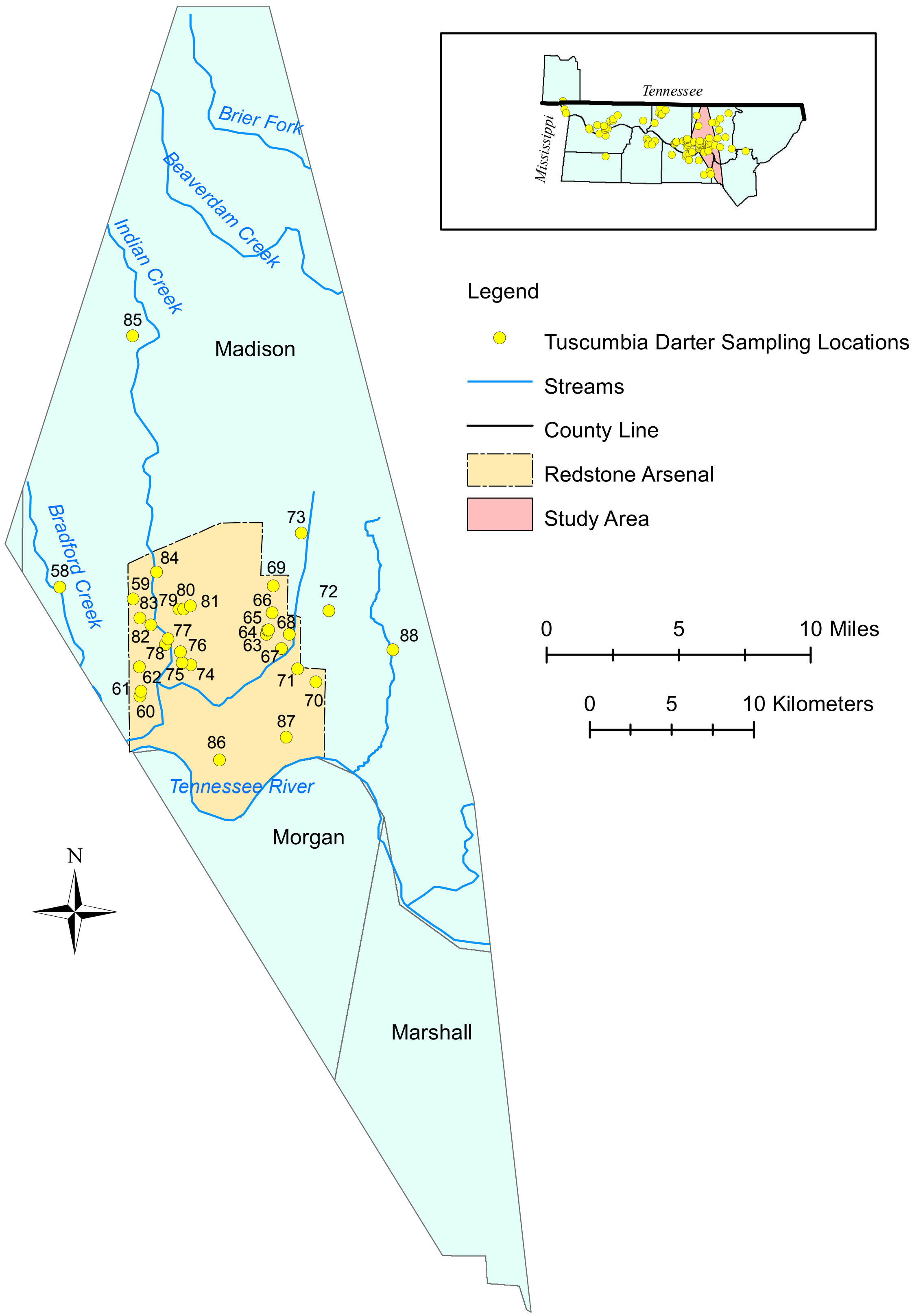

Figure 6. Map of collection locations in upper study area 2.

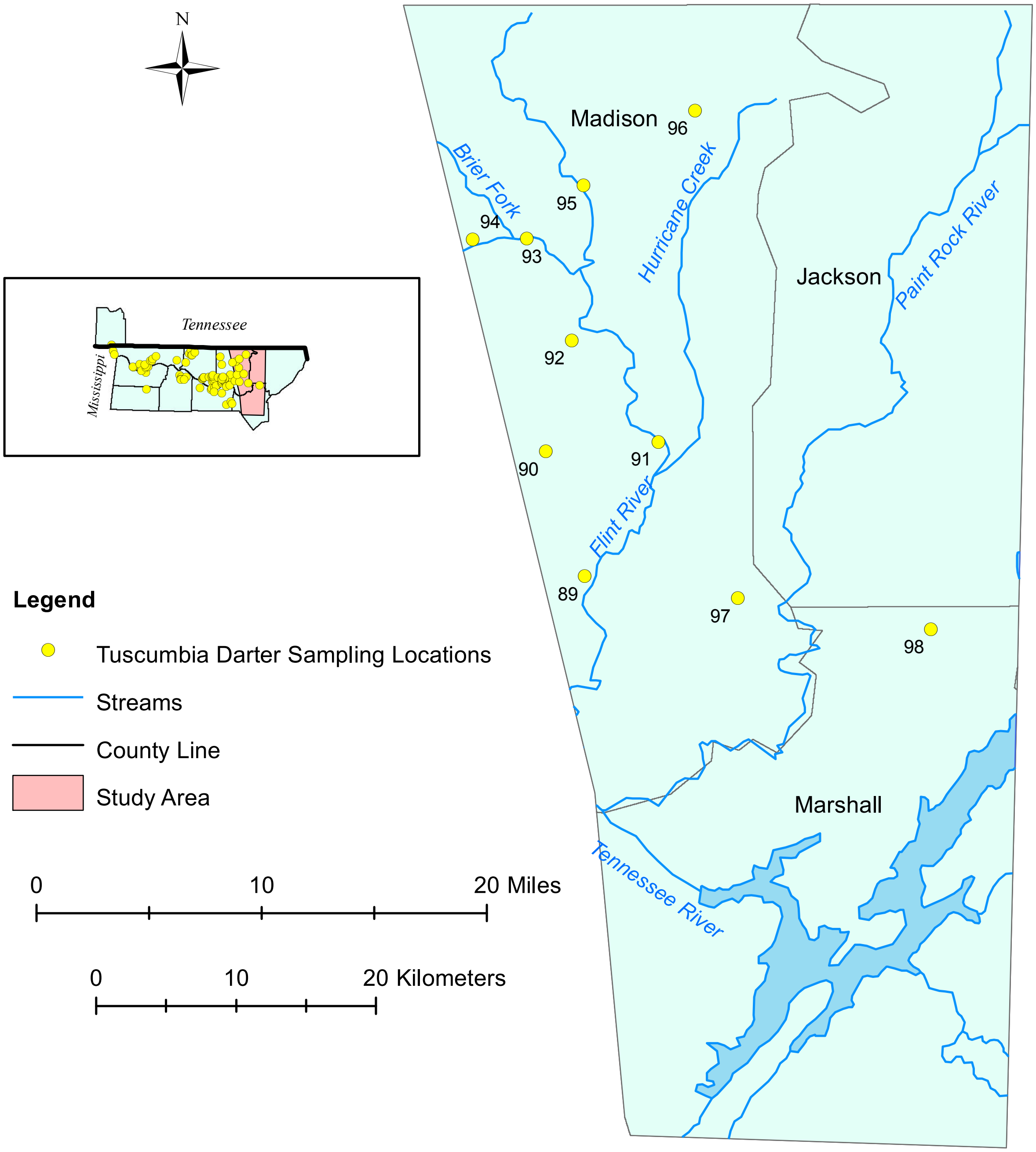

Figure 7. Map of collection locations in upper study area 3.

through pooled areas (effort). Area sampled is estimated based on the width of the seine and distance sampled during each effort and is recorded along with species and numbers of each species collected per effort. During each visit CPUE is determined by dividing the number of fish collected (total or by species) by the total number of efforts. Density (per 100 ft^2) is determined by dividing the total number of fish (total or by species) collected during each sampling visit by the total area sampled and multiplying by 100.

Information from recent collections by outside parties is also included in this report. The Byrd Spring location, just to the east of RSA, was sampled during one day by a large group of workers representing several agencies targeting several taxa groups and employing various sampling methods. During that effort total numbers of Tuscumbia Darters collected and effort expended were not recorded. Jeff Selby of AST Environmental in Decatur, Alabama, shared results from quantitative fish sampling in the Beaverdam Creek Spring complex for an unrelated project wherein Tuscumbia Darters were collected. Mike Sandel of the University of West Alabama, formerly of the UA Department of Biological Sciences, shared recent collection records of Tuscumbia Darters from qualitative field sampling in the Beaverdam Creek Spring complex. Locations of historic Tuscumbia Darter collections were secured from the University of Alabama Ichthyological Collection (UAIC), the database maintained by the Natural Heritage Section of ADCNR, and TVA.

WATER QUALITY MONITORING

Continual water quality monitors were installed at three locations on Redstone Arsenal where Tuscumbia Darters are known to occur. Two monitors were located on the unnamed tributary to Indian Creek (Airport 1 and Airport 2) near the south end of the Redstone Army Airfield and the third monitor at Williams Spring. The Hach/Hydromet MS5 multiprobe units were configured to measure water level to a range of 0 to 10 meters (m) with an accuracy of ± 0.01 m (reported as feet in this study); temperature to a range of -5 to 50 ºC with an accuracy of ± 0.10 ºC; dissolved oxygen to a range of 0 to 30 milligrams per liter (mg/L) with an accuracy of ± 0.01 mg/L; specific conductance to a range of 0 to 100,000 micro Siemens per centimeter (µS/cm) with an accuracy of 1.0 µS/cm; and pH to a range of 0 to 14 standard units with an accuracy of ± 0.2 units. Monitors were housed in temporary, wood-constructed boxes near the stream/spring margins. Wires and probes were secured in PVC piping with probes placed near the stream/spring bottom in the current. Monitors were programmed to take readings four times daily. Data was downloaded every 6 to 8 weeks and the probes were inspected and cleaned, recalibrated if necessary, and discharged batteries were changed.

RESULTS

FISH SAMPLING

A total of 98 locations were visited across the range of the Tuscumbia Darter during this project (fig. 2, appendix A) and approximately 120 person hours of effort using a variety of sampling gear and techniques were expended searching for Tuscumbia Darters. Effort ranged from 0.15 person hour (10 minutes) to 6.25 person hours per location, depending on conditions and faunas encountered and available personnel. Summary information on stations sampled is found in appendix A. As noted previously, the range of the Tuscumbia Darter spans about 125 miles (200 km) west to east and numerous large valley floor springs are found throughout the area. Sampling was conducted in and near these springs and associated spring runs and spring/swamp complexes, and in creeks near such complexes. For discussion purposes sampling stations are loosely grouped based on their relative position within the range starting from the most downstream location. Discussion of the results of this study follows that progression. The only previously unknown populations of Tuscumbia Darters documented during this study were found on RSA property along the margins of swamps possibly created by the impoundment of the Tennessee River. At those locations, springs were inundated but still retain habitat characteristics sufficient to permit the Tuscumbia Darter to complete its necessary life history requirements.

In the lower study area collections were made among spring/swamp complexes and streams known to be influenced by springs (fig. 2, stations 1-18; appendix A). Much of the lower study area is rural and very heavily used for agriculture and silviculture and many locations sampled displayed evidence of such uses, including heavy silt loads and hypereutrophic conditions. While some of the locations sampled displayed habitat suitable for Tuscumbia Darters, only two yielded Tuscumbia Darters, and both were historic collection locations.

The most downstream location where Tuscumbia Darters have been recorded historically was a series of springs adjacent to the Tennessee River in Hardin County, Tennessee (station 1). That location is in an area where the Highland Rim intersperses with the Fall Line Hills District of the East Gulf Coastal Plain Physiographic Section near the western terminus of the Highland Rim (Griffith and others, 1998). That location was inundated by Pickwick Reservoir of the Tennessee River and is no longer suitable for Tuscumbia Darters (Etnier and Starnes, 1993; Mettee and others, 1996). We visited the adjacent stream system (Dry Creek and its tributary Mill Creek) hoping to find suitable Tuscumbia Darter habitat but were unsuccessful. We walked most of the length of Mill Creek from its confluence with Dry Creek upstream to near its source near the Alabama state line, and the fish fauna encountered was very diverse and the stream system appeared to be in relatively pristine condition. No collections were made within Dry

Creek itself, as it was heavily affected by vehicular traffic and was very unstable and lacking in suitable Tuscumbia Darter habitat.

Streams adjacent to the Panther Creek embayment and in Union Hollow (stations 2, 3) are generally clear with stable cobble/gravel/sand substrates and perennial flow due to small springs and seeps. These springs are not typical of the ‘large valley floor springs’ that Tuscumbia Darters prefer, but due to the occurrence of a historic population of Tuscumbia Darters just a few miles downstream, we felt investigation in the area was warranted. That area of Lauderdale County, which is mostly in the Fall Line Hills, is largely silvicultural, with periodic clearcutting and replanting of pine trees and some row crops and pasture in bottomlands. It is somewhat protected due to its location within and near the Lauderdale Wildlife Management Area and TVA property boundaries. Both streams were in good physical shape and yielded fish faunas expected in streams in that area, but no Tuscumbia Darters were collected.

The Rowell/Stewart springs complex (station 4) may have been suitable for occupation by Tuscumbia Darters in the past, as it is a relatively large, vegetated spring complex near the Tennessee River, but during our visit showed the effects of sedimentation from the surrounding agricultural landscape, which is used for cotton and other row crops, as well as pasturing cattle. The riparian border was choked with Chinese Privet, *Ligustrum sinestre*, and other competitive undergrowth species commonly found in disturbed habitats. The nearby historic Cave Spring location for Tuscumbia Darters (station 5) was lost when Pickwick Reservoir was created and no collection was attempted at that location. Other similar large spring/swamp complexes in the area that showed the most suitable habitat in addition to the Rowell/Stewart Springs complex were Sinking Creek Swamp (station 6), a tributary of Sinking Creek, and a large, unnamed spring at the Florence Waste Water Treatment Plant (station 10), a tributary of Coffee Slough. All of these complexes are subjected to heavy agricultural activity and are choked with sediments and have unconsolidated, muddy substrates. Key Spring (station 9) has a short run to Coffee Slough over cobble and gravel, lacks the vegetation necessary for the Tuscumbia Darter, and is heavily influenced by changes in river stage and the resultant introduction of top predators.

Good Spring (station 7) is a relatively large spring at the foot of a bluff in the Little Mountain District of the Highland Rim Physiographic Section in Franklin County. It lies in the headwaters of Little Bear Creek and has been highly modified into a spring pool in the parking lot of a restaurant. It is filled with non-native vegetation and did not yield Tuscumbia Darters. During our visit, the owner stated that the local Farmers Cooperative was giving away bass (*Lepomis* sp.) and he was going to secure some to stock the pool, further lessening the likelihood of native species persisting at this location.

The type locality for the Tuscumbia Darter is Tuscumbia (Big) Spring (station 8), a tributary of Spring Creek within the city limits of Tuscumbia, Colbert County. The spring has been heavily used as a drinking water source and public use area for many years and has seen conversion of the outflow to a contained pool through erection of concrete walls and barriers. More recently it endured yet another major alteration when it was converted from a spring to a pseudo-waterfall. Water is now piped from the spring to the top of an artificial bluff and allowed to run back into the spring pool over fabricated rocks. The spring has been repeatedly sampled over many years and the population of Tuscumbia Darters there remains strong, despite the modifications. A 6-ft seine was used to sample for 0.25 hour. Twenty-seven Tuscumbia Darters were collected among others species typical of similar large springs in the area. Jones and others (1995) determined the Tuscumbia Darter population at this location to be endangered due to observed habitat alteration and low CPUE.

A number of spring/creek complexes in the lower Cypress Creek system (stations 11-15) were sampled and no Tuscumbia Darters were found in most of them. These systems are less influenced by agricultural activities, but some suffer current and possible future effects of urbanization. The historic location of Tuscumbia Darters in Buffler (King) Spring (station 14) did, however, yield 12 Tuscumbia Darters along with another headwater darter species during 0.25 hour of sampling using a small hand net. Jones and others (1995) found this population to be stable. A relatively large spring at the foot of a low ridge in the headwaters of the Cypress Creek system (station 15) is adjacent to a public golf course and associated housing development but has a narrow riparian border. Its location proximal to Buffler Spring offered some hope that Tuscumbia Darters might be present, but none were found.

Two springs and associated streams were sampled within the Shoal Creek system (stations 16-17). No Tuscumbia Darter records exist from this watershed, but the quality of the fish fauna in this system, 92 species according to Mettee and others (2002), and the proximity to other Tuscumbia Darter locations encouraged us to sample there. Visits to these locations were made during an unrelated project and some effort was expended to search for Tuscumbia Darters. The outflow of one unnamed spring near the community of St. Florian (station 16) has been modified into a pool and lacks canopy, but the area immediately around the spring pool is mowed grass and suffers few ill effects from development or agricultural practices. Below the vegetated pool, water flows a few yards into a first order stream. Only the Green Sunfish, a species tolerant of environmental perturbations, was found at this location. Farther upstream in that system a small, unnamed spring rises at the foot of a long, gradual slope that has been affected by recent housing development along the ridge top (station 17). The hillside below the homes has been cleared of timber to permit open views of the creek from the homes, and the hillside is periodically maintained by bush hogging. The spring flows a few yards into Bretherick Branch, and only a few species typical of small streams in the Tennessee Valley were collected. A fairly small but high quality vegetated spring in a wooded setting located in the Blowing Spring Forever Wild Tract (fig. 3, station 18) in eastern Lauderdale County did not yield Tuscumbia Darters, but did yield other species typical of springs and headwaters in the Tennessee Valley.

The middle study area (fig. 4, stations 19-36; appendix A) includes numerous springs and spring-associated streams in the Elk River system (stations 19-24) along with numerous locations in eastern Lawrence and western Limestone and Morgan Counties (stations 25-36). These locations are in agricultural areas characterized by extensive row crop production and cattle pastures, with some relatively extensive woodlands.

Neither the Tuscumbia Darter nor its sister species, the Slackwater Darter (*Etheostoma boschungi*), have ever been collected in the Elk River system (stations 19-24). Despite being somewhat heavily affected by agricultural practices, many streams in this area are quite diverse in their fish communities: 102 species of fish have been documented to occur in the drainage (Mettee and others, 2002). No Tuscumbia Darters were collected in that system.

The Wheeler Branch system (stations 25-28) lies in a heavily agricultural area, with extensive row crops, pastures with unrestricted cattle access, and narrow to absent riparian vegetation. However, the Tuscumbia Darter is still found within the system, aside from the lowermost station, which is inundated by Wheeler Reservoir. Aside from the immediate outflow at Wheeler Spring, the stream, which flows through level river bottom land, is somewhat sluggish and the substrate is composed of clay/mud over cobble/gravel/sand, is highly organic, and is littered with woody debris. Nonetheless, Tuscumbia Darters have been found at three historic locations in recent years (stations 26-28). The nearby Mallard Creek locations (stations 29-30) lie in a similar agricultural area, but did not yield Tuscumbia Darters during this project. The most downstream location (station 29) is inundated by Wheeler Reservoir and the upper location (station 30) has been heavily affected by agricultural practices and is located in a wooded bottomland containing dense undergrowth, including Chinese Privet.

The Pryor Spring system in Limestone County (stations 31-35) hosts several locations where Tuscumbia Darters have been collected historically. The lowermost station, Pryor Branch at Harris Station Road (station 31) is inundated by Wheeler Reservoir. We collected the margin of that location briefly (about 0.15 hour) with dipnets but did not find appropriate habitat for Tuscumbia Darters and none were collected. The substrate was unconsolidated, with abundant emergent vegetation around loose riprap with no flow. No Tuscumbia Darters were collected in two attempts at an old railroad bed just upstream (station 32). An abandoned concrete dam backs up water forming a large, shallow, weed choked wetland, with some flow where water passes over the dam. The substrate there was detritus and soft mud over cobble and gravel, and a few reservoir tolerant species were collected. Farther upstream Tuscumbia Darters were collected easily at two stations, including 25 specimens in 0.5 hour with a 6-foot seine at one location (station 33) and 27 specimens, including some subadults, at another (station 34) in 0.5 hour with dipnets. The most upstream location, near the source of Pryor Spring (station 35), located just across U.S. Highway 31 upstream of station 34, did not yield Tuscumbia Darters in 0.25 hour with a 6-foot seine. The water is somewhat deep with little flow and an unconsolidated, muddy substrate and abundant emergent vegetation. The riparian border is absent and row crops are present up to the edge of the spring.

Clear Creek Branch (aka Clark Spring) (station 36) is a historic location for Tuscumbia Darters. It is located within the city limits of Decatur and affected by extreme urbanization, is completely lacking in a riparian border, and contains substrate composed of gravel/sand/silt with scattered Water Willow (*Justicia* sp.), woody debris, and garbage. Apartments and a car wash are located immediately adjacent to the creek, with further housing construction ongoing downstream. Hundreds of Largescale Stonerollers and Western Mosquitofish along with two Largemouth Bass, species very tolerant of degraded streams, were collected there.

The upper study area has the most historic collection records of Tuscumbia Darters and for that reason was the primary focus area for this study. As noted earlier, for ease in discussion, it was further subdivided into three subareas: Upper Study Area 1 (fig. 5, stations 37-57; appendix A), Upper Study Area 2 (fig. 6, stations 58-88; appendix A), and Upper Study Area 3 (fig. 7, stations 89-98; appendix A).

Upper Study Area 1 included numerous stations within the greater Limestone Creek system, including the Beaverdam Creek system (stations 37-48), as well as several independent tributaries of the Tennessee River (stations 49-53), and the Cotaco Creek system (stations 54-57). In this study area Tuscumbia Darters were only found within the Beaverdam Creek system, where they were fairly common.

A few stations were sampled in the Limestone Creek subwatershed of the Beaverdam Creek system. An unnamed tributary of Limestone Creek alongside Limestone County Road 71 (station 37) was sampled twice during this study and did not yield Tuscumbia Darters, though there are historic records from this location. However, a fairly diverse fish fauna was encountered, including species typical of both large and small streams in the Tennessee Valley. It appeared that this former spring has been severely altered and is now routinely mowed during right-of-way maintenance and is effectively a roadside ditch lacking vegetation characteristic of Tuscumbia Darter habitat. Toney Spring (station 38) is a fairly large roadside spring in the headwaters of Limestone Creek that has been severely modified in the past with block walls. It is heavily choked with *Spirogyra* sp. and has an unconsolidated, muddy substrate. We sampled with dipnets among vegetation in the spring pool and in a feeder ditch. The ditch had some vegetation and considerable household garbage and did not yield Tuscumbia Darters.

Beaverdam Creek and the associated Beaverdam Swamp complex is fed by a few very large springs, including Beaverdam, Moss, Sulcer, and Thorsen Springs, along with numerous smaller springs, and its flow is well sustained year round. Over much of its length it maintains a very swampy character, including considerable forest cover, and therefore is not often subject to instream alteration. Much of the lower section of the system is protected within the boundaries of Wheeler National Wildlife Refuge. However, in its upper reaches it does suffer considerable pressure from surrounding agricultural practices and, due to its proximity to the rapidly expanding Huntsville/Madison metropolis and nearby Interstate Highways 65 and 565, it will soon be subject to urbanization and large scale commercial development. Nonetheless, populations of Tuscumbia Darters were documented at six stations within the system during this study (stations 39, 41, 45, 46, 47, and 48).

No Tuscumbia Darters were found in Sulcer Spring (station 40) though they have been found there in the past. The spring source has been severely altered, with a high berm effectively halting flow, and the resultant pool was choked with lilies and considerable woody debris. No fish species were found there. However, we did not sample in the lower reach of that system and Tuscumbia Darters may remain where sufficient flow is encountered. Similarly Withers Spring (station 42) also failed to yield Tuscumbia Darters. None have ever been reported from there but we chose to sample it based on the fact that it feeds into Beaverdam Creek and the source is still ostensibly protected by a narrow riparian border. However, the border of dense undergrowth is not sufficient to protect the spring from nearby row crop production and the stream was filled with red clay sediments. A similar situation exists in a muddy spring run alongside Alabama Highway 20 just north of I-565 (station 43). Jones and others (1995) found the mud there to be too deep for effective seining, but still managed to collect five Tuscumbia Darters. We found a similar situation, with dense mud and detritus, and failed to find Tuscumbia Darters. None were found in two efforts at another historic location, a spring on Limestone County Road 119 (station 44). A small spring alongside a first order tributary of Beaverdam Creek is affected by unrestricted cattle access and no suitable Tuscumbia Darter habitat remains.

Several independent tributaries of the Tennessee River in this area (stations 49-52) were also sampled and none yielded Tuscumbia Darters. Cave Spring (station 49) is a huge limestone spring at the foot of a high bluff within Wheeler National Wildlife Refuge that opens into a large swampy area immediately adjacent to the Tennessee River, and bears a strong resemblance to

Beaverdam Swamp. Rockhouse Landing (station 50) was a historic location for Tuscumbia Darters, but the springs there were inundated by Wheeler Reservoir and are no longer suitable for Tuscumbia Darters. Only reservoir-tolerant species were collected. The same applies to Blair Spring (station 51). That location was inundated by Wheeler Reservoir and only yielded reservoir-tolerant species. Blackwell Swamp (station 52) is reminiscent of Beaverdam Creek and it, too, failed to yield Tuscumbia Darters, despite the fact that suitable habitat is present. These stations were all sampled during an independent study searching for populations of the federally endangered Spring Pygmy Sunfish, a new population which was recently discovered in Blackwell Swamp by Dr. Lori Tolley-Jordan and students of Jacksonville State University.

Wright Spring (station 53) is a relatively large limestone spring at the foot of a bluff that flows through a creek channel for about 2 miles (3.2 km) directly into the Tennessee River. A very old collection of Tuscumbia Darters from that location was georeferenced at a road crossing about 1 mile (1.6 km) downstream of the actual spring, likely due to vague locality data recorded at the time of collection, and the coordinates for this location were taken at the actual spring. The ridge above the spring has been recently clearcut almost down to the level of the spring, and the spring outflow runs for a short distance in a wooded bottom with dense undergrowth before opening into a large, highly modified agricultural field with no riparian border. Only a single tolerant fish species was found there. Three of four springs sampled in the Cotaco Creek watershed (stations 54-57) contained at least some habitat appropriate for Tuscumbia Darters. Grantland, Hughes, and Skidmore Springs (stations 54, 56, and 57) are fairly large springs and had rooted aquatic vegetation, adequate flow, clear water, and at least some riparian borders protecting them from surrounding agricultural fields, and yielded fish faunas typical of headwater streams in the area, but no Tuscumbia Darters. Entrekin Spring (station 55) was relatively small in comparison and lacked adequate depth and vegetation for Tuscumbia Darters.

Upper Study Area 2 (fig. 6, stations 58-88; appendix A) encompasses the Indian Creek system (stations 58-85) as well as a few independent tributaries to the Tennessee River (stations 86-88). This is a rather complex and convoluted system for several reasons. The underlying geology is karst in nature with solution channels forming numerous caves, springs, lime sinks, and sinkholes. It is located along a relatively broad, flat river floodplain among outliers of the Jackson County Mountains (Bradford, Hatton, Madkin, and Weeden Mountains) where the Tennessee River drops out of the higher elevations of the lower Appalachian Mountains into the Tennessee Valley. Here the river bends in a serpentine fashion across southern Madison County and some watershed boundaries within RSA are indistinct, due, in part, to a history of connection and separation not only in the geologic past but also post-impoundment of the Tennessee River. For instance, Byrd Spring (station 72) and Thiokol Pond (station 71) both have direct surface connections to Huntsville Spring Branch of the Indian Creek system to the west, yet part of their waters also feed into a small, unnamed tributary that flows directly south to the Tennessee River along the eastern boundary of RSA. Also, when a topographic map is examined, what is commonly referred to as Indian Creek in the vicinity of Martin Road was once two streams, Indian Creek and an unnamed tributary that met Indian Creek some distance to the south. However, Indian Creek in the vicinity of Martin Road has been channelized and apparently rerouted in the past, and those two streams are now indistinguishable. The proximity of RSA to the rapidly expanding Huntsville/Madison metropolis adds developmental pressures to the landscape and, therefore, resources, but there is some level of protection provided by RSA and Wheeler National Wildlife Refuge.

The Indian Creek system drains most of Redstone Arsenal (figs. 6, 8) and still harbors vigorous populations of Tuscumbia Darters at several locations, though other historic populations in that area have been lost or are subject to loss due to habitat degradation from urban development, poor natural resource management, and dewatering of springs. Much of the low-lying area along the Tennessee River has been inundated by Wheeler Reservoir of the Tennessee River since 1936 and undoubtedly other Tuscumbia Darter populations were lost before being documented. Access to those areas can be difficult from logistical and security standpoints, but with further surveys it is possible that other isolated populations will be found.

The location sampled in Bradford Creek (station 58) was composed of gravel/sand/silt with woody debris and abundant rooted aquatic vegetation and, shortly before our survey, had a fairly intact riparian border. It resembled typical Tuscumbia Darter habitats, though it lies within an urban area. However, a short time before our first sampling effort was attempted (August 12, 2014), the timber along part of the riparian border of the creek was cut and left lying on the ground to rot; additionally, the area down to the streambank was denuded, ostensibly to allow an unrestricted view of the water from a nearby apartment complex, putting more pressure on the creek system. While a very diverse population of fishes typical of a high quality Tennessee Valley headwater stream was collected, no Tuscumbia Darters were found.

Several large swamps and associated wetlands in the Indian Creek system on the west side of RSA (stations 59-62) were sampled in hopes that residual springs along their margins might yield sufficient habitat quality to support Tuscumbia Darters. Most had standing water and were highly organic due to the abundance of deadfall and detritus, and no Tuscumbia Darters were collected in any of them. The fishes collected were tolerant species typical of such habitats.

Another cluster of sampling locations was in the Huntsville Spring Branch tributary of Indian Creek in the northeast quadrant of RSA and just off post to the north and east (stations 63-73). This area includes two historic Tuscumbia Darter locations where Tuscumbia Darters persist

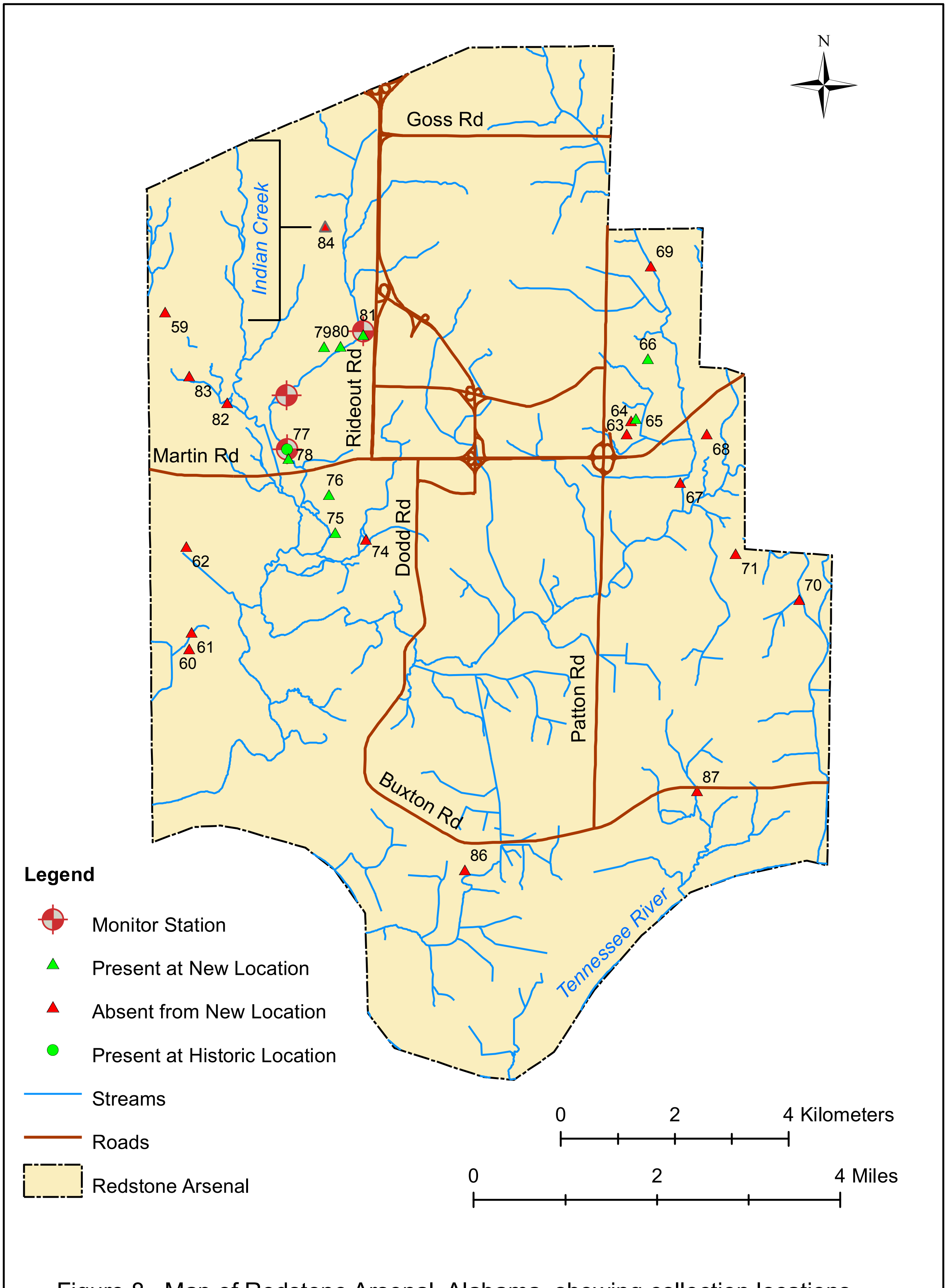

Figure 8. Map of Redstone Arsenal, Alabama, showing collection locations.

(stations 72, 73) and two new locations (stations 65, 66). Byrd Spring (station 72) was a new location per Jones and others (1995). During the period of this study it was the subject of an unrelated day-long ‘bio-blitz’, wherein workers from various specialties and agencies cooperate to summarize the fauna of a particular system. The effort was somewhat informal and data on exact numbers of Tuscumbia Darters collected, gear employed, and time expended sampling are not available. However, according to Jeff Powell (USFWS, pers. comm., 2015), who orchestrated the collecting effort at Byrd Spring, the Tuscumbia Darters reported that day would have numbered in the ‘hundreds.’ It is somewhat of a different story farther upstream in the city of Huntsville at Brahan Spring (station 73). That station has long been used for water supply and recreation and is highly urbanized. Jones and others (1995) reported the population there to be endangered due to the low numbers of individuals collected and severely limited and/or polluted habitat conditions. Nonetheless, a small population of Tuscumbia Darters persists there and one individual was collected in 0.25 hour near the original spring outflow, which is now housed within a tin shed.

Two new locations for Tuscumbia Darters found during this study (stations 65, 66) were on RSA and relatively near Byrd Spring. They were both at spring outflows at the foot of a low ridge along the west and northwest margins of a swampy area of McDonald Creek between Almond and Martin Roads. While this is a vast swampy area and appears generally unsuitable for Tuscumbia Darters, sufficient temperature moderation and appropriate vegetation for Tuscumbia Darters occurs where springs emerge. A few other locations in the immediate vicinity (stations 63, 64, 67, 68, and 69), while similar in nature, lacked the spring influence necessary for Tuscumbia Darters, and none were collected at those stations. Access to these areas can be difficult by road or foot trail, but with access to remote locations via skiff, canoe, kayak, or other vessel, additional populations might be found.

Stations 70 and 71 are large, stagnant lakes and associated wetlands with connections to surface water outlets to Indian Creek via Huntsville Spring Branch to the west and to an unnamed tributary of the Tennessee River to the south. Much like stations 59-62 on the western boundary of RSA, they are essentially large standing pools with abundant detritus and deadfall. No fish were collected at either location.

A large wetland known as Isa Spring (station 74) did not yield Tuscumbia Darters, but it is secured by NASA gates and access is limited. It did not possess the low ridge with evident spring influence that the other locations did, but further sampling there may yield populations. Another large, swampy area south of Martin Road with a low ridge on its north and east margins has springs along its base. It is located within Wheeler National Wildlife Refuge and NASA property and also yielded new populations of Tuscumbia Darters (stations 75 and 76). While numbers of darters collected at each station were low (1-3 per collection), the extent of the wetland complex suggests that, should other springs be located along the perimeter, more populations of darters might be found.

One previous location and several recent locations are known from the Indian Creek system upstream of Martin Road (stations 77-85) and are the primary reason for this study. Williams Spring (station 77) was a new population reported by Jones and others (1995) and has been the focus of annual monitoring by GSA for the past 16 years. The population there will be discussed in detail in a subsequent section of this report. This station regularly yields Tuscumbia Darters, ranging from 9 to107 individuals per visit.

An early collection effort during this study involved walking upstream in Indian Creek from Martin Road searching for appropriate spring habitat. While no springs reminiscent of typical Tuscumbia Darter habitat were found, two individuals were collected in marginal habitat (station 78). The location where those darters were collected was used as the georeference point for that effort, though a much larger area was searched. The substrate in that reach of Indian Creek was composed of clear water over cobble/gravel/sand substrate with little to no aquatic vegetation present throughout most of its length. The darters were found in small side channels with roots and minimal vegetation.

Farther upstream in an unnamed tributary of Indian Creek along and downstream of the RSA Airfield (stations 79, 80, and 81), Tuscumbia Darters were routinely collected. While this area did not display isolated springs typical of Tuscumbia Darter habitat, the entire reach contained rooted aquatic vegetation typical of such springs and is considered to be one contiguous population. We sampled over long distances in these reaches and the georeferenced points for these stations represent approximate midpoints for each effort. The collection of 10 Tuscumbia Darters in 1.5 hours sampling time with a dipnet at station 80 during an unrelated project in 2009 is what prompted this project. A large Beaver (*Castor canadensis*) dam impounds the upper portion of this location and those darters were found in the flowing portion of the stream downstream of that dam. The most upstream station (81) yielded only two Tuscumbia Darters in one hour of sampling and appeared to be at or near the upstream limit for Tuscumbia Darters in this system. We sampled at that location immediately after sampling downstream at station 80 during this project, where we collected 33 Tuscumbia Darters among several other species. The water at station 81 was noticeably warmer than that at station 80 and appeared to be warm and stagnant, with a substantially different fauna present (personal observation).

Two collections made in a tributary of Indian Creek on the laser range and upstream near its source, a spring-fed, swampy area west of Anderson Road that contained rooted aquatic vegetation (stations 82 and 83), did not yield Tuscumbia Darters. Another long walking survey/collection effort in Indian Creek was also undertaken, from Hale Road on the laser range upstream to near the northern boundary of RSA (station 84), and no appropriate spring habitat was observed nor were Tuscumbia Darters collected. While that effort covered a distance of about 2 linear miles, the georeferenced point is located near mid-reach.

One of the more disappointing discoveries during this project was the apparent demise of one of the most vigorous populations of Tuscumbia Darters reported by Jones and others (1995). Kelly Spring (station 85) has been modified in the past for fish production but until at least the mid-90s maintained a thriving population of Tuscumbia Darters. During our study it was sampled twice and the only species encountered were species tolerant of modified or reservoir type habitats. Jones and others (1995) found this population to have the second highest CPUE and highest CPUT among eight historic locations sampled repeatedly during their study, and reported the population to be stable due to the abundance of habitat present, the apparent stability of the population based on population estimates, and the lack of imminent threats to the quality of the habitat. However, the landowner reported that subsequent to that study, the Madison County Water Authority increased production of groundwater from a well across the road from the spring and during dry years, as demand for water increases, Kelly Spring goes dry for extended periods. It should be noted that our sampling was confined to the spring head and immediately downstream, and a huge but relatively inaccessible wetland complex exists further downstream. It may harbor pockets of Tuscumbia Darters that could repopulate Kelly Spring should excessive withdrawals from the water supply well cease.

Two wetlands and one fairly large spring that are independent tributaries to the Tennessee River (stations 86-88) also failed to yield Tuscumbia Darters during this study. Stations 86 and 87 both yielded only Western Mosquitofish, a species tolerant of slack, organic water. Those locations had no perceptible flow and, as with many such locations on RSA, had emergent vegetation, abundant organic matter, and woody debris from downfalls. Station 86, known as Igloo Pond, is apparently fed by a large spring vent from the valley floor and slowly flows to the Tennessee River, but the outflow was never observed and the area is now off limits due to contamination. Station 88 is a modest spring that issues from the valley floor within a public park adjacent to a busy thoroughfare in a highly urbanized area of Huntsville. It flows under a road and through a short, vegetated run to Aldridge Creek, a highly urbanized stream. Despite the pressures of its location, it did produce a fairly diverse fish fauna, including some species typical of headwater and relatively pristine Tennessee Valley streams.

Upper Study Area 3 encompasses the Flint River system (fig. 7, stations 89-96) and the Paint Rock River system (stations 97-98). Typical of streams in the Tennessee River valley, both of these river systems support diverse and abundant fish faunas, with 63 species known from the Flint River system and 95 from the Paint Rock system (Mettee and others, 2002). All of the Paint Rock River system and the lower part of the Flint River system are in the Jackson County Mountains District of the Cumberland Plateau Physiographic Section (fig. 1). The Flint River has extreme pressure from agricultural activities in its upper reaches, which are in the Tennessee Valley district of the Highland Rim, and from growing urban pressure from the nearby Huntsville metropolis. The Paint Rock is better protected due to the presence of the rugged Jackson County Mountains throughout its length and due to the fact that much of the property is held by private landowners and protected by various conservation organizations.

Several large springs occur in the lower Flint River system within the Jackson County Mountains. A huge spring/swamp complex in that area has been given permanent protection by a private foundation and is known as the Goldsmith-Schiffman Nature Preserve (station 89). Despite that protection, the buffer zone around the complex is minimal and the complex is heavily affected by runoff from row crop production and urbanization. While the complex does possess characteristics of a spring-fed swamp, there was no recognized spring outflow typical of that occupied by the Tuscumbia Darter and no darters were collected in the accessible channel or along the upper margin of the swamp where springs would be expected. Blue Spring (station 90), located at the foot of a spur of Monte Sano Mountain in Big Cove, is a historic location for the Tuscumbia Darter. That area is undergoing rapid growth with dense housing and commercial developments nearby. Five fish species typical of healthy headwater streams in the Tennessee Valley were collected there. While the spring is somewhat protected by the forest cover and minimal development on Monte Sano Mountain, future demands on the watershed could destroy what is left of the fauna. The same may be said for Sublett Spring (station 91), another large spring at the foot of a spur of Monte Sano Mountain. It has been affected by agricultural practices in the past, and while it, too, still retains a fauna indicative of headwater and spring environments in the Tennessee Valley, the substrate is very soft and unstable. The spring is also subject to urbanization from growth of the Huntsville metropolis. Acuff Spring (station 92) is a large valley floor spring that has been drastically altered by residential development. The spring head has been modified into a large pool, the tree canopy has been removed for some distance downstream, and grass is mowed down to the stream’s edge. The instream substrate is unstable and dominated by soft mud and detritus.

Historic populations of Tuscumbia Darters are found farther upstream in the drainage within the Tennessee Valley district, land that is very suited for and affected by agricultural activities. At one historic Tuscumbia Darter location, Fishing Hole Spring (station 93), we found that the spring has been enclosed and the water within is stagnant, filled with logs and other woody debris, and no longer suitable for Tuscumbia Darters. This condition was previously reported by Jones and others (1995). Another historic location, Meridianville Spring (station 94), still has a vigorous population of Tuscumbia Darters. As were many springs in the area, at some point in the past this spring was modified for watercress production. Nonetheless, we found 18 Tuscumbia Darters in 1.0 hour using dipnets. This spring issues from the foot of a steep bluff in a low hill and spreads out into an extensive wetland and flows into Beaverdam Creek, much like the Beaverdam Spring/Beaverdam Swamp system in Limestone County. Jones and others (1995) reported this population to be stable, and it appears to remain so. A smaller but still significant unnamed spring tributary to the Flint River near the confluence with Mountain Fork (station 95) was also sampled using dipnets. The surrounding landscape is heavily agricultural and, while the spring run did appear to have potential Tuscumbia Darter habitat characteristics, no darters were collected. Another historic collection location, an unnamed spring just upstream of a watercress pond (station 96) is located adjacent to a Madison County Water Well. It is nestled at the foot of an outlier of the Jackson County Mountains and represents the eastern extent of known Tuscumbia Darter populations. In 0.5 hour sampling with a dipnet, 20 Tuscumbia Darters were found. This was one of the new populations reported by Jones and others (1995) and, though only one collection there was attempted during their study, they considered it to be a very healthy population. Based on the results of our collection, it remains so.

Two springs in the lower Paint Rock River system, which has never produced Tuscumbia Darters, were visited in an effort to extend the range of the Tuscumbia Darter eastward. Bethel Spring (station 97) is a fairly small but apparently healthy spring located at the foot of Keel Mountain in the Jackson County Mountains district. We sampled there with dipnets but found no Tuscumbia Darters. The other, much larger spring, which is unnamed (station 98) did have characteristics of Tuscumbia Darter habitat. We thoroughly sampled this spring with dipnets for 1.5 hours but only collected tolerant species. The spring is situated at an intersection of two county roads and is adjacent to a wet weather stream channel in a highly karst area and is likely subject to extreme fluctuations in water level.

LONG-TERM MONITORING AT WILLIAMS SPRING

Twenty-two fish species and two hybrid sunfish have been documented in Williams Spring and the spring drainage channel over a 16-year monitoring project (fig. 8, station 77; appendix B) (McGregor and others, 2015). Over that period the Tuscumbia Darter was the dominant species encountered, representing about 36 percent of the cumulative catch and ranging from a low of 7.0 percent of the catch in 2005 to a high of 70 percent of the catch in 2009 (figs. 9, 10). The next most frequently encountered and numerically abundant species collected are the Banded Sculpin (25 percent), Bluegill (13 percent), Largescale Stoneroller (8

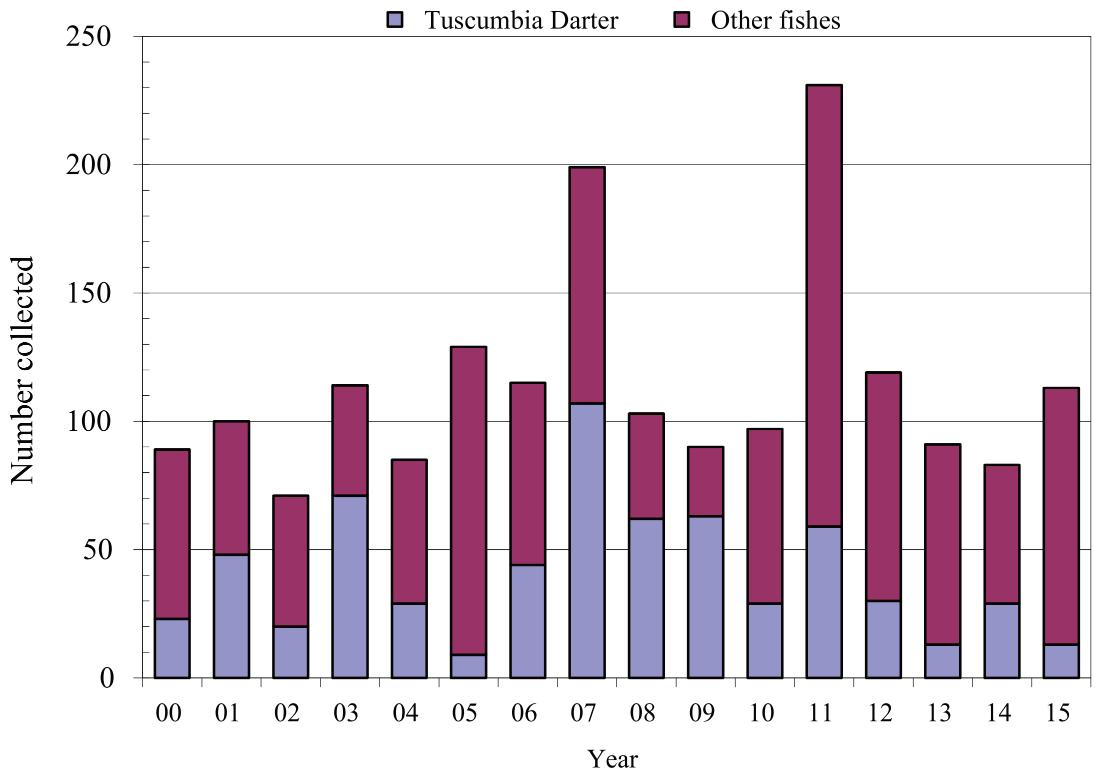

Figure 9. Catch of fishes and the Tuscumbia Darter in Williams Spring, 2000-15.

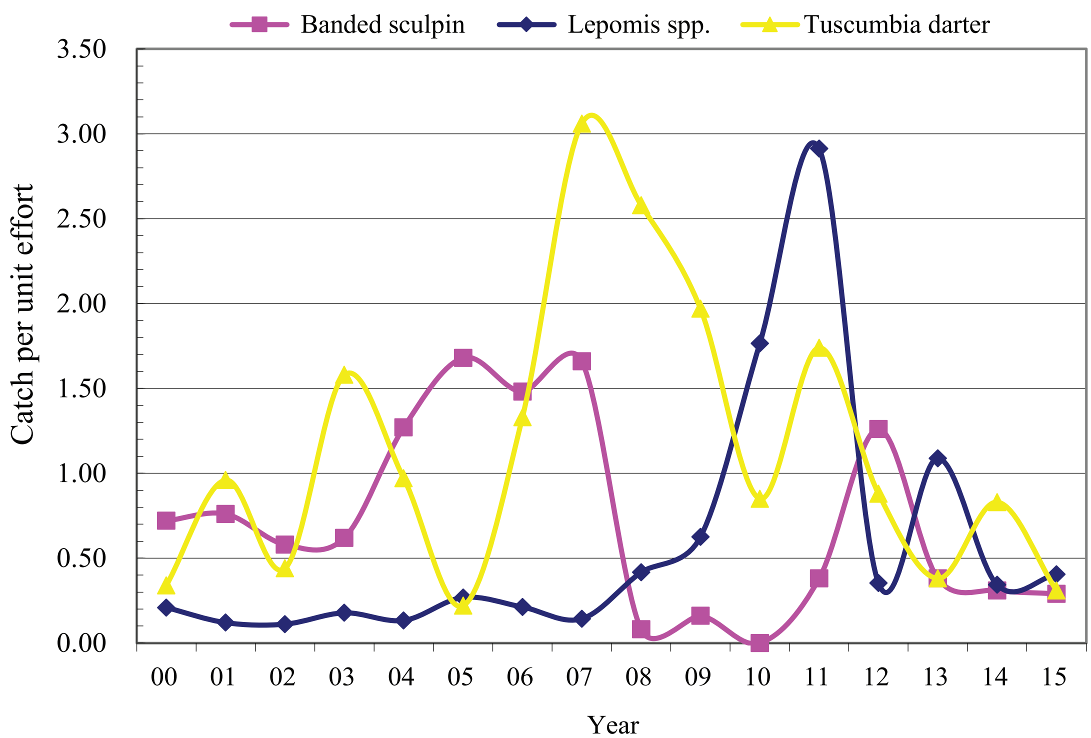

Figure 10. Catch per unit effort (CPUE) of the Tuscumbia Darter, Banded Sculpin, and all sunfishes in Williams Spring, 2000-15.

percent), and Black Darter (7 percent). Several species including the Chain Pickerel, Largescale Stoneroller, Banded Sculpin, Green Sunfish, Warmouth, Bluegill, Black Darter, and Tuscumbia Darter are regularly collected (7 or more occurrences over 16 years) and are considered resident species. The infrequent collection and/or generally low numbers of Redfin Pickerel, Flame Chub, Striped Shiner, Scarlet Shiner, Bluntnose Minnow, Blacknose Dace, Creek Chub, Northern Hog Sucker, Spotted Sucker, Western Mosquitofish, Redbreast Sunfish, Redear Sunfish, Largemouth Bass, and Logperch, suggest those species are occasional migrants from Indian Creek.

During the period 2008-10 collections began to show a gradual shift in the composition of the fish fauna (appendix B) manifested by a marked increase in the frequency of occurrence and abundance of sunfishes and a corresponding decrease in the frequency of occurrence and abundance of pickerel, minnow, darter, and sculpin species (McGregor and others, 2015). The Banded Sculpin, Largescale Stoneroller, and Black Darter were not collected at all in 2010, and Bluegill dominated the catch, almost equaling in one collection the cumulative total for that species over the previous 10-year period. Furthermore, only one individual minnow (a Striped Shiner) and no sucker or pickerel species were collected in 2010, and all sunfish species known from throughout the study period were collected during a single visit for the first time. The 2011 collection was again dominated by Bluegill, with 96 specimens collected representing 42 percent of the catch that day, and 53 percent of the cumulative catch for that species over the entire project period up to that time. The only other sunfish collected that day, the Warmouth, was represented by only three individuals. However, the 2012 collection of Bluegill was reduced to 9 individuals (8 percent of the catch that day) and single specimens of Green Sunfish and Warmouth were collected as well, in addition to a single hybrid sunfish, the second of the project to that point.

Beaver dams in the downstream spring channel significantly alter the ecology and population dynamics of fishes in the Williams Spring complex, leading to observed shifts in composition of the fauna from lotic to lentic species over time. Beaver dams were not present in the channel from 2000-2002 and the stream channel and spring run during that period was flowing and varied in depth from about 0.5 foot (0.15 m) to about 2.5 feet (0.76 m) in the deepest holes. Substrate near the spring consisted of gravel mixed with fine clay, and aquatic vegetation consisted of milfoil and filamentous algae on the shore margins. The aquatic vegetation extended into the stream channel for about 1 to 2 feet (0.3 to 0.6 m). The higher velocities in the mid-channel area during the early sampling period appeared to be sufficient to limit aquatic vegetation to the margins of the channel and spring run. Beginning in 2003 Beavers began constructing dams in the lower channel reaches. These dams were about 2 feet (0.6 m) high and backed water into the spring and spring run, increasing depth an additional 1.0 to 1.5 feet (0.3 to 0.45 m). The dams were variously successful for a few years until 2006, when they began to be more permanent and increased in size. The largest dam created a significant pool volume up to 4 feet (1.2 m) deep for several years beginning in 2006, slowing stream velocities and creating channel conditions suitable for expansion and heavy growth of milfoil in the spring run and some of the spring channel. A parallel expansion of the darter population was observed in response to the expanded amount of aquatic vegetation in the spring and spring channel while the dam was intact. However, in 2011 the dam was breached, causing reduced water level and pool volume, with a corresponding increase in flow velocity and reduced vegetation. By 2013 the dams had been fully rebuilt, again slowing flow velocity and encouraging vegetative production. During the 2014 sampling event the Beaver dam had been built to the highest level observed during the 15-year study period to that time and considerable effort was expended to knock out the dam to allow the stream to reach a workable level (observed drop of over 4 feet). Over the past few years efforts to address the Beaver problem were instituted by RSA personnel and several were trapped and removed. However, during the current effort there was evidence that other Beavers were rebuilding the dams and they were once again removed.

These habitat changes are mirrored in other fish populations as well (fig. 10; appendix B). The Banded Sculpin population has varied somewhat over the years, displaying a precipitous decline over a three-year period from 2008-2010, but showed a modest recovery during 2011-2012, with another slight dip in 2013 that continued in this recent sampling effort, perhaps in response to the flow regime again being modified by Beaver dams. Sculpins thrive in flowing water over gravel substrates, are most commonly found in gravelly mid-channel reaches, and generally do not occur with Tuscumbia Darters among aquatic vegetation. Conversion of the stream from a primarily lotic to a primarily lentic system by the Beaver dams may have been responsible for past decreases in Banded Sculpin numbers. Reduced available habitat preferred by this species and alteration of the available prey base led to reduced numbers, and the apparently breached dam and resultant return to a primarily lotic system may be responsible for the slight uptick in Banded Sculpin numbers recently. The catch of sunfish species increased as habitat became more pooled. That increase was substantial and may now be a significant biological factor in limiting small fish populations in the spring and spring channel. We collected 42 Bluegill and 10 Warmouth among six sunfish species in 2010 (54 percent of the total catch), and 96 Bluegill and 3 Warmouth in 2011 (43 percent of the total catch). However, during 2010 four other sunfish species were collected and in 2011 no other sunfish species were collected. During 2012, 9 Bluegill, 1 Green Sunfish, and 1 Warmouth were collected, representing 9 percent of the catch on that sampling day. During the 2013 effort 31 Bluegill along with 1 Green Sunfish and 4 Warmouth were collected, representing 40 percent of the total catch. During the final sampling effort, only 8 Bluegill and 8 Warmouth were collected, representing 14 percent of the catch, the same percent as during the 2013 effort. Bluegill typically feed on insects and crustaceans commonly found in aquatic vegetation, and this species may at times coexist and compete with Tuscumbia Darters for food resources. Warmouth are predators on sculpins, darters, and other smaller fishes and present a competitive pressure for Tuscumbia Darters. They are most commonly associated with snag, limb, and root cover and are not likely to occur in the same aquatic vegetation habitat with Tuscumbia Darters. However, should the spring channel habitat become permanently pooled by Beaver dams or snag habitat, the Warmouth may play an increasing role in limiting Tuscumbia Darters in the future.

Another instream habitat change noted, but not measured, in the Williams Spring complex during recent site visits is the preponderance of pond scum (*Spirogyra* sp.). In the past, algae and other vegetation encountered in the complex were types normally associated with valley floor spring environments in the Tennessee Valley of north Alabama, which is the reason for the presence of Tuscumbia Darters. However, the pond scum encountered during 2010 was hyper-abundant. The cause of this phenomenon is unknown, but pond scum is generally associated with lentic and/or hypereutrophic systems and is caused by several factors, including organic enrichment from outside sources, the natural decay of organic matter within a system, and increased exposure to sunlight leading to noxious algal blooms. In Williams Spring the explosion of pond scum was likely due to one or more of several factors, including enrichment of the ground water feeding the system from urbanization off post to the north and the removal of the tree canopy. The latter effect is due to the loss of riparian cover when water is allowed to stand on the floodplain for long periods of time, killing those trees, as when Beaver dams lead to a permanent rise in the surface level. An increase in vegetation from changes in the flow pattern from lotic to lentic by Beaver dams may provide the necessary increase in volume of organic matter, and the recent reduction in flow may have prevented the system from being able to flush the system of excess nutrients. This condition, along with the recent increase in abundance and diversity of sunfishes, may contribute to the occasional presence of hybrid sunfish in the system. During the 2011 and 2012 collections, there were no observations of excessive pond scum, likely due to the increased flow velocity from the breached dam, permitting the system to flush excess nutrients. However, more pond scum was observed during subsequent visits.

WATER QUALITY SAMPLING

WILLIAMS SPRING

The monitor at Williams Spring (station 77) was located at the confluence of a wet weather drainage channel with the spring run, approximately 200 feet (61 m) downstream of the actual spring head (fig. 8). As such, water level was determined by flow from both the spring and the drainage channel during storm water events. Beaver dams downstream in the spring run made consistent water level measurement difficult because of the variability in control. Water levels varied from near 0 feet to in excess of 5 feet during the year of measurement. Most of the peak water levels were due to storm water runoff while base flow levels were related to variability in outflow from the spring. Discharge of Williams Spring ranged from 0.86 to 6.48 cubic feet per second (ft^3/s) and averaged 4.69 ft^3/s based on 15 single yearly measurements from 2000 to 2015 made during dry periods of the year (June-August) (McGregor and others, 2015). Beaver dams were removed in the spring run downstream of the monitor (to enhance darter habitat) in late November 2014 and again in August 2015. Beaver damming activity was active once more in mid-October 2015 and the results of their work are evident in the rising water level record after this date (fig. 11). Temperature of the spring water was very consistent, hovering around 16.0 to 16.5ºC (fig. 11) year round. Stormwater runoff events were readily observed in the temperature record where colder stormwater runoff in the winter months dropped the temperature of the spring outflow. The hydrogen ion concentration (pH) varied from near 5.0, during a storm event on March 5, 2015, to near 6.6 in early December 2014 (fig. 11). Normal variation of pH was in the range of 6.0 to 6.5. Specific conductance was also relatively stable in Williams Spring run varying between 370 and 410 µS/cm except during storm events when it would consistently drop to between 100 and 200 µS/cm for one to two days post storm due to dilution of water flowing out of Williams Spring. Dissolved oxygen was relatively consistent through the year varying for the most part between 5.0 to 7.0 mg/L with most variability observed in the winter months, again attributed to high flow events (fig. 12). A reading on March 11, 2015, was near 4.0 mg/L during a storm event but had increased to 7.0 mg/L by the next reading 6 hours later (fig. 12). Graphs of dissolved oxygen and specific conductance in relation to water level are also presented in fig. 12.

AIRPORT 1

The Airport 1 monitor was located in a forested hardwood bottom along an unnamed tributary to Indian Creek (fig. 8, near station 79). The stream at this point is perennial, exhibiting flashy hydrological characteristics typical of an urbanized headwater stream with a quick rise and subsequent recession during and after storm events. The contributing watershed area at the Airport 1 monitor is 7.12 mi^2 and extends north, just east of Redstone Army Airfield, past I-565 to Research Park and other commercial development in the immediate area. Urban land cover/land use comprises about 33.4 percent of the watershed (2.38 mi^2) with an estimated impervious surface area of 11.9 percent (0.85 mi^2) (USGS Streamstats, 2015).

Water level varied from near 0.5 feet in late summer and fall to in excess of 3.0 feet during storms. The annual temperature profile is reflective of a surface stream channel and varied from 2.6 to 26.2 ºC, averaging 17.1ºC through the 2014-15 period. The pH varied from 5.7 to 7.6, averaging 7.0 units, and generally was lower during the colder months and higher during warmer periods. Specific conductance ranged from 228 to 401 µS/cm, average of 332 µS/cm, with little day-to-day variability except during storm events, when runoff diluted

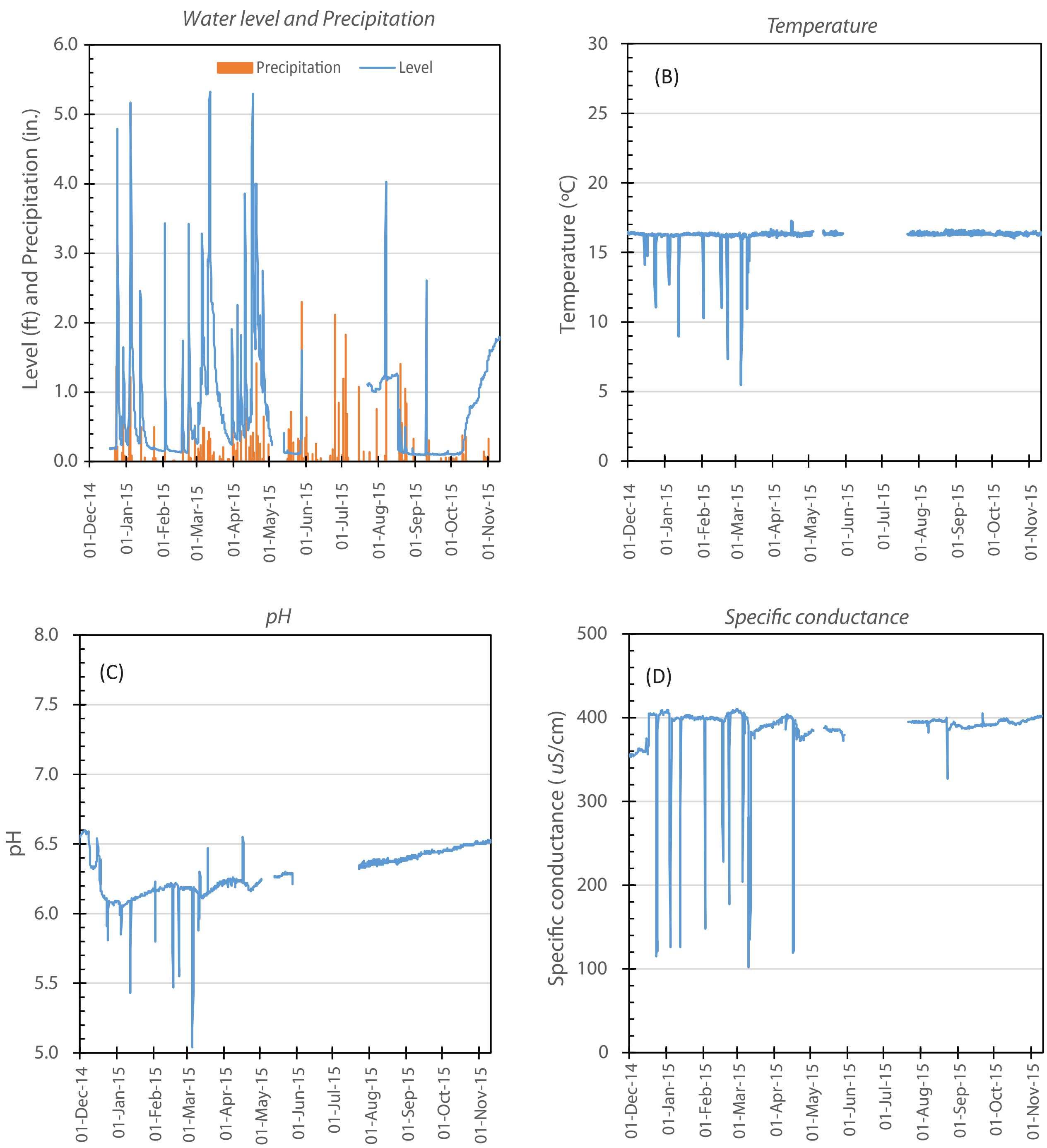

Figure 11. Water level, temperature, pH, and specific conductance plots, Williams Spring, Redstone Arsenal, Alabama, December 2014 through November 2015.

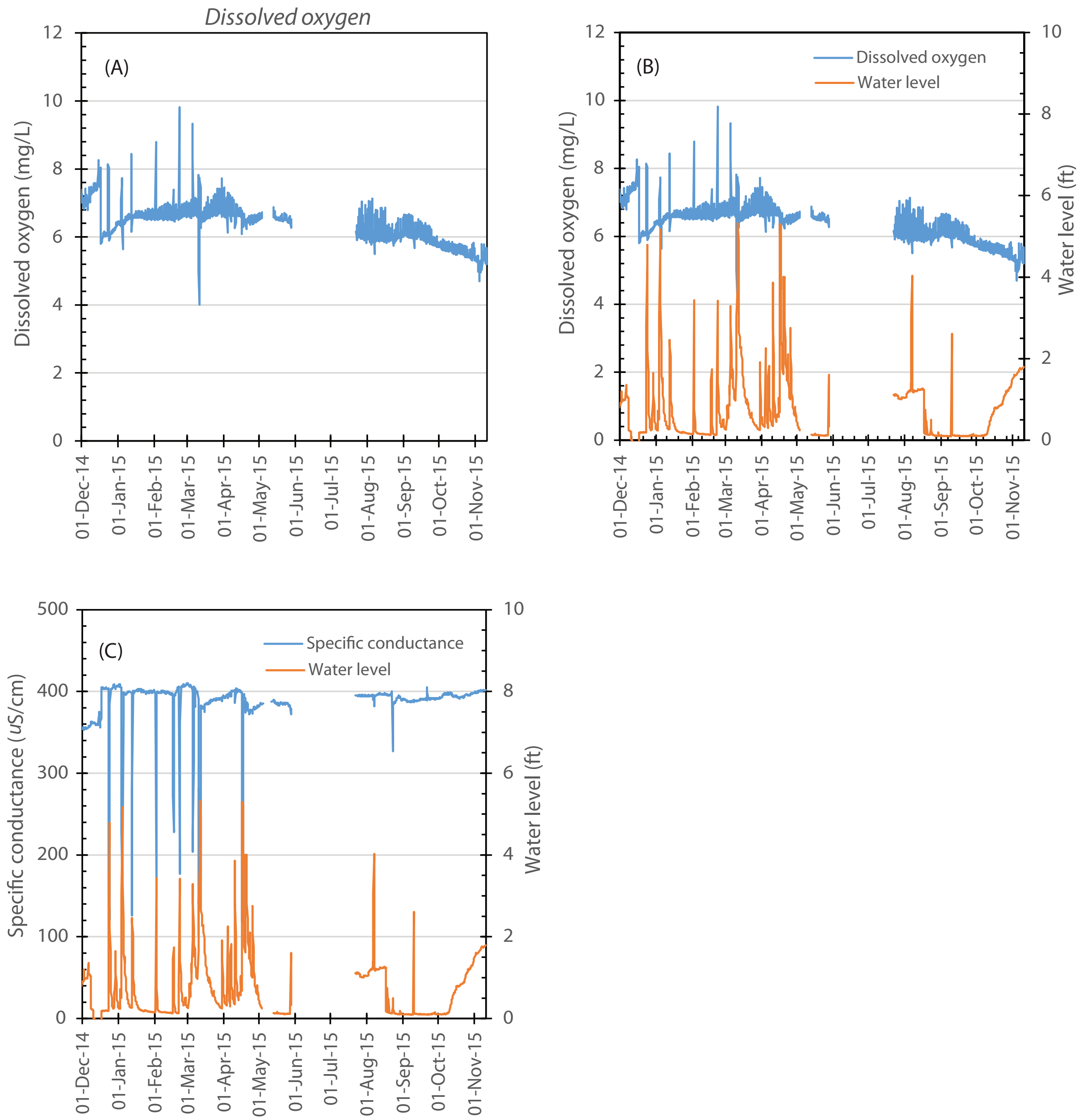

Figure 12. Dissolved oxygen, water level/dissolved oxygen, and water level/specific conductance plots, Williams Spring, Redstone Arsenal, Alabama, December 2014 through November 2015.

dissolved solids in the stream (figs. 13, 14). The seasonal pattern of dissolved oxygen was atypical. Extreme variability was evident in December 2014 and January 2015 with values ranging from 0 to near 9.5 mg/L. Comparing water level to dissolved oxygen for the entire year, it was noted that for every increase in water level, small or large, there was a corresponding decrease in dissolved oxygen. Sometimes this decrease was large, sometimes small. This pattern was also noted for specific conductance, for every increase in flow there was a corresponding decrease in specific conductance (fig. 14).

AIRPORT 2

The Airport 2 monitor (fig. 8, near station 81) was located in a forested wetland about 400 feet (122 m) south of Hale Road and just east of Redstone Army Airport. The monitor was located in a pool with the probes situated about 1 foot deep from the surface. Streamflow was extremely low most of the year, only occurring during storm events, and stream water level essentially mirrored groundwater level for most of the year. No perennial flow entered the pool even though the upstream contributing watershed was about 6.4 mi^2 in area. The monitored pool was created by a significant Beaver dam complex, downstream of which an extensive wetland has developed. Because of the ephemeral drainage upstream of the pool, the only surface water captured by the pool is supplied during storm events. The pool/wetland complex is essentially functioning as a stormwater collection basin, holding water between rain events, with limited water volume turnover between rain events. As such, certain physicochemical parameters are modified from normally expected patterns.

Water level varied from about 1.0 to 2.0 feet through the year varying with groundwater level and storm events (fig. 15). The water level spikes corresponded to rain events which would raise water levels up to 2.5 feet at times. Temperature varied from 2.2 to 27.9 ºC and averaged 16.8 ºC during the year of study, slightly cooler than the Airport 1 monitor. The pH was slightly more alkaline, ranging from 6.0 to 7.9 units and averaging 7.2. Specific conductance ranged from 75 to 504 µS/cm and averaged 284 µS/cm during the year of study (fig. 15). Specific conductance variability for Airport 2 was much higher than for Airport 1, further supporting the observation that the pool at Airport 2 is functioning as a holding pond with highly dynamic water quality.

Dissolved oxygen at the Airport 2 monitor was extremely atypical, with nearly 86 percent of the values recording 0 mg/L (fig. 16). We obviously suspected instrument error but several checks with a field dissolved oxygen meter over a month demonstrated that water in the pool was indeed very low—with many readings at or below 1.5 mg/L. The monitor was also swapped with another site and that monitor also recorded very low dissolved oxygen. Therefore, although the monitor was recording 0 mg/L, we are assuming that dissolved oxygen is likely in the range of ≤2.0 mg/L.

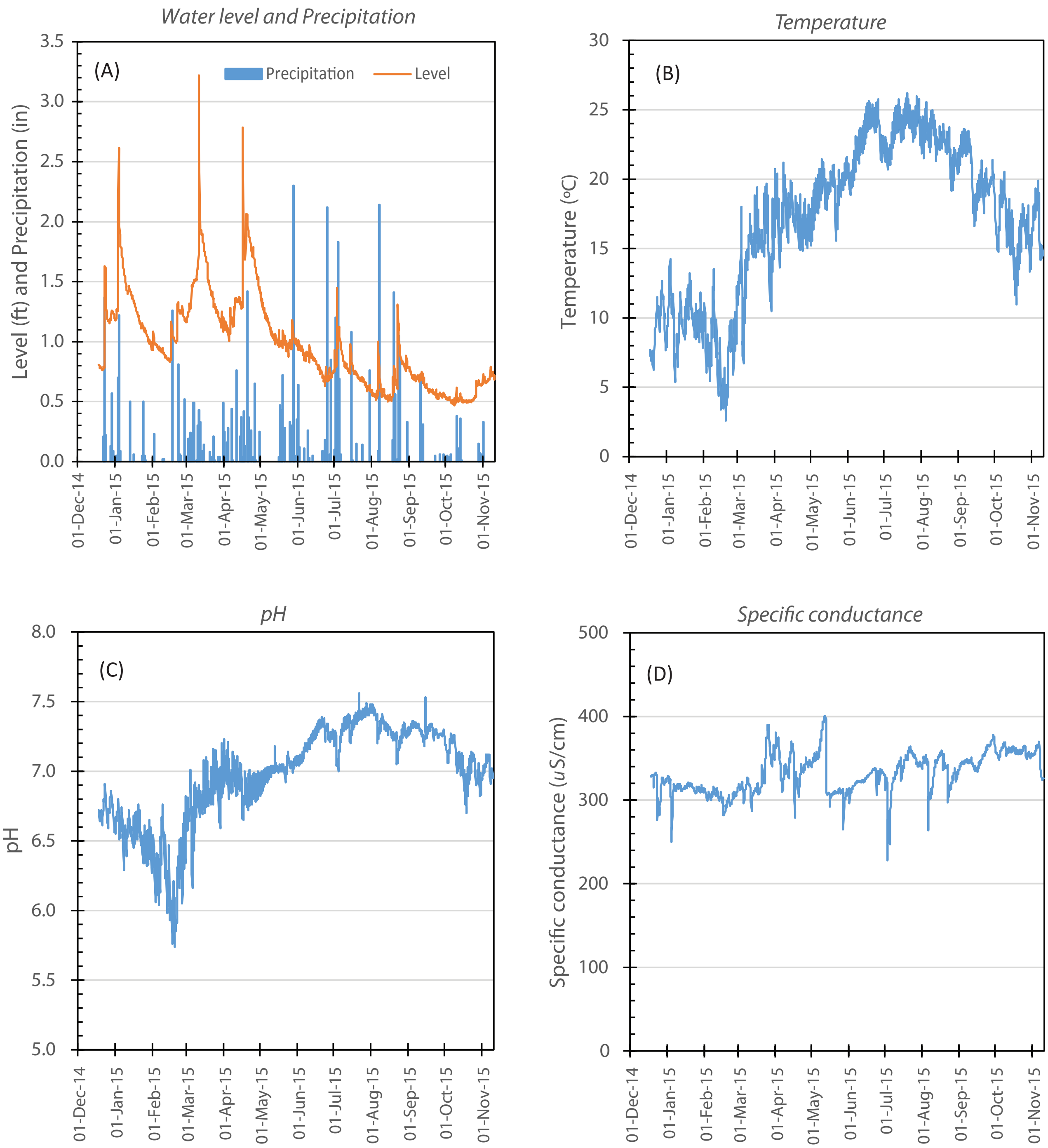

Figure 13. Water level, temperature, pH, and specific conductance plots, Indian Creek tributary (site Airport 1), Redstone Arsenal, Alabama, December 2014 through November 2015.

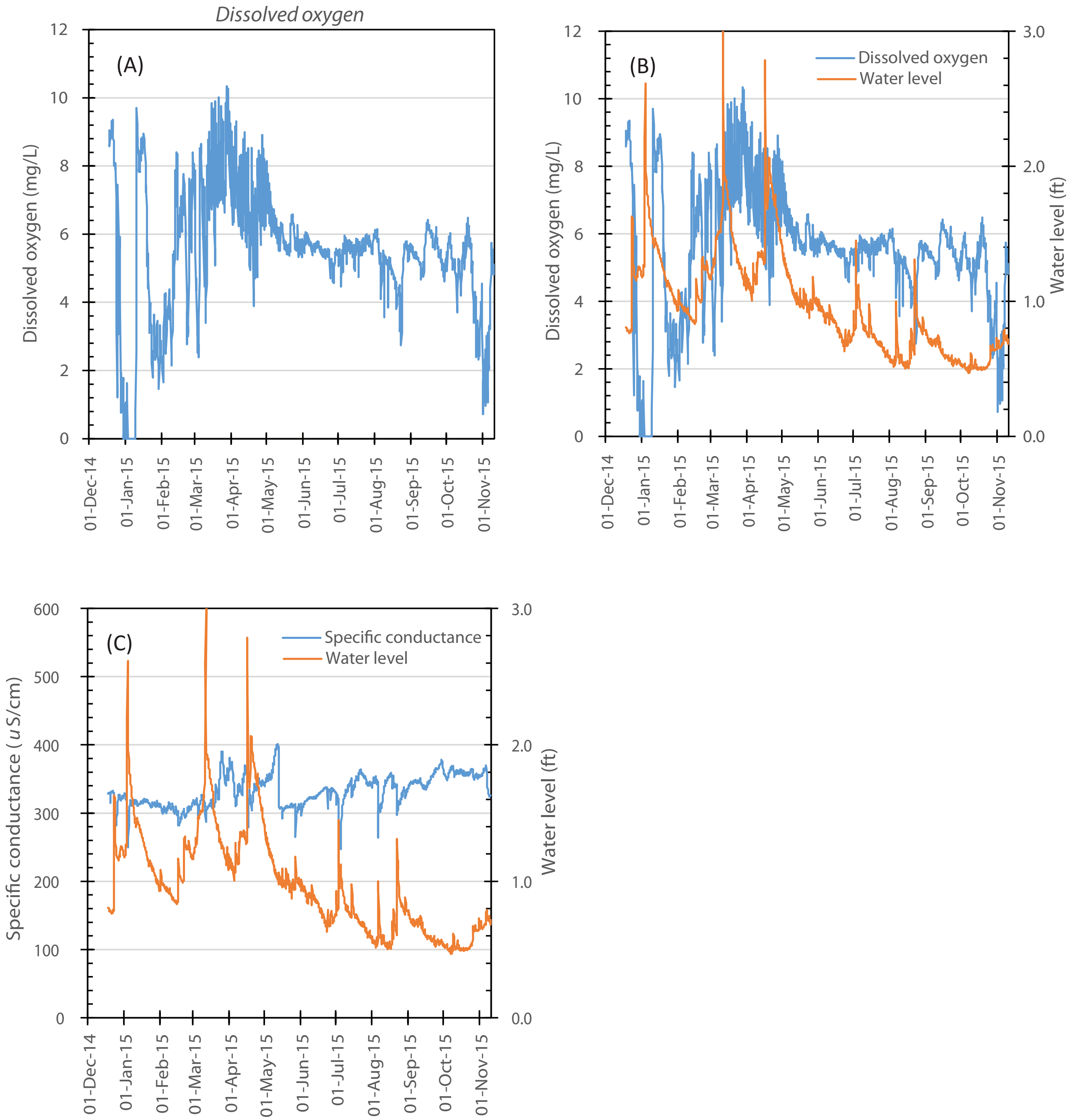

Figure 14. Dissolved oxygen, water level/dissolved oxygen, and water level/specific conductance plots, Indian Creek tributary (site Airport 1), Redstone Arsenal, Alabama, December 2014 through November 2015.

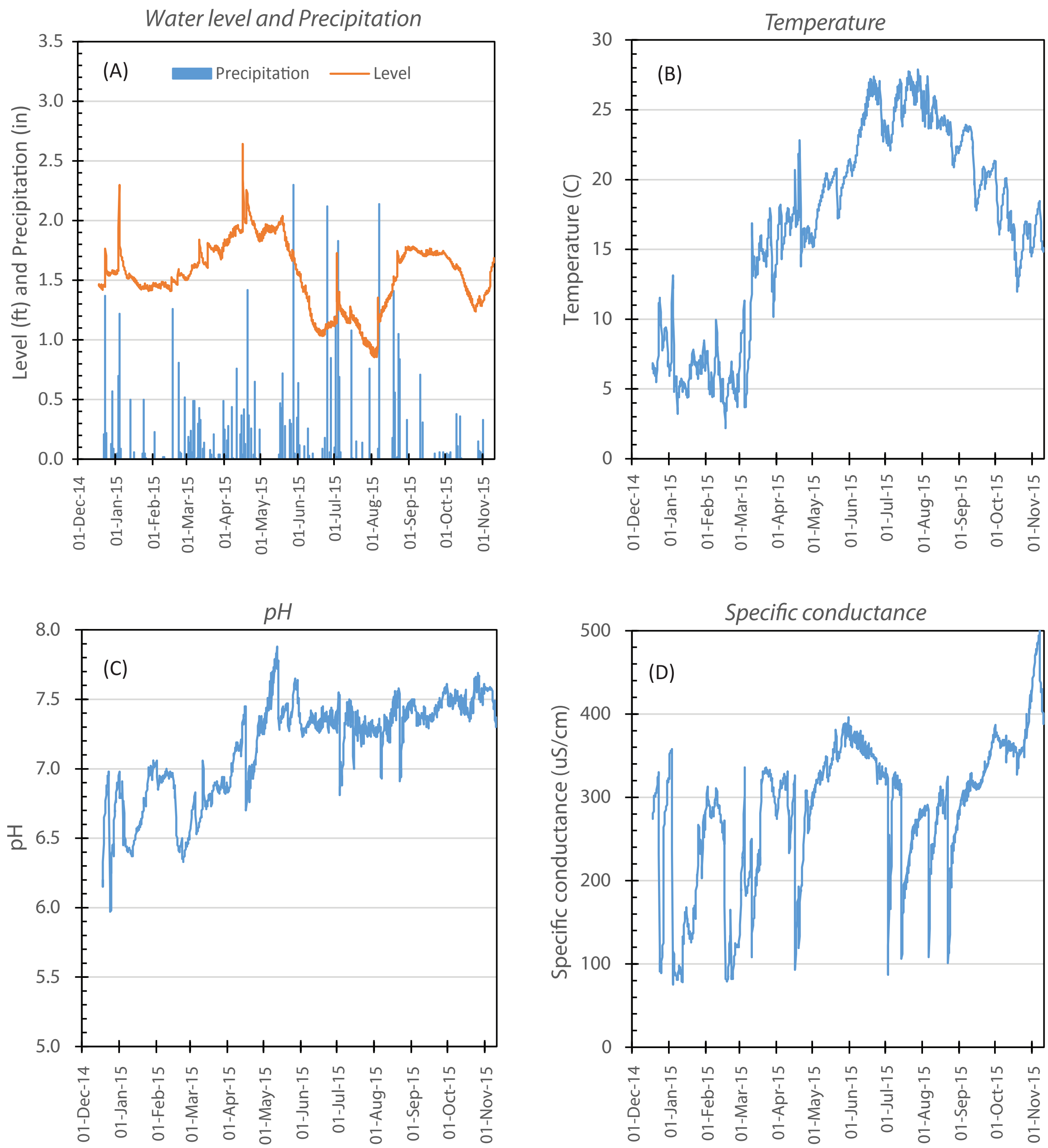

Figure 15. Water level, temperature, pH, and specific conductance plots, Indian Creek tributary (site Airport 2), Redstone Arsenal, Alabama, December 2014 through November 2015.

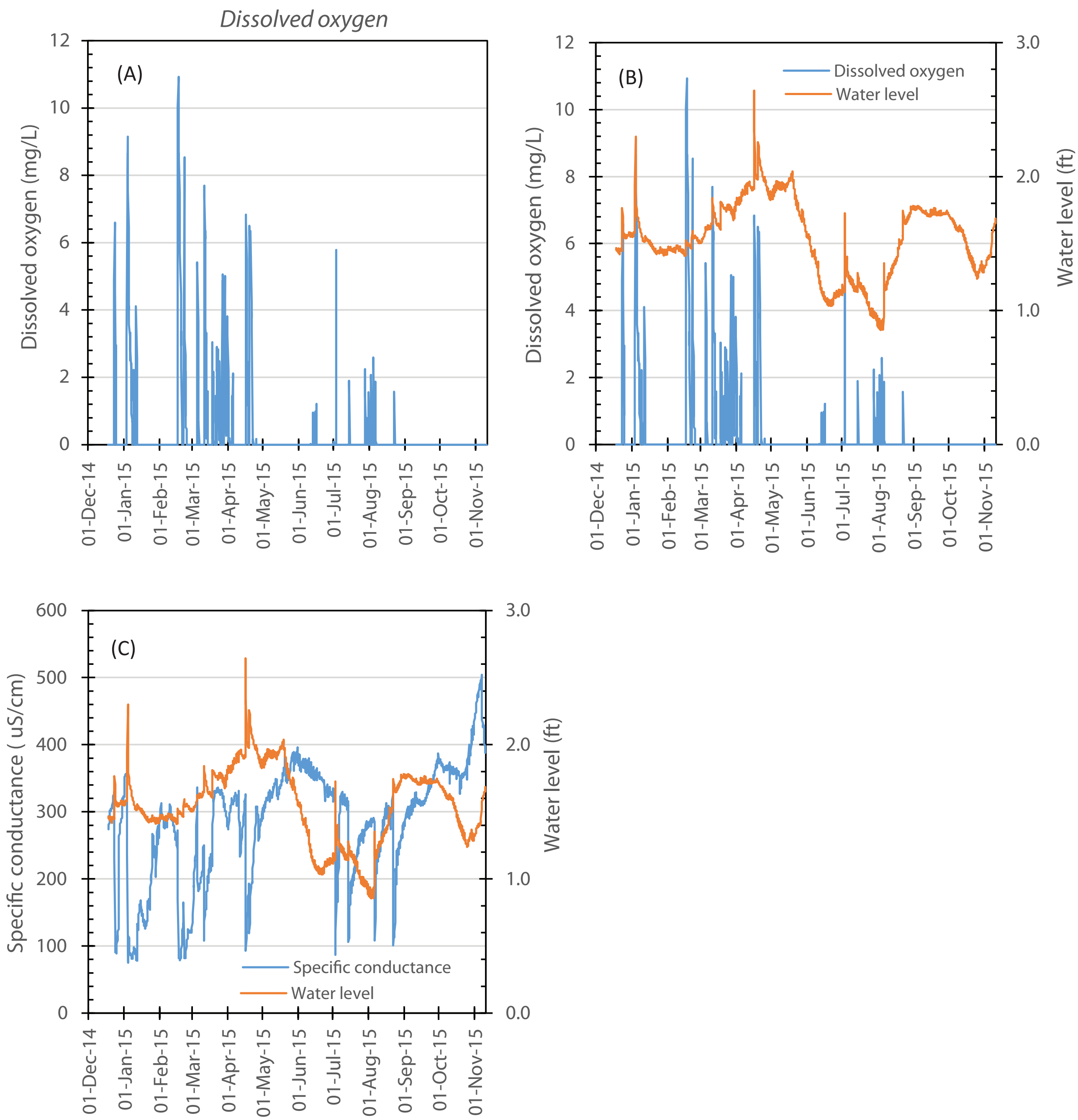

Figure 16. Dissolved oxygen, water level/dissolved oxygen, and water level/specific conductance plots, Indian Creek tributary, (site Airport 2), Redstone Arsenal, Alabama, December 2014 through November 2015.

From a limnological perspective, our best hypothesis is the stream at the Airport 2 monitor is functioning much like a settling basin used to treat pollutants and manage stormwater runoff in urban areas. Between rain events there is a significant amount of high biological oxygen demand (BOD) producing material that accumulates in the pool in the form of anaerobic sediments, high organic content, and nonpoint source pollutants, which consume oxygen at a high rate. With little surface and subsurface inflow into the pool, sometimes for significant periods of time in the summer and fall, dissolved oxygen stays depressed in the ≤1.0 to 2.0 mg/L range. Dissolved oxygen is injected into the system during storm events through surface runoff into the pool. The monitor record of dissolved oxygen at Airport 2 clearly shows the pattern of increasing dissolved oxygen with increasing water levels (fig. 16), then a rapid decline soon after water levels fall. Specific conductance also varies with level, decreasing as surface runoff increases (increasing water level and dilution). When stormwater runoff flows through Airport 2 then downstream to Airport 1, it transports a volume of low dissolved oxygen water which is detected by the Airport 1 monitor (fig 14.). As water level increases, dissolved oxygen decreases at this site. Close examination of water level and dissolved oxygen plots confirm these observations for both sites.

MANAGEMENT IMPLICATIONS FOR THE TUSCUMBIA DARTER

The Tuscumbia Darter is a habitat specific species restricted to large, perennial, vegetated, valley floor springs in the Highland Rim Section of the Tennessee River system, and also to spring runs and associated tributary systems in karst environments. Numerous historic populations disappeared when their host springs were inundated by large, run-of-the-river dams constructed on the main channel of the Tennessee River in the mid-1900s. Other populations have suffered under habitat modification due to urban encroachment and degradation from poorly managed agricultural practices. As the Huntsville/Madison metropolis and the I-65 and I-565 corridors grow and more demands are made on dwindling water resources, it is important to protect existing populations through wise planning and to restore the quality of degraded spring systems. To achieve these goals and prevent further loss of this species, we make the following recommendations:

- Minimize further degradation of spring environments by leaving substantial vegetated riparian buffer zones and tree canopy around spring margins and better manage stormwater runoff that discharges into springs.
- Repair existing spring habitats with extirpated or diminished populations of Tuscumbia Darters through restoration of riparian borders, exclusion of cattle and other potential sources of physical destruction, and protection of recharge areas.

- Minimize the introduction of animal waste, herbicides, pesticides, fungicides, fertilizers, and other chemicals into recharge areas that could alter water quality.
- In areas with anticipated urban growth, best management practices for stormwater runoff should be implemented and maintained during all phases of construction, and use of low impact development (LID) should be promoted and practiced in the immediate spring areas, including the use of pervious surfaces, roof gardens, vegetated swales, and retention ponds.
- Carefully plan for additional groundwater well construction and associated increases in withdrawals to minimize further dewatering of springs.

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APPENDIX A

Summary data for Tuscumbia Darter collection locations in the study areas
2005-2015

[1]SWM=Stuart W. McGregor
PEO=Patrick E. O’Neil
TES=Thomas E. Shepard
CCJ=Cal C. Johnson
EAW=E. Anne Wynn
RAB=Rebecca Ann Bearden
SMS=Sandra M. Stanley
GP=Greg Pierce
DKT=David K. Tidwell
BRK=Bernard R. Kuhajda
SLA=Shannon L. Allen
JRP=Jeffrey R. Powell
MWS=Michael W. Sandel
JMS=Jeffrey M. Selby
RH=Rob Hurt
LH=Lee Holt
JG=Jay Grantland
CFE=Christine F. Easterwood
RB=Randall Blackwood
SS=Sam Sandlin
DJP=David J. Peters
ASP=Ashley S. Peters
LAS=Louis A. Stumpe
AC=Allen Collie

Abbreviations:
CR=County Road
d/s=downstream
u/s=upstream
WWTP=waste water treatment plant

No.	Station	Drainage	County	Lat	Long	*Etheostoma tuscumbia* presence	Others	Effort	Date	Collectors
Lower Study Area										
Dry Creek system										
1	Mill Creek from confluence with Dry Creek upstream to near headwaters	Direct tributary of Tennessee River	Hardin, TN	35.0283	-88.1620	No	*Clinostomus funduloides* (1); *Campostoma oligolepis* (2); *Phoxinus erythrogaster* (1); *Etheostoma nigripinne* (1); *Semotilus* sp. (3); *Etheostoma caeruleum* (1); *Rhinichthys atratulus* (1)	1.0 hour/6' seine	11/07/12	SWM, CCJ
Springs/Swamp Complexes in Lower Study Area										
2	Unnamed tributary to Panther Creek embayment of Tennessee River	Panther Creek	Lauderdale	34.9596	-88.1451	No	*Gambusia affinis; Lepomis macrochirus; Semotilus atromaculatus; Notropis texanus*	1.25 hours/dipnet	02/26/14	SWM
3	Unnamed tributary to Tennessee River in Union Hollow	Tennessee River	Lauderdale	34.9230	-88.1259	No	*Gambusia affinis; Semotilus atromaculatus; Fundulus olivaceus; Etheostoma rufilineatum; Etheostoma crossopterum*	0.15 hour/dipnet	02/26/14	SWM
4	Rowell/Stewart springs complex	Tennessee River direct tributary	Lauderdale	34.7829	-87.8697	No	*Etheostoma caeruleum*	0.5 hour/dipnet	06/20/12	SWM
5	Cave Spring, Tennessee River near Smithsonia	Tennessee River direct tributary	Lauderdale	34.7884	-87.8857	No, Inundated	none	0	02/25/14	SWM
6	Sinking Creek swamp	Sinking Creek	Lauderdale	34.8210	-87.7907	No	*Gambusia affinis; Micropterus* sp.; *Aphredoderus sayanus*	0.25 hour/dipnet	06/20/12	SWM
Little Bear Creek										
7	Good Spring	Little Bear Creek	Franklin	34.54603	-87.7002	No	*Etheostoma kennicotti* (1); *Gambusia affinis* (common)	0.3 hour/dipnets	12/17/13	SWM, CCJ

No.	Station	Drainage	County	Lat	Long	*Etheostoma tuscumbia* presence	Others	Effort	Date	Collectors
Spring Creek system										
8	Tuscumbia Spring (type locality)	Spring Creek	Colbert	34.72887	-87.7062	Yes	*Etheostoma tuscumbia* (27); *Lepomis macrochirus* (8); *Lepomis microlophus* (2); *Ambloplites rupestris* (1); *Esox americanus* (1)	0.15 hour/6' seine	12/17/13	SWM, CCJ
Springs/Swamp Complexes in Lower Study Area										
9	Key Spring	Direct to Tennessee River via Coffee Slough	Lauderdale	34.74858	-87.7692	No	*Gambusia affinis* (10); *Fundulus notatus* (3); *Lepomis microlophus* (7); *Lepomis macrochirus* (10)	0.5 hour/dipnets	12/17/13	SWM, CCJ
10	Spring at Florence WWTP	Direct to Tennessee River via Coffee Slough	Lauderdale	34.7806	-87.7111	No	none	0.5 hour/6' seine, dipnets	04/08/13	SWM, CCJ
Cypress Creek system										
11	Unnamed spring and run alongside Ala. Hwy. 20 at McFarland Park	Cypress Creek	Lauderdale	34.7904	-87.6798	No	*Gambusia affinis* (common); *Lepomis microlophus* (2)	0.15 hour/6' seine	10/25/13	SWM, CCJ
12	Unnamed stream alongside Ala. Hwy. 20	Cypress Creek	Lauderdale	34.7978	87.7057	No	*Rhinichthys atratulus* (6)	0.5 hour/6' seine	12/16/13	SWM, CCJ
13	Spring tributary to Cypress Creek on Brandance family property	Cypress Creek	Lauderdale	34.8165	-87.7225	No	*Cottus carolinae* (2)	0.25 hour/6' seine	12/16/13	SWM, CCJ
14	King (Buffler) Spring	Cypress Creek	Lauderdale	34.8572	-87.6541	Yes	*Etheostoma tuscumbia* (12); *Etheostoma crossopterum* (1)	0.25 hour/dipnet	01/30/13	SWM
15	Gresham Spring	Cypress Creek	Lauderdale	34.8614	-87.6257	No	*Etheostoma crossopterum; Lepomis cyanellus; Semotilus atromaculatus; Clinostomus funduloides*	0.75 hour/dipnet	02/25/14	SWM

No.	Station	Drainage	County	Lat	Long	*Etheostoma tuscumbia* presence	Others	Effort	Date	Collectors
Shoal Creek system										
16	Spring tributary to St. Florian Branch and branch itself in St. Florian	Shoal Creek	Lauderdale	34.8760	-87.6228	No	*Lepomis cyanellus*	1.25 hours/dipnet	02/25/14	SWM, DJP, LAS
17	Bretherick Branch and spring tributaries u/s CR 37	Shoal Creek	Lauderdale	34.9063	-87.5754	No	*Semotilus atromaculatus; Cottus carolinae; Clinostomus funduloides*	1.25 hours/dipnet	05/08/14	
	First Creek									
18	Blowing Spring Cave and run, tributary to First Creek upstream of CR 92	First Creek	Lauderdale	34.8650	-87.3033	No	*E. caeruleaum; Cottus carolinae*	0.5 hour/dipnets	07/02/15	SWM, ASP
Middle Study Area										
Elk River										
19	Unnamed spring tributary to Maple Swamp Branch	Elk River	Limestone	34.8414	-87.1831	No	*Cottus carolinae*	1.5 hours/dipnets	04/09/13	JDC, CCJ
20	Unnamed tributary of Mechanic Branch at Mt. Rozell on Ala. Hwy. 99	Elk River	Limestone	34.9342	-87.1376	No	*Hemitrema flammea; Semotilus atromaculatus; Rhinichthys atratulus*	1.0 hour/dipnets	04/09/13	SWM, CCJ
21	Monday Spring (downstream in creek) at Kieff Hollow Rd.	Elk River	Limestone	34.9793	-87.1213	No	none	0.5 hour/dipnets	04/09/13	JDC, CCJ
22	Salem Spring at Ala. Hwy. 99	Elk River	Limestone	34.9156	-87.1117	No	*Gambusia affinis; Cottus carolinae; Etheostoma nigripinne*	0.5 hour/dipnets	04/09/13	JDC, CCJ
23	Blue Spring in Chapman Hollow	Elk River	Limestone	34.9209	-87.1033	No	none	0.35 hour/dipnets	04/09/13	JDC, CCJ
24	Cedar Bluff Spring at Leggtown	Elk River	Limestone	34.9559	-87.0648	No	*Luxilus chrysocephalus; Lepomis cyanellus; Gambusia affinis; Semotilus atromaculatus; Cottus carolinae; Campostoma oligolepis; Etheostoma nigripinne*	1.0 hour/6' seine	04/09/13	SWM, CCJ

No.	Station	Drainage	County	Lat	Long	*Etheostoma tuscumbia* presence	Others	Effort	Date	Collectors
Wheeler Branch										
25	Wheeler Branch	Spring Creek	Lawrence	34.7026	-87.2666	Inundated	none	0	11/08/12	SWM, CCJ
26	Wheeler Branch at Swoope Pond Road (CR 388)	Spring Creek	Lawrence	34.6870	-87.2445	Yes	*Notemigonus crysoleucas* (2); *Pimephales notatus* (1); *Minytrema melanops* (3); *Ameiurus melas* (2); *Ictalurus punctatus* (1); *Fundulus notatus* (3); *Morona mississippiensis* (3); *Lepomis gulosus* (35); *Lepomis cyanellus* (26); *Lepomis humilis* (12); *Lepomis macrochirus* (251); *Lepomis megalotis* (91); *Lepomis microlophus* (66); *Lepomis* spp. (1); *Micropterus salmoides* (4); *Etheostoma tuscumbia* (5); *Perca flavescens* (1); *Percina caprodes* (4)	~2.0 hours/12' seine (TVA IBI)	06/17/05	TVA IBI crew
			Lawrence			No	*Gambusia affinis; Lepomis microlophus; Lepomis gulosus; Fundulus olivaceous*	0.25 hour/6' seine	11/08/12	SWM, CCJ
27	Wheeler Branch at CR 377 S of Alt. U.S. Hwy. 72/Ala. Hwy. 20	Spring Creek	Lawrence	34.6590	-87.2496	Yes	*Etheostoma tuscumbia* (1); *Hemitrema flammea* (few); *Gambusia affinis* (few)	0.25 hour/6' seine	11/08/12	SWM, CCJ
28	Wheeler Spring	Spring Creek	Lawrence	34.6522	-87.2522	Yes	*Etheostoma tuscumbia* (50); *Hemitrema flammea* (2); *Campostoma oligolepis*	0.5 hour/dipnets; 0.5 hour/dipnets	06/04/15	SMS, RAB, CCJ
Mallard Creek										
29	Pond Mallets	Mallard Creek	Lawrence	34.68650	-87.1758	No	no data		11/08/12	SWM, CCJ
30	Mallard Creek just downstream of Alt. U.S. Hwy. 72/Ala. Hwy. 20	Mallard Creek	Lawrence	34.6532	-87.2067	No	*Lepomis* sp.; *Gambusia affinis*	0.5 hour/6' seine	11/06/12	SWM, CCJ

No.	Station	Drainage	County	Lat	Long	*Etheostoma tuscumbia* presence	Others	Effort	Date	Collectors
Pryor Branch										
31	Pryor Branch at Harris Station Road	Pryor Branch	Limestone	34.6585	-86.9718	No	no data	0.15 hour/dipnet	11/09/12	SWM, CCJ
32	Pryor Branch at old railroad bed	Pryor Branch	Limestone	34.6642	-86.9659	No	*Gambusia affinis* (common); *Lepomis gulosus*	0.25 hour/ 6' seine	11/09/12	SWM, CCJ
						No	*Gambusia affinis* (common); *Lepisosteus oculatus* (1)	0.25 hour/ 6' seine	12/18/13	SWM, CCJ
33	Pryor Spring #2 at old rest stop on U.S. Hwy. 31	Pryor Branch	Limestone	34.6748	-86.9523	Yes	*Etheostoma tuscumbia* (25)	0.5 hours/6' seine	09/24/14	CCJ, BRK
34	Pryor Spring alongside U.S. Hwy. 31 (d/s)	Pryor Branch	Limestone	34.6756	-86.9500	Yes	*Etheostoma tuscumbia* juveniles (27); *Lepomis macrochirus* (7); *Gambusia affinis; Lepomis gulosus; Ameiurus* sp.	0.5 hours/dipnets	06/04/15	SMS, RAB, CCJ
35	Pryor Spring u/s U.S. Hwy. 31	Pryor Branch	Limestone	34.6780	-86.9486	No	no data	0.25 hour/6' seine	11/09/12	SWM, CCJ
Flint Creek										
36	Clear Spring Branch (Clark Spring on topo)	Flint Creek	Morgan	34.56298	-86.9995	No	*Campostoma oligolepis* (common); *Gambusia affinis* (common); *Micropterus salmoides* (2)	0.5 hour/6' seine	12/18/13	
Upper Study Area 1										
Beaverdam Creek										
37	Unnamed tributary to Limestone Creek at CR 71 (Mooresville-Elkton Road)	Limestone Creek	Limestone	34.68417	-86.8783	No	*Lepomis cyanellus* (1); *Lepomis macrochirus* (1); *Pimephales notatus* (2)	0.5 hour/dipnets	12/20/13	SWM, CCJ
						No	*Lepomis macrochirus; Campostoma oligolepis; Hypentelium nigricans; Lepisosteus osseus; Luxilus chrysocephalus; Etheostoma duryi*	0.25 hour/dipnets	6/3/15	SMS, RAB, CCJ

No.	Station	Drainage	County	Lat	Long	*Etheostoma tuscumbia* presence	Others	Effort	Date	Collectors
38	Toney Spring at Old Railroad Bed Road and Dan Crutcher Road	Limestone Creek	Madison	34.90406	-86.7316	No	none collected	0.35 hour/dipnets	12/19/13	SWM, CCJ
39	Unnamed tributary to Beaverdam Creek at west end of Barlow Road, aka Pickett Pond	Beaverdam Creek	Limestone	34.6199	-86.8172	No	*Pimephales notatus; Etheostoma kennicotti; Micropterus salmoides; Lepomis cyanellus; Lepomis miniatus; Notemigonus crysoleucas; Gambusia affinis; Ameiurus natalis*	0.35 hour/6' seine	10/24/13	SWM, CCJ
						Yes	*Pimephales notatus; Lepomis cyanellus; Etheostoma tuscumbia* (7); *Notemigonus crysoleucas; Gambusia affinis; Lepomis miniatus* (1); *Semotilus atromaculatus*	1.0 hour/dipnets	06/03/15	SMS, RAB, CCJ
40	Sulcer Spring	Beaverdam Creek	Limestone	34.6323	-86.8372	No	none	0.35 hour/dipnet	10/24/13	SWM, CCJ, SLA
41	Thorsen Spring	Beaverdam Creek	Limestone	34.6400	-86.8092	Yes	*Etheostoma tuscumbia* (5)	0.75 hour/dipnets	11/18/08	
42	Withers Spring	Beaverdam Creek	Limestone	34.6767	-86.7923	No	none	0.75 hour/dipnets	05/20/14	SWM, EAW
43	Spring along Ala. Hwy. 20, just north of I-565	Beaverdam Creek	Limestone	34.6486	-86.8244	No	none	0.25 hour/dipnet	06/03/15	SMS, RAB, CCJ
44	Spring on CR 119 (old CR 11 opposite old Mt. Pleasant School site) on Segars Road	Beaverdam Creek	Limestone	34.6767	-86.8164	No	*Lepomis auritus*	0.15 hour/dipnet; 0.25 hour/dipnets	5/20/2014; 6/3/15	SWM/SMS, RAB, CCJ
45	Beaverdam Creek at old Ala. Hwy. 20	Beaverdam Creek	Limestone	34.6675	-86.8150	Yes	*Etheostoma tuscumbia* (4)	0.25 hour/dipnet	12/16/13	MWS
						Yes	*Etheostoma tuscumbia* (1); *Elassoma alabamae* (1); *Lepomis macrochirus* (1); *Gambusia affinis*	1.0 hour/dipnet	06/10/15	JMS
46	Moss Spring	Beaverdam Creek	Limestone	34.69150	-86.8425	Yes	*Etheostoma tuscumbia* (1)	1.0 hour/dipnets	06/10/15	MWS

No.	Station	Drainage	County	Lat	Long	*Etheostoma tuscumbia* presence	Others	Effort	Date	Collectors
47	Beaverdam Spring complex at McDonald tract	Beaverdam Creek	Limestone	34.6934	-86.8303	Yes	*Etheostoma tuscumbia* (8); *Elassoma alabamae* (33); *Gambusia affinis; Lepomis macrochirus; Etheostoma duryi; Erimyzon oblongus*	1.0 hour/dipnets	05/19/15	JMS
48	Beaverdam Spring-Lowe Ditch	Beaverdam Creek	Limestone	34.70280	-86.8294	Yes	*Etheostoma tuscumbia* (6)	0.5 hour/dipnets	02/07/08	MWS
						Yes	*Etheostoma tuscumbia* (7); *Elassoma alabamae* (120); *Gambusia affinis; Esox niger*	1.0 hour/dipnets	05/12/15	JMS
Cave Spring										
49	Cave Spring	Cave Spring	Morgan	34.5460	-86.8509	No	*Hemitrema flammea; Lepomis macrochirus; Etheostoma duryi; Gambusia affinis*	1.0 hour/dipnets	03/11/14	SWM
						No	*Hemitrema flammea* (5); *Gambusia affinis* (30); *Etheostoma duryi* (7); *Lepomis cyanellus* (4)	1.0 hour/dipnets	11/05/15	CCJ, SMS, PEO, RH, LH
Independent Tributaries										
50	Rockhouse Landing		Limestone	34.5636	-86.8419	Historic Yes; No	Inundated		10/24/13	CCJ, SWM
51	Blair Spring		Limestone	34.5673	-86.8105	Historic Yes; No	*Gambusia affinis* (147); *Lepomis gulosus* (1); *Lepomis cyanellus* (1)	2.5 hours/dipnets	11/05/15	CCJ, SMS, PEO, RH, LH
52	Blackwell Swamp		Madison	34.5881	-86.7827	No	*Gambusia affinis* (common); *Elassoma alabamae* (97); *Lepomis gulosus* (6); *Lepomis macrochirus* (11)	6.25 hours/dipnets	11/04/15	CCJ, SMS, PEO, RH, LH
Wright Spring										
53	Wright Spring	Wright Spring Creek	Morgan	34.5174	-86.8180	No	*Lepomis macrochirus* (common)	1.25 hour/dipnet	03/11/14	SWM

No.	Station	Drainage	County	Lat	Long	*Etheostoma tuscumbia* presence	Others	Effort	Date	Collectors
Cotaco Creek										
54	Grantland Spring at Grantland/Curry Chapel Bridge	Cotaco Creek	Morgan	34.5084	-86.7119	No	*Cottus carolinae* (2); *Rhinichthys atratulus* (2); *Phoxinus erythrogaster* (1)	1.5 hours/dipnets	05/15/15	SWM, RAB, JG
55	Entrekin Spring at Entrekin Road	Cotaco Creek	Morgan	34.3864	-86.6544	No	none	1.0 hour/dipnets	05/15/15	SWM, RAB, JG
56	Hughes Spring at Pine Ridge Road	Cotaco Creek	Morgan	34.4173	-86.5933	No	*Phoxinus erythrogaster*	1.5 hourr/dipnets	05/15/15	SWM, RAB, JG
57	Skidmore Spring	Cotaco Creek	Morgan	34.3922	-86.5829	No	*Etheostoma crossopterum; Etheostoma duryi; Fundulus olivaceus; Cottus carolinae*	1.5 hours/dipnets	05/15/15	SWM, RAB, JG
Upper Study Area 2										
Indian Creek										
58	Tributary of Bradford Creek at Westchester Rd.	Indian Creek	Madison	34.6775	-86.7615	No	*Gambusia affinis* (2); *Hemitrema flammea* (7); *Semotilus atromaculatus; Campostoma oligolepis* (3); *Etheostoma simoterum* (13); *Etheostoma nigripinne* (13)	1.0 hour/dipnet	08/12/14	SWM
						No	*Campostoma oligolepis* (2); *Luxilus chrysocephalus* (1); *Hemitrema flammea* (4); *Lepomis macrochirus* (15); *Lepomis microlophus* (1); *Etheostoma duryi* (20); *Etheostoma nigripinne* (50); *Gambusia affinis* (20); *Fundulus olivaceus* (1)	1.0 hour/6' seine	12/18/14	PEO, GP, DKT
59	Large, spring-fed swamp (a.k.a. 'Cow Sump') N Bobcat Cave, tributary to Betts Spring Branch	Indian Creek	Madison	34.6707	-86.7127	No	*Gambusia affinis* (common); *Lepomis macrochirus* (1)	3.0 hour/dipnets	03/18/15	SWM, RAB, SMS

No.	Station	Drainage	County	Lat	Long	***Etheostoma tuscumbia* presence**	Others	Effort	Date	Collectors
60	Swan Pond, W Anderson and Centerline roads, along E margin	Indian Creek	Madison	34.6173	-86.7082	No	*Gambusia affinis* (common); *Lepomis* (2)	1.0 hour/dipnets	05/14/15	SWM, RAB
61	Wetland NE Swan Pond, W Anderson and Centerline roads	Indian Creek	Madison	34.6200	-86.7078	No	none	1.0 hour/dipnets	05/14/15	SWM, RAB
62	Spring at head of large lake tributary to Indian Creek on TA1, south of Martin Road	Indian Creek	Madison	34.6335	-86.7087	No	none	1.5 hours/dipnets	10/24/13	SWM, CCJ, SLA
63	Swamp behind Outdoor Recreation Center on Sportsmans Road	Indian Creek	Madison	34.6511	-86.6242	No	*Gambusia affinis* (common)	1.5 hours/dipnets	12/16/14	SWM, SLA, AC
						No	*Lepomis macrochirus* (1)	1.0 hour/dipnets	05/12/15	SWM, SLA
64	Swamp off Almond Road near powerline on S end	Indian Creek	Madison	34.6532	-86.6234	No	*Gambusia affinis*	1.0 hour/dipnets	05/13/15	SWM, RAB
65	Swamp off Almond Road near powerline on W end	Indian Creek	Madison	34.6536	-86.6225	Yes	*Etheostoma tuscumbia* (7); *Gambusia affinis*	1.0 hour/dipnets	12/16/14	SWM
66	Swamp off Almond Road near powerline on N end	Indian Creek	Madison	34.6630	-86.6202	Yes	*Etheostoma tuscumbia* (7) (including one SA); *Gambusia affinis* (common); *Esox* sp. (1)	2.0 hours/dipnets	11/19/14	SWM, CCJ, SLA, EAW
67	Swamp off McDonald Creek near Creek Road south of Martin Road	Indian Creek	Madison	34.6434	-86.6140	No	*Etheostoma duryi* (16); *Lepomis macrochirus* (3); *Gambusia affinis* (1); *Lepomis gulosus* (1); *Pimephales notatus* (2); *Lepomis miniatus* (9); *Etheostoma kennicotti* (8)	1.0 hour/6' seine	10/23/13	CCJ, SLA, SWM

No.	Station	Drainage	County	Lat	Long	*Etheostoma tuscumbia* presence	Others	Effort	Date	Collectors
68	Spring/swamp complex along Martin Road at E boundary RSA	Indian Creek	Madison	34.6511	-86.6089	No	no data	1.0 hour/dipnets	12/17/14	PEO, DKT
69	McDonald Creek from spring near Hansen Road upstream to RSA boundary	Indian Creek	Madison	34.6777	-86.6195	No	*Campostoma oligolepis; Semotilus atromaculatus; Gambusia affinis; Etheostoma duryi; Etheostoma flaballare*	1.0 hour/6' seine	02/10/00	SWM, TES
						No	none	4.0 hours/dipnets	11/18/14	SWM, CCJ, SLA, EAW
70	Swamp S Thiokol Pond	Indian Creek	Madison	34.6248	-86.5913	No	none	0.35 hour/dipnets	12/17/14	SWM, SLA, GP
71	Thiokol Pond	Indian Creek	Madison	34.6321	-86.6034	No	none	0.35 hour/dipnets	12/17/14	SWM, SLA, GP
72	Byrd Spring	Indian Creek	Madison	34.6642	-86.5825	Yes	*Etheostoma tuscumbia* (100s)	Several hours/several crews	07/16/14	JRP et al.
73	Brahan Spring	Indian Creek	Madison	34.7067	-86.6005	Yes	*Etheostoma tuscumbia* (1)	0.25 hour/dipnets	03/28/12	SWM et al.
74	Isa Spring/swamp complex on NASA property	Indian Creek	Madison	34.6346	-86.6743	No	none	1.0 hour/dipnets	12/18/14	SWM, SLA, CFE
75	Spring/swamp complex south of NASA small arms range, east bank	Indian Creek	Madison	34.6357	-86.6802	Yes	*Etheostoma tuscumbia* (1)	0.75 hour/dipnets	12/18/14	SWM, SLA, CFE
76	Spring/swamp complex south of NASA small arms range, north bank near Moore Cemetery	Indian Creek	Madison	34.6417	-86.6814	Yes	*Etheostoma tuscumbia* (2)	2.25 hours/dipnet	11/17/14	SWM
						Yes	*Etheostoma tuscumbia* (3)	3.0 hours/dipnet	12/18/14	SWM, SLA, CFE
77	Williams Spring	Indian Creek	Madison	34.6472	-86.6894	Yes	*Etheostoma tuscumbia*, range of 9-107 individuals per year	Repeated, intensive annual efforts with 10' seine	Annually	SWM, PEO, et al.
78	Indian Creek from Martin Rd. upstream to Hale Road	Indian Creek	Madison	34.6474	-86.6891	Yes	*Etheostoma tuscumbia* (2)	4.0 hours/6' seine	03/27/12	SWM, TES, CCJ, SLA

No.	Station	Drainage	County	Lat	Long	***Etheostoma tuscumbia* presence**	Others	Effort	Date	Collectors
79	Indian Creek tributary near Redstone Arsenal airport on Hale Road	Indian Creek	Madison	34.6572	-86.6906	Yes	*Etheostoma duryi* (57), *Campostoma oligolepis (* 1); *Hemitrema flammea* (10); *Luxilus chrysocephalus* (38); *Etheostoma tuscumbia* (3)*; Lepomis cyanellus* (2); *Lepomis megalotis* (1); *Gambusia affinis* (1); *Lepomis gulosus* (1)*; L auritus* (1); *Minytrema melanops* (3)*; Esox niger* (2)	2.25 hours/dipnets, 6' seine	10/22/13	SWM, CCJ, SLA
						No	*Etheostoma duryi* (10)*; Gambusia affinis* (20); *Lepomis macrochirus* (4); *Luxilus chrysocephalus* (2); *Lepomis gulosus* (1)	4.0 hours, dipnets	11/18/14	SWM, SLA, CCJ, EAW
						Yes	*Etheostoma tuscumbia* (3)	no data	12/16/14	PEO, CCJ, DKT
80	Indian Creek tributary near Redstone Arsenal airport on Hale Road, further upstream	Indian Creek	Madison	34.6652	-86.6790	Yes	*Etheostoma tuscumbia* (10)	1.5 hours, dipnet	10/21/09	SWM
						Yes	*Etheostoma tuscumbia* (33); *Gambusia affinis* (common)*; Esox* sp. (few)*; Lepomis* sp.(common)	1.5 hours/dipnets	05/21/14	SWM, EAW
81	Indian Creek tributary near Redstone Arsenal airport on Hale Road, upstream limit	Indian Creek	Madison	34.6670	-86.6747	Yes	*Etheostoma tuscumbia* (2)	1.0 hour/dipnets	05/21/14	SWM, EAW
82	Indian Creek tributary on laser range, d/s of following station	Indian Creek	Madison	34.6563	-86.7008	No	*Gambusia affinis* (2)	0.75 hour/dipnets	03/18/15	SWM, RAB
83	Indian Creek tributary on Anderson Road, spring fed	Indian Creek	Madison	34.6605	-86.7081	No	none	1.0 hour/dipnets	01/14/15	SWM, RAB

No.	Station	Drainage	County	Lat	Long	***Etheostoma tuscumbia* presence**	Others	Effort	Date	Collectors
84	Indian Creek from Hale Road upstream to northern boundary of Redstone Arsenal	Indian Creek	Madison	34.6856	-86.6972	No	none	4.0 hours/6' seine	03/28/12	SWM, TES, CCJ
						No	none	4.0 hours/6' seine	12/16/14	PEO, DKT
85	Kelly Spring at Jeff Road	Indian Creek	Madison	34.8156	-86.7125	No	*Gambusia affinis* (common)	0.35 hour/6' seine	10/23/13	SWM, CCJ
						No	*Gambusia affinis* (common); *Lepomis macrochirus* (1)	1.5 hours/dipnets	12/19/13	SWM, CCJ
						No	*Gambusia affinis* (common); *Micropterus* sp. (1); *Lepomis* sp.(1)	1.0 hour/dipnets	05/14/15	SWM, RAB
Independent tributaries										
86	Igloo Pond just S of Buxton Rd. on Redstone Arsenal	Direct tributary of Tennessee River	Madison	34.5821	-86.6556	No	*Gambusia affinis*	0.5 hour/dipnets	04/10/13	SWM, CCJ
87	Independent tributary to Tennessee River S Buxton Road/E Patton Road	Direct tributary of Tennessee River	Madison	34.5946	-86.6110	No	*Gambusia affinis*	2.0 hour/dipnets	05/13/15	SWM, RAB

No.	Station	Drainage	County	Lat	Long	*Etheostoma tuscumbia* presence	Others	Effort	Date	Collectors
88	Spring tributary to Aldridge Creek on Bailey Cove Road in SE Huntsville	Direct tributary of Tennessee River	Madison	34.6425	-86.5398	No	*Campostoma oligolepis; Gambusia affinis; Rhinichthys atratulus; Etheostoma simoterum; Carassius auratus*	0.75 hour/dipnet	06/15/12	SWM
						No	*Campostoma oligolepis; Luxilus chrysocephalus; Gambusia affinis; Rhinichthys atratulus; Etheostoma simoterum; Lepomis cyanellus; Lepomis auritus*	0.35 hour/6' seine	10/23/13	SWM, CCJ
Upper Study Area 3										
Flint River										
89	Spring complex at Goldsmith-Schiffman Nature Preserve	Flint River	Madison	34.6278	-86.4822	No	*Lepomis macrochirus; Fundulus notatus; Etheostoma crossopterum; Gambusia affinis*	0.75 hour/dipnet	04/23/14	SWM, SS
						No	no data	1.0 hour/dipnet	03/08/15	SWM, RAB, SMS, SS
90	Blue Spring near Dug Hill Road and U.S. Hwy. 431 intersection	Big Cove Creek	Madison	34.7084	-86.5123	No	*Cottus carolinae; Rhinichthys atratulus; Semotilus atromaculatus; Etheostoma simoterum; Etheostoma crossopterum; Lepomis* sp.	0.75 hour/dipnet	04/23/14	SWM
91	Sublett Spring	Flint River	Madison	34.7143	-86.4243	No	*Etheostoma caeruleum* (3); *Cottus carolinae* (4); *Rhinichthys atratulus; Hemitrema flammea; Etheostoma duryi* (3); *Lepomis macrochirus* (1); *Gambusia affinis;* Minnow (2); *Etheostoma nigripinne* (2)	3.0 hours/dipnets	09/17/15	SWM, RB

No.	Station	Drainage	County	Lat	Long	*Etheostoma tuscumbia* presence	Others	Effort	Date	Collectors
92	Acuff Spring at Jordan Road	Chase Creek	Madison	34.7799	-86.4917	No	*Cottus carolinae; Gambusia affinis; Etheostoma crossopterum; Clinostomus funduloides*	1.0 hour/dipnets	04/23/14	SWM, SS
93	Fishing Hole Spring	Brier Fork Flint River	Madison	34.84540	-86.5261	No	none	observation; no sample	12/19/13	SWM, CCJ
94	Watercress Spring near Meridianville	Beaverdam Creek-Brier Fork Flint River	Madison	34.8453	-86.5683	Yes	*Gambusia affinis* (1); *Etheostoma tuscumbia* (18); *Etheostoma crossopterum* (2)	1.0 hour/dipnets	04/10/13	SWM, CCJ
95	Unnamed spring at Oscar Patterson Road, tributary to Flint River u/s Mountain Fork confluence	Flint River	Madison	34.8796	-86.4815	No	*Rhinichthys atratulus* (1); *Gambusia affinis; Lepomis macrochirus; Lepomis cyanellus; Cottus carolinae*	1.0 hour/dipnets	3/19/2015	SWM, RAB, SMS, SS
96	Water Cress Spring at Mountain Fork Water Well	Mountain Fork Flint River	Madison	34.9275	-86.3942	Yes	*Gambusia affinis; Cottus carolinae* (1)*; Etheostoma tuscumbia* (20)	0.5 hour/dipnets	04/17/13	SWM
Paint Rock River										
97	Bethel Springs on Cherry Tree Road	Paint Rock River	Madison	34.6129	-86.3632	No	*Cottus carolinae; Rhinichthys atratulus; Semotilus atromaculatus; Hemitrema flammea; Etheostoma nigripinne*	1.5 hours/dipnet	09/17/15	SWM, RB
98	Spring at Babe Wright Rd & Cathedral Caverns Rd.	Paint Rock River	Marshall	34.5921	-86.2127	No	*Lepomis* sp.; *Gambusia affinis*	1.5 hours/dipnet	09/17/15	SWM, RB

APPENDIX B

Fish collection data and water quality data for the Williams Spring complex, 2000-2015

Species	Sampling dates and times					
	12-Jun-00 1500-1615	23-Aug-01 1310-1410	25-Jul-02 1330-1430	22-Jul-03 1315-1430	27-Jul-04 1255-1340	17-Aug-05 1105-1220
Esox americanus - Redfin Pickerel	--	--	--	--	--	--
Esox niger - Chain Pickerel	1	3	2	--	--	--
Campostoma oligolepis - Stoneroller	--	--	7	--	4	35
Hemitremia flammea - Flame Chub	--	--	--	--	--	--
Luxilus chrysocephalus - Striped Shiner	--	--	--	2	--	--
Lythrurus fasciolaris - Scarlet Shiner	--	--	--	--	--	--
Pimephales notatus - Bluntnose Minnow	--	--	--	1	--	--
Rhinichthys atratulus - Blacknose Dace	--	--	--	1	9	5
Semotilus atromaculatus - Creek Chub	--	--	--	--	--	--
Hypentelium nigricans - Northern Hogsucker	--	--	--	--	--	--
Minytrema melanops - Spotted Sucker	--	--	1	--	--	--
Gambusia affinis - Western Mosquitofish	1	--	--	--	--	--
Cottus carolinae - Banded Sculpin	48	38	26	28	38	69
Lepomis auritus - Redbreast Sunfish	--	1	--	1	--	--
Lepomis cyanellus - Green Sunfish	3	--	5	--	1	3
Lepomis gulosus - Warmouth	8	3	--	3	--	2
Lepomis macrochirus - Bluegill	3	2	--	4	3	6
Hybrid sunfish	--	--	--	--	--	--
Lepomis microlophus - Redear Sunfish	--	--	--	--	--	--
Micropterus salmoides - Largemouth Bass	--	--	1	--	--	--
Etheostoma duryi - Black Darter	2	5	9	2	--	--
***Etheostoma tuscumbia* - Tuscumbia Darter**	**23**	**48**	**20**	**71**	**29**	**9**
Percina caprodes - Logperch	--	--	--	1	1	--
Total catch	89	100	71	114	85	129
Total species	8	7	8	10	7	7
Total efforts	67	50	45	45	30	41
Catch per unit effort (CPUE)	1.33	2.00	1.58	2.53	2.83	3.15
Sampling time (hrs)	1.25	1.00	1.00	1.25	0.75	1.25
Catch per hour	71	100	71	91	113	103
Area sampled (ft^2)	2,562	2,547	3,944	3,000	3,230	5,040
Density per 100 ft^2	3.47	3.93	1.80	3.80	2.63	2.56
Tuscumbia darter CPUE	0.34	0.96	0.44	1.58	0.97	0.22
Tuscumbia darter density per 100 ft^2	0.90	1.88	0.51	2.37	0.90	0.18
Temperature (°C)	17.0	17.6	17.6	17.1	16.4	19.0
Dissolved oxygen (mg/L)	7.1	6.2	6.2	nd	7.1	7.4
pH	6.6	6.4	6.4	6.8	6.8	7.0
Specific conductance (µS/cm)	298	310	310	304	326	306
Williams Spring discharge (ft^3/s)	4.90	5.36	3.73	6.41	5.72	5.12

Species	Sampling dates and times					
	23-Aug-06 1115-1240	23-Aug-07 1200-1330	13-Aug-08 1410-1540	25-Aug-09 1110-1215	16-Aug-10 1315-1425	16-Aug-11 1130-1240
Esox americanus - Redfin Pickerel	--	--	1	--	--	--
Esox niger - Chain Pickerel	2	--	1	1	--	--
Campostoma oligolepis - Stoneroller	1	4	17	--	--	21
Hemitremia flammea - Flame Chub	--	--	--	--	--	2
Luxilus chrysocephalus - *S*triped Shiner	--	7	--	--	5	13
Lythrurus fasciolaris - Scarlet Shiner	--	1	--	--	--	--
Pimephales notatus - Bluntnose Minnow	--	--	--	--	--	2
Rhinichthys atratulus - Blacknose Dace	--	--	--	--	--	--
Semotilus atromaculatus - Creek Chub	--	1	--	--	--	--
Hypentelium nigricans - Northern Hogsucker	6	--	--	--	--	--
Minytrema melanops - Spotted Sucker	1	1	--	--	--	--
Gambusia affinis - Western Mosquitofish	2	12	2	--	2	2
Cottus carolinae - Banded Sculpin	49	58	2	5	0	13
Lepomis auritus - Redbreast Sunfish	--	--	1	1	1	--
Lepomis cyanellus - Green Sunfish	--	--	--	1	2	--
Lepomis gulosus - Warmouth	3	--	3	6	10	3
Lepomis macrochirus - Bluegill	4	5	5	11	42	96
Hybrid sunfish	--	--	--	--	1	--
Lepomis microlophus - Redear Sunfish	--	--	1	1	4	--
Micropterus salmoides - Largemouth Bass	--	--	1	--	1	--
Etheostoma duryi - Black Darter	3	3	7	--	--	20
***Etheostoma tuscumbia* - Tuscumbia Darter**	**44**	**107**	**62**	**63**	**29**	**59**
Percina caprodes - Logperch	--	--	--	1	--	--
Total catch	115	199	103	90	97	231
Total species	10	10	12	9	10	10
Total efforts	33	35	24	32	34	34
Catch per unit effort (CPUE)	3.48	5.69	4.29	2.81	2.85	6.79
Sampling time (hrs)	1.40	1.50	1.50	1.08	1.20	1.20
Catch per hour	82	133	69	83	81	193
Area sampled (ft^2)	2,480	2,450	3,192	2,520	1,960	1,960
Density per 100 ft^2	4.64	8.12	3.23	3.57	4.95	11.79
Tuscumbia darter CPUE	1.33	3.06	2.58	1.97	0.85	1.74
Tuscumbia darter density per 100 ft^2	1.77	4.37	1.94	2.50	1.48	3.01
Temperature (°C)	19.6	17.3	18.2	17.4	22.0	19.0
Dissolved oxygen (mg/L)	7.0	7.8	8.0	9.3	8.4	7.3
pH	6.1	6.4	6.6	6.6	7.7	6.8
Specific conductance (µS/cm)	383	302	310	314	488	320
Williams Spring discharge (ft^3/s)	6.48	1.99	0.86	5.76	4.72	4.76

Species	Sampling dates and times				Totals
	21-Aug-12 1105-1210	13-Aug-13 1210-1315	13-Aug-14 1355-1520	17-Aug-15 1005-1125	
Esox americanus - Redfin Pickerel	--	3	2	--	6
Esox niger - Chain Pickerel	2	--	--	1	12
Campostoma oligolepis - Stoneroller	3	4	1	50	147
Hemitremia flammea - Flame Chub	--	--	--	--	2
Luxilus chrysocephalus - Striped Shiner	--	1	1	2	31
Lythrurus fasciolaris - Scarlet Shiner	--	--	--	--	1
Pimephales notatus - Bluntnose Minnow	--	--	--	--	3
Rhinichthys atratulus - Blacknose Dace	--	--	--	--	15
Semotilus atromaculatus - Creek Chub	--	--	--	--	1
Hypentelium nigricans - Northern Hogsucker	2	1	--	2	11
Minytrema melanops - Spotted Sucker	--	--	6	--	9
Gambusia affinis - Western Mosquitofish	--	2	1	1	25
Cottus carolinae - Banded Sculpin	43	13	11	12	453
Lepomis auritus - Redbreast Sunfish	--	--	--	--	5
Lepomis cyanellus - Green Sunfish	1	1	--	1	18
Lepomis gulosus - Warmouth	1	4	4	8	58
Lepomis macrochirus - Bluegill	9	31	--	8	229
Hybrid sunfish	1	--	8	--	10
Lepomis microlophus - Redear Sunfish	--	1	--	--	7
Micropterus salmoides - Largemouth Bass	--	1	--	2	6
Etheostoma duryi - Black Darter	27	13	20	13	124
***Etheostoma tuscumbia* - Tuscumbia Darter**	**30**	**13**	**29**	**13**	**649**
Percina caprodes - Logperch	--	3	--	--	6
Total catch	119	91	83	113	1,828
Total species	10	10	9	12	22
Total efforts	34	34	35	42	615
Catch per unit effort (CPUE)	3.50	2.68	2.37	2.69	2.97
Sampling time (hrs)	1.20	1.20	1.20	1.33	19
Catch per hour	99	76	55	85	95
Area sampled (ft^2)	1,960	1,960	3,240	3,360	45,405
Density per 100 ft^2	6.07	4.64	2.56	3.36	4.03
Tuscumbia darter CPUE	0.88	0.38	0.83	0.31	1.06
Tuscumbia darter density per 100 ft^2	1.53	0.66	0.9	0.39	1.43
Temperature (°C)	16.4	19.8	19.6	20.4	
Dissolved oxygen (mg/L)	7.5	10	5.6	8.2	
pH	7	7.3	8.7	6.2	
Specific conductance (µS/cm)	333	301	336	278	
Williams Spring discharge (ft^3/s)	6.04	3.124	5.34	3.01	

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