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The Fish Community of London Creek, Cherokee County, SC, in 2008-2009

THE FISH COMMUNITY OF LONDON CREEK; CHEROKEE COUNTY, SC, IN 2008 – 2009

by

David J. Coughlan

Senior Fisheries Scientist

Corporate Environment, Health & Safety Services

Duke Energy Corporation

13339 Hagers Ferry Road

Huntersville, NC 28078

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EXECUTIVE SUMMARY

London Creek is a small, second order, intermittent stream located in the Broad River drainage in east-central Cherokee County, SC. This stream may be inundated to form Make-Up Pond C for the proposed William States Lee Nuclear Station. A portion of the London Creek fish community will likely be lost as a consequence of this action so the community was sampled by electrofishing at three locations during March and September of 2008 and 2009 to assess the impact.

London Creek was impacted by low rainfall in 2007 and the first half of 2008 with the rainfall totals increasing in the latter half of 2008 and 2009. Fish community parameters appeared to be a function of water quantity in the stream, with possible interactions associated with recreational and agricultural activities and instream barriers to migration.

Twenty-one species of fish, representing six families, were collected in London Creek during the two-year study. Collections in March and September of both years were numerically dominated by cyprinids (minnows), secondarily by centrarchids (sunfish), and followed by still smaller contributions from the other family groups. The 21 species are consistent with those observed from nearby streams in the Broad River drainage of NC and SC, and a survey of 10 nearby SC streams by the SCDNR. None of the fish species found in London Creek are federally or state listed as threatened or endangered. The highback chub and the flat bullhead were found in the creek and have been recently designated as species of moderate conservation concern in the SCDNR Comprehensive Wildlife Conservation Strategy.

Estimated fish densities were variable and ranged from 144 - 18,907 fish/ha (58 - 7,652 fish/ac) during 2008 – 2009. Fish density was generally highest at the most downstream location, but not on all occasions (March 2008). Estimated fish biomass values ranged from 1.24 - 95.00 kg/ha (1.11 - 84.75 lb/ac) in 2008 – 2009. Fish biomass was highest at the midstream location in 2008 and highest at the most downstream location in 2009. The highest fish biomass estimates at the three locations were observed in September 2009. A general trend of declining fish density and increasing fish biomass at each location during the study period indicated that the average fish size was increasing and likely a response to increased water quantity.

The highback chub was the only species found in the creek that was considered to be intolerant of pollution. Fish species capable of withstanding pollution were found throughout

the creek in all samples, but numerically dominated the collections after March 2008. There was a paucity of piscivorous (fish-eating) species until the capture of numerous young-of-the-year largemouth bass in September 2009. The panfish community was dominated by numerous small individuals of minimal fishing importance.

Based on the observed fish community data, intermittent flow (possibly related to drought conditions) and watershed activities may be acting in combination with impediments to fish passage during periods of low flow to impact the fish community in London Creek.

INTRODUCTION

London Creek is a small, second order, intermittent stream with a drainage area of 1,005 hectares (ha, 3.88 sq mi) located in the Broad River drainage in east-central Cherokee County, SC (Figure 1). A mixed hardwood and pine plantation forest covers the majority of the London Creek watershed and is interspersed with pastureland, some upslope farmsteads, and residences. The upstream headwaters of London Creek were impounded by the SC Department of Natural Resources (SCDNR) to create Lake Cherokee. The surface area of the lake covers 18.2 ha (45 acres) and the watershed drains an additional 40 ha (99 acres).

The majority of the flow in London Creek is provided by spillage at the Lake Cherokee standpipe which is influenced by season, the relatively small watershed, and local meteorology. Additional inflows to London Creek occur downstream of Lake Cherokee and include small, intermittent, un-named streams and seeps. Upon exiting Lake Cherokee, London Creek flows 5.3 km (3.3 mi) in a northeasterly direction and enters the upper end of Ninety-Nine Islands Reservoir; a Duke Energy Corporation (DE) run-of-the-river hydroelectric impoundment on the Broad River. The London Creek valley is located adjacent to DE's proposed William States Lee Nuclear Station.

Proposed electric power and associated water needs in the vicinity may necessitate the creation of a new water supply reservoir (Make-Up Pond C) in the London Creek valley. Impoundment of London Creek would destroy stream habitat and the obligate stream-dwelling portion of the resident fish community. The purpose of this sampling was to characterize the London Creek fish community during spring and fall of 2008 and 2009 at three selected locations.

This report is a compilation of fishery surveys conducted in London Creek during 2008 and 2009. An earlier report summarizing just the 2008 surveys (The Fish Community of London Creek, Cherokee County, SC by David J. Coughlan - December 12, 2008) remains a stand-alone document. Those data were completely assimilated into this 2009 report in order to have both years of data under the same cover.

METHODS AND MATERIALS

Locations - Fish collections occurred at three locations (Locations 0.9, 1.7, and 2.6) approximately 0.9, 1.7, and 2.6 river miles, respectively, upstream from the London Creek-Broad River confluence (Figure 1). The initial selection of sampling locations in 2008 was somewhat restricted by permission from some landowners, but did encompass all representative habitats in downstream, midstream, and upstream reaches.

Substrate at all locations was characterized by abundant gravel and cobble, with smaller amounts of sand and bedrock (Figure 2). Additional instream habitat features included pools, riffles, leaf litter, woody debris, root wads, and minor amounts of trash. Riparian vegetation and overhead cover were generally abundant. Location 1.7 included a stretch of sloughing bank and instream sediment deposits resulting from erosive recreational activities associated with an electric transmission line right-of-way (see Figure 2D). During September 2009, drainage from an upslope cattle pasture was observed entering the creek at Location 1.7.

In January 2009, access to all reaches of London Creek between Locations 0.9 and 2.6 was obtained and subsequently surveyed to identify unique or poorly represented habitats not encountered at the three sampling locations (Figure 3). While no new sampling locations were added, several impediments to fish movement during low flow periods were identified.

Similarly, in June 2009, access to the most upstream reach of London Creek between Hwy 329 and the Lake Cherokee Dam was obtained and the reach surveyed (Figure 3). Substrate was similar to the generally sediment-free gravel, cobble, and bedrock observed in other areas of London Creek, and overhead cover was abundant.

Field Methods - Fish collections occurred in March and September of 2008 and 2009. Fish were collected with backpack electrofishing equipment and population numbers were estimated with a multiple pass depletion procedure (Raleigh and Short 1981). Stream segments were approximately 100 m (328 ft) long and were measured for total length and width (every 10 m [32.8 ft]) to calculate the area sampled (Table 1). Based on stream width, one or two electrofishing units were used to achieve adequate coverage. Sample segments were blocked with nets at the upstream and downstream ends to prevent fish movement into or out of the stream reach during sampling. In all cases, three electrofishing passes were sufficient to achieve depletion of the resident fish population. Water temperature (°C and °F)

and dissolved oxygen concentration (DO, mg/L) were measured at each location with a calibrated thermistor and DO probe, respectively.

In June 2009, a one-time, single-pass fish collection occurred in a 95-m reach at Location 3.2 (approximately 3.2 river miles upstream from the London Creek-Broad River confluence) between Hwy 329 and the Lake Cherokee Dam. One electrofishing unit was employed to investigate the possibility of collecting new species. Stream area, water temperature, and DO were measured by the same methods outlined previously.

Fish Processing - Fish collected at Locations 0.9, 1.7, and 2.6 were identified, sorted by species, measured for total length (mm), and weighed in aggregate by species (g). Generally, large fish were released well downstream of the sample area, and small fish were preserved in 10% formalin for taxonomic identification in the laboratory. Fish identification followed the keys of Menhinick (1991) and Rohde et al. (2009), although Rohde et al. (2009) was specifically followed regarding the naming and distribution of the greenhead shiner *Notropis chlorocephalus*. Representative voucher specimens of each species were placed into the DE Fish Museum, and a subset of the collected species are pictured in Figures 4 and 5. Taxonomy followed Nelson et al. (2004), except for the use of the generic name *Scartomyzon* for the jumprocks.

Fish collected at Location 3.2 in June 2009 were identified and measured for total length (mm). Most fish were released, and a few very small specimens were preserved in 10% formalin for taxonomic identification in the laboratory. Taxonomic methods were the same as outlined previously.

Meteorological Data – Rainfall is the major determinant of flow into London Creek via over-the-standpipe spillage from Lake Cherokee. It was used as a coarse measure of the amount of water and, thus, fish habitat in London Creek. While long-term rainfall data specific to the London Creek watershed were unavailable, National Climatic Data Center (NCDC) precipitation data from nearby Greer, Spartanburg County, SC, were used as a surrogate. Monthly rainfall totals from 2005 through September 2009 and the 1968 – 2008 monthly average rainfall totals were plotted as an aid in the evaluation of fish community data (Figure 6).

Data Analysis - The number of fish species, exclusive of hybrid complexes, was presented for Locations 0.9, 1.7, and 2.6 during each sampling event. The population size for each

species was calculated with the MicroFish Program, Version 3.0 (Van Deventer and Platts 1989). The average weight of an individual fish and the total weight for the estimated population of each species were calculated. Fish population numbers and weights were then adjusted for stream area to provide density (no/hectare [ha] and no/acre [ac]) and biomass (kg/ha and lb/ac) estimates. Individual species biomasses were combined for total fish biomass at each location. The number of fish/100 m (and fish/100 ft) was also calculated to provide fish densities on a linear basis.

Fish community data were evaluated with respect to the available meteorological data. Additionally, the London Creek fish community was assessed for the presence of rare and endangered species, and analyzed for its pollution tolerance and trophic guild structure. Length ranges of several centrarchid species were graphed to provide information on the size distribution of sunfish and largemouth bass inhabiting London Creek.

RESULTS AND DISCUSSION

Meteorological Data - The average annual precipitation in Greer, SC, from 1968 – 2008 measured 48.92 inches (in) while the 2007 and 2008 totals were reduced and measured 31.08 and 38.02 in, respectively (NCDC 1997 and 2008). The 2007 rainfall total was the lowest measured since 1968 and placed the entire watershed in a significant water deficit prior to the sampling that occurred in March 2008. Monthly rainfall totals in May and June 2008 were well below average (Figure 6) and some regions of London Creek ceased to flow (GE Vaughan, DE, personal communication). Rainfall rebounded in July, August, and September 2008 and restored stream flow, although mean stream widths measured in September 2008 were less than those observed in March 2008 (Table 1).

Monthly rainfall totals in late 2008 and early 2009 were elevated but still generally below the long-term average. Average stream widths measured in March 2009 were generally some of the widest measured during the two years of study. Sampling in early September 2009 was preceded by below average rainfall totals in June, July, and August (NCDC 2009). Stream widths measured in September 2009 were all less than those measured in March 2009. Significant rainfall occurred in latter portion of September 2009 and brought the January through September total to 33.23 in, although this nine month total was still below the average 1968 – 2008 January through September total of 37.65 in.

General Comparison - The collective London Creek fish community sampled in 2008 and 2009 was comprised of 21 species and one hybrid combination, representing six families (Table 2). The combined London Creek fish community from the three locations during specific sampling periods varied and ranged from a low of 11 species (representing five families) in March 2008 to a high of 19 species (representing six families) in September 2009.

The fish species found in London Creek are consistent with those expected from distribution maps for the NC portion of the Broad River drainage (Menhinick 1991), the SC portion of the Broad River drainage (Rohde et al. 2009), and a SCDNR survey of 10 nearby streams sampled in 2003 and 2004 (Bettinger et al. 2006). Bettinger used similar collection methods as employed in this study and found nearby streams to contain from 9 to 28 fish species (Table 3). A total of 35 species were collected from the 10 streams and included all species found in London Creek except green sunfish *Lepomis cyanellus*. None of the fish species found in London Creek, or the 10 nearby streams, are federally or state listed as threatened or endangered. The highback chub *Hybopsis hypsinotus* and the flat bullhead *Ameiurus platycephalus* were recently designated as species of moderate conservation concern in the SCDNR Comprehensive Wildlife Conservation Strategy (SCDNR 2005).

A one-time fish sampling event in June 2009 at Location 3.2 resulted in the collection of 10 fish species that included: rosyside dace *Clinostomus funduloides*, highback chub, bluehead chub *Nocomis leptocephalus*, creek chub *Semotilus atromaculatus*, white sucker *Catostomus commersoni*, eastern mosquitofish *Gambusia holbrooki*, redbreast sunfish *Lepomis auritus*, warmouth *L. gulosus*, bluegill *L. macrochirus*, and tessellated darter *Etheostoma olmstedi*. All had been collected within the previous year at downstream London Creek locations, and the community was not considered substantially different from that observed at Location 2.6. No additional fish sampling or data analysis activities were undertaken at Location 3.2.

March 2008 Data Analysis – Electrofishing catches were numerically dominated by cyprinids (65.35%), followed in descending order by centrarchids (23.94%), percids (6.34%), poeciliids (4.08%), and ictalurids (0.28%). A total of 710 fish was collected. Fish sampling at Locations 0.9, 1.7, and 2.6 in March 2008 resulted in the collection of nine, nine, and one species, respectively (Tables 4 - 6).

The total number of fish collected at these same three locations was 75, 631, and 4, yielding population estimates of 75, 634, and 4, respectively. In general, the similarity of the

collected fish number to the population estimate and the tight confidence limits generated around the individual population estimates indicate that fish populations were effectively depleted in three passes.

Density estimates at Locations 0.9, 1.7, and 2.6 produced values of 1,933, 15,616, and 144 fish/ha (782, 6,320, and 58 fish/ac), respectively, while biomass estimates were 2.36, 16.03, and 1.24 kg/ha (2.11, 14.30, and 1.11 lb/ac, Figure 7). Data indicate that Location 1.7 had the highest fish density and biomass, and this was primarily due to the high numbers of bluehead chub and redbreast sunfish collected. Despite flowing water and sediment-free, gravel substrate, the most upstream location (Location 2.6) had the lowest density and biomass estimates based on the collection of only four creek chub. Density and biomass estimates at Location 0.9 (the most downstream location) were several times higher than those observed at Location 2.6 but still well below those estimated at Location 1.7. The anomalous trend of high fish density and biomass estimates at the midstream location and lower estimates at the downstream location may indicate a negative water quality impact in parts of London Creek or possibly relate to the drought experienced in 2007 and the first part of 2008.

The numbers of fish/100 m at Locations 0.9, 1.7, and 2.6 were 74, 619, and 4 (23, 189, and 1 fish/100 ft), respectively. A stream-wide average of 232 fish/100 m (71 fish/100 ft) was calculated for London Creek in March 2008.

<u>September 2008 Data Analysis</u> – Electrofishing catches in September 2008 were numerically dominated by cyprinids (42.32%), followed in descending order by centrarchids (38.74%), poeciliids (16.01%), catostomids (1.61%), percids (1.02%), and ictalurids (0.29%). A total of 1,368 fish was collected in September. Fish sampling at Locations 0.9, 1.7, and 2.6 in September 2008 resulted in the collection of 17, 13, and 10 species, respectively (Tables 7 - 9).

The total number of fish collected at these same three locations was 676, 412, and 280, and yielded population estimates of 709, 447, and 285, respectively. Again, the number of collected fish and the estimated population size were close and indicated effective depletion sampling.

Density estimates at Locations 0.9, 1.7, and 2.6 produced values of 18,907, 13,383, and 12,338 fish/ha (7,652, 5,416, and 4,993 fish/ac), respectively, while biomass estimates were

26.45, 33.32, and 14.89 kg/ha (23.59, 29.73, and 13.29 lbs/ac, Figure 7). All September 2008 biomass estimates exceeded those measured at the same location in March. Similar to the March sample, biomass estimates were highest at the midstream location (Location 1.7), lowest at the upstream location (Location 2.6), and intermediate at the downstream location (Location 0.9). Unlike the March 2008 sample, however, there was a progressively decreasing trend in the number of species collected and the densities of fish estimated from the location nearest the Broad River (Location 0.9) to locations further upstream (Locations 1.7 and 2.6). The high density and somewhat reduced biomass estimate at Location 0.9 in September were due to the collection of large numbers of relatively small eastern mosquitofish and green sunfish. At Location 1.7, the high fish density was driven by large numbers of redbreast sunfish, while the high biomass estimate was due to redbreast sunfish, bluehead chub, and green sunfish. Creek chub once again dominated the fish community at Location 2.6 (accounting for over 60% of the density and biomass estimates) but, in September 2008, shared this portion of the stream with nine other species.

The numbers of fish/100 m at Locations 0.9, 1.7, and 2.6 were 709, 361, and 287 (216, 110, and 87 fish/100 ft), respectively. A stream-wide average of 452 fish/100 m (138 fish/100 ft) was calculated for London Creek in September 2008. The average number of fish/100 m collected in September 2008 was almost twice that collected the previous March.

March 2009 Data Analysis – Electrofishing catches in March 2009 were numerically dominated by cyprinids (50.21%), followed in descending order by centrarchids (41.63%), percids (3.04%), catostomids (2.77%), ictalurids (1.38%), and poeciliids (0.97%). A total of 723 fish was collected. Fish sampling at Locations 0.9, 1.7, and 2.6 in March 2009 resulted in the collection of 17, 10, and 8 species, respectively (Tables 10 - 12).

The total number of fish collected at Locations 0.9, 1.7, and 2.6 was 354, 141, and 228, yielding population estimates of 383, 147, and 228, respectively. In general, the similarity of the collected fish number to the population estimate and the tight confidence limits generated around the individual population estimates indicate that fish populations were effectively depleted in three passes.

Density estimates at Locations 0.9, 1.7, and 2.6 produced values of 8,063, 3,995, and 7,729 fish/ha (3,263, 1,617, and 3,128 fish/ac), respectively, while biomass estimates were 29.92, 13.77, and 21.69 kg/ha (26.69, 12.29, and 19.35 lbs/ac, Figure 7). Data indicate that the most downstream location (Location 0.9) had the highest fish density and biomass, and this was

attributed to the high number of green sunfish collected. Contrary to observations in 2008, the lowest fish density and biomass in March 2009 were observed at the midstream location (Location 1.7). The most upstream location (Location 2.6) had intermediate density and biomass estimates due to the collection of a large number of creek chub.

The numbers of fish/100 m at Locations 0.9, 1.7, and 2.6 were 353, 146, and 231 (108, 44, and 70 fish/100 ft), respectively. A stream-wide average of 243 fish/100 m (74 fish/100 ft) was calculated for London Creek in March 2009.

September 2009 Data Analysis – Electrofishing catches in September 2009 were numerically dominated by cyprinids (44.46%), followed in descending order by centrarchids (37.62%), catostomids (7.25%), percids (4.04%), poeciliids (3.94%), and ictalurids (2.69%). A total of 965 fish was collected in September. Fish sampling at Locations 0.9, 1.7, and 2.6 in September 2009 resulted in the collection of 16, 15, and 11 species, respectively (Tables 13 - 15).

The total number of fish collected at these same three locations was 483, 340, and 142, and yielded population estimates of 510, 342, and 142, respectively. Again, the number of collected fish and the estimated population size were close and indicated effective depletion sampling.

Density estimates at Locations 0.9, 1.7, and 2.6 produced values of 14,286, 11,032, and 6,396 fish/ha (5,781, 4,465, and 2,588 fish/ac), respectively, while biomass estimates were 95.00, 72.71, and 29.32 kg/ha (84.75, 64.87, and 26.15 lb/ac, Figure 7). All September 2009 biomass estimates exceeded those measured at the same location in March 2009, as well as all of 2008. Unlike any of the three previous sampling events, there was a progressively decreasing trend in the number of species collected, density, and the biomass of fish estimated from the location nearest the Broad River (Location 0.9) to the location furthest upstream (Location 2.6). The high biomass estimate at Location 0.9 in September was due to the collection of green sunfish, redbreast sunfish, white sucker, flat bullhead, and creek chub. At Location 1.7, the high biomass was driven by redbreast sunfish, white sucker, bluehead chub, and creek chub. Creek chub once again dominated the fish community at Location 2.6 (accounting for over 51% of the estimated biomass) and shared this portion of the stream with 10 other species.

The numbers of fish/100 m at Locations 0.9, 1.7, and 2.6 were 510, 344, and 142 (155, 105, and 43 fish/100 ft), respectively. An average of 332 fish/100 m (101 fish/100 ft) was calculated for London Creek in September 2009. The average number of fish/100 m collected in September 2009 exceeded that collected in March 2009, but was less than the number observed in September 2008 (452 fish/100 m).

Pollution Tolerance - The presence or absence of various fish species may provide clues regarding conditions in a specific stream reach. These conditions may include habitat quality, water quality, biotic interactions, and energy supply. The ability of fish species to withstand pollution or environmental perturbations has been documented, and a methodology developed where each species is assigned a pollution tolerance rating of Intolerant, Intermediate, or Tolerant (NC Department of Environment and Natural Resources [NCDENR] 2006). While Tolerant species (i.e., those that do not readily succumb to pollution) are typically encountered in most fish surveys, a stream segment is considered stressed when members of these species numerically dominate the sample. Tolerant species collected in 2008 and 2009 from London Creek included creek chub, white sucker, flat bullhead, eastern mosquitofish, redbreast sunfish, green sunfish, and hybrid sunfish. Conversely, the more Intolerant species (i.e., those that do not tolerate polluted environments) encountered in a sample, the less the likelihood that the stream is negatively impacted by pollution. The only Intolerant species collected in London Creek in 2008 and 2009 was highback chub.

Tolerance data from all London Creek locations in March and September 2008 and 2009 are summarized in Table 16. The percentage of Tolerant individuals collected throughout London Creek ranged from 30.84% (March 2008) to 67.33% (September 2008). Percentages considered indicative of an undisturbed wadeable reference stream (Tolerant individuals comprising ≤25% of the total collected) were not observed in London Creek. During a period of extreme low flow in March 2008, the percentage of Tolerant individuals (30.84%) was indicative of values typically observed in a disturbed stream. During the other three sampling events (September 2008 through September 2009), the percentages of Tolerant individuals exceeded 35% and were indicative of disturbed streams that deviate greatly from reference conditions per NCDENR criteria (NCDENR 2006).

As noted previously, the numerically dominant Tolerant species (and thus family) at a given stream location varied with month and year. As a result of the drought conditions experienced throughout 2007 and that continued into early 2008, the dominant species at

Locations 0.9, 1.7, and 2.6 in March 2008 were eastern mosquitofish, bluehead chub, and creek chub, respectively. Except for collection of large numbers of redbreast sunfish at Location 1.7, the London Creek fish community was dominated by fishes of small size and comprised of cyprinids, poeciliids, and percids (darters).

A moderate recovery in London Creek flow in September 2008 resulted from July - September rains and may have contributed to the greatest percentage of Tolerant individuals (67.33%) observed during this two-year study. The high percentage of Tolerant individuals was probably an indication of the ability of these species to quickly respond to favorable flow regimes. The dominant species at Locations 0.9, 1.7, and 2.6 were eastern mosquitofish, redbreast sunfish, and creek chub, respectively. Fish collections in September 2008 were more productive than in March and included several sunfish species and largemouth bass.

Monthly rainfall totals in the latter half of 2008 and early 2009 were low but more consistent and probably lead to more continuous stream flows than observed in March 2008. The percentage of Tolerant individuals collected during March 2009 (61.13%) was lower than observed in September 2008. The dominant species at Locations 0.9, 1.7, and 2.6 were green sunfish, redbreast sunfish, and creek chub, respectively. A shift towards pollution tolerant centrarchids was noticeable at the two downstream locations; creek chub maintained their dominance at the upstream location throughout the two-year study.

London Creek rainfall totals during summer 2009 were slightly depressed compared to historic monthly averages, but exceeded those from the previous summer. The percentage of Tolerant individuals in September 2009 (53.06%) was the lowest since September 2008 (67.33%) and continued the downward trend. The dominant species at Locations 0.9, 1.7, and 2.6 were green sunfish, redbreast sunfish, and creek chub, respectively. Decreased percentages of Tolerant individuals during September 2009, combined with the highest recorded fish biomass estimates of this two-year study, indicate that more fish with Intermediate and Intolerant pollution ratings were occupying London Creek.

While high percentages of Tolerant individuals were collected at the three locations; the Tolerant fish species assemblage changed in number and composition from downstream to upstream. At no time during any sampling event did the same Tolerant species dominate the fish community at any two locations. Factors potentially accounting for these observations include the ability of Tolerant species to locally tolerate drought or some type of water

quality impairment, in combination with the effects of natural barriers to migration during low flows (Figure 3, photos D - F).

The only Intolerant species collected from London Creek was the highback chub. It was collected at all locations except the most upstream location (Location 2.6) during March of both years. The density (fish/ha) of highback chub was always greatest at Location 1.7. The presence of just one Intolerant species in the Piedmont of the Broad River basin was an indicator of good water quality and rated the stream as comparable to an undisturbed reference stream for this metric (NCDENR 2006).

Trophic Status - Just as tolerance ratings provide clues to fish distributions and pollution impacts, trophic ratings reflect the effects of biotic interactions and energy supply (NCDENR 2006). For example, a stream receiving excessive nutrient enrichment may be expected to show an increased abundance of omnivores and herbivores. The NCDENR (2006) rates wadeable North Carolina Piedmont streams by three trophic metrics and classifies streams as undisturbed if the total percentage of omnivores and herbivores is between 10 and 35%, the percentage of insectivores is between 60 and 90%, or the percentage of piscivores is $\geq$ 1%. Additionally, streams with a total percentage of omnivores and herbivores < 10% or a percentage of piscivores <0.24% are considered to deviate greatly from values expected for undisturbed streams. Trophic guild data from all London Creek collections are summarized in Table 16.

No herbivorous species (e.g., central stoneroller *Campostoma anomalum* or eastern silvery minnow *Hybognathus regius*) were collected during the 2008 – 2009 sampling activities in London Creek. Thus, the trophic metric related to the combined percentages of omnivores and herbivores was totally dependent on omnivorous species. The percentages of omnivores, ranged from 11.48 - 37.61%. Only the value observed in March 2008 (37.61%) exceeded the 35% criterion for undisturbed streams that might indicate impacts due to low flow or some other water quality impairment.

Insectivores dominated the London Creek fish community and comprised from 62.39 - 88.52% of the individuals collected. All six families of fish collected in London Creek contained insectivorous species. All observed values were within the 60 - 90% range typical for undisturbed Piedmont streams.

The solitary piscivorous species (largemouth bass *Micropterus salmoides*) observed in London Creek was only collected during the September sample in both years. All largemouth bass were small (see next section) and considered young-of-the-year individuals that were probably spawned in Ninety-Nine Islands Reservoir during spring and subsequently immigrated to London Creek. The percentage of piscivores ranged from 0.00 - 5.28% during the four sampling periods, and only the value observed in September 2009 (5.28%) would not be considered representative of a stream that deviates greatly from an undisturbed stream. The higher percentage of bass observed in September 2009 may relate to the higher rainfall totals, and thus water quantity in 2009, relative to the years immediately preceding the September 2008 sample.

Centrarchid Length Frequencies - During the 2008 and 2009 sampling on London Creek, a total of seven centrarchid species were collected. More species and larger individuals were collected in 2009 than 2008 (Table 17, Figures 8 and 9). Generally, most of the sunfish collected in London Creek were small (< 100 mm).

All largemouth bass were less than 100 mm total length and were considered young-of-the-year. Fishable populations of largemouth bass were not present in London Creek in 2008 or 2009.

CONCLUSION

Variable rainfall and flows in the London Creek watershed led to two distinct hydrologic years. Sampling in 2008 was impacted by low rainfall in 2007 and the first half of 2008. Between the March and September 2008 samples, most reaches of London Creek ceased to flow and dried up during early summer (G.E. Vaughan, DE, personal communication). The remnants of Hurricane Fay crossed the region on August 26 and, in combination with two minor rainfall events in September 2008, restored flows and habitat for fish. Rainfall in the latter months of 2008 through September 2009 was more regular, though still below average for the area, and led to more consistent stream flow in 2009 and some observed changes in the fish community.

The London Creek fish community observed in 2008 – 2009 was comprised of six families that were represented by 21 species. These fish species were consistent with those documented by other sources and included no federally or state listed threatened or

endangered species. Two species of moderate conservation concern, as defined by the SCDNR Comprehensive Wildlife Conservation Strategy, (highback chub and flat bullhead) occur in London Creek. Bettinger et al. (2006) found the highback chub to occur in over half of their Broad River tributary stream sampling sites. The flat bullhead is a species of concern due to its potential extirpation by introduced flathead catfish *Pylodictis olivaris* populations.

London Creek is a small stream with clean gravel, cobble, and bedrock substrate, negligible amounts of instream sediment, abundant riparian vegetation, and good overhead cover. Generally, an accumulation of fish species, numbers of individuals, and biomass might be expected with movement downstream, although this was rarely the case in London Creek. In March 2008, the highest fish densities and biomass were observed at the midstream location, while only the highest biomass was recorded there in September 2008. The numbers of fish species and fish densities increased from upstream to downstream in September 2008. The high density of fish at Location 0.9 in September 2008; however, was due to large numbers of small eastern mosquitofish and green sunfish. In March 2009, the lowest fish density and biomass estimates were observed at the midstream location. All September 2009 biomass estimates exceeded those measured at the same location in March 2009 as well as all of 2008. The September 2009 data was the first instance where the number of fish species, fish density, and fish biomass all increased with downstream direction. A general trend of decreasing fish densities and higher biomass estimates at the three locations (Figure 7) indicated that the average fish size was increasing as rainfall (i.e., water quantity) became more consistent.

The 21 species of fish collected in London Creek should be considered extremely resilient. Fish designated Tolerant of pollution typically dominated the collections on a numerical or gravimetric basis, and the species with the most individuals in each sample was, in all but one case, a pollution Tolerant species. Intolerant species (those not typically encountered in polluted environments) were solely represented by the highback chub and constituted, in all but one case, less than 5% of the fish community.

On a trophic basis, the high abundance of cyprinids, eastern mosquitofish, and small centrarchids was associated with a lack of large piscivores in both years. No herbivorous species were collected in London Creek, and an unusually high number of omnivores was observed in March 2008. Insectivores were always present in percentages typical for undisturbed Piedmont streams. Young-of-the-year largemouth bass were the only piscivores observed and then only in large numbers in September 2009. Based on these trophic

observations, biotic interactions and energy supply pathways in London Creek generally appeared typical for an undisturbed Piedmont stream with some slight impairment.

Most of the sunfish observed in London Creek were small and generally less than 100 mm TL. Length frequencies observed in 2009 included larger individuals than observed in 2008, and this trend was corroborated by the previously noted increasing average fish size. The creek would support a minimal sunfish fishery.

Despite the high quality habitat of London Creek, analyses of fish population parameters, pollution tolerance scores, and trophic metric data indicated a disturbed fish community. Presently, it is unknown whether prolonged drought and resulting intermittent flows, water quality impairment, impediments to fish passage during low flow, or some combination of all three are interacting to restrict the London Creek fish population.

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Table 1. Measured stream lengths, widths, and summary statistics at three fish sampling locations on London Creek during March and September, 2008 – 2009.

				Stream Widths (m)*														Width (m)			
Year	Month	Location	Length (m)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Mean	Min	Max	Area (ha)
2008	Mar	0.9	102.0	5.3	4.3	2.6	2.4	2.3	6.1	4.3	3.7	2.8	5.9	3.0	2.9			3.80	2.3	6.1	0.0388
	Mar	1.7	102.6	3.7	5.5	3.8	3.9	5.7	2.7	2.5	4.7	4.1	4.1	3.5	3.3			3.96	2.5	5.7	0.0406
	Mar	2.6	99.3	3.3	4.5	1.7	2.1	2.7	2.9	4.2	1.3	2.0	2.6	3.4				2.79	1.3	4.5	0.0277
	Sep	0.9	100.0	3.2	3.4	3.3	1.9	2.0	6.1	4.5	3.3	3.7	5.5	4.3				3.75	1.9	6.1	0.0375
	Sep	1.7	124.0	3.3	3.6	3.4	3.5	1.7	2.4	2.1	2.3	3.6	4.3	2.7	2.2	1.6	1.0	2.69	1.0	4.3	0.0334
	Sep	2.6	99.0	3.6	3.4	1.3	1.8	2.2	2.6	4.2	1.4	2.5	1.7	1.0				2.34	1.0	4.2	0.0231
2009	Mar	0.9	108.5	5.1	3.8	3.3	2.0	2.4	6.0	4.1	3.9	3.8	7.9	6.3	3.9			4.38	2.0	7.9	0.0475
	Mar	1.7	101.0	3.4	4.2	3.9	4.0	4.8	3.6	2.9	3.2	4.2	3.4	3.0	3.1			3.64	2.9	4.8	0.0368
	Mar	2.6	98.4	4.3	3.4	1.7	2.1	2.8	2.9	4.1	2.4	2.7	2.6	4.0				3.00	1.7	4.3	0.0295
	Sep	0.9	100.0	5.1	4.0	2.8	1.3	0.9	6.0	3.6	3.1	2.7	6.0	3.8				3.57	0.9	6.0	0.0357
	Sep	1.7	99.0	2.9	3.3	1.7	3.6	4.1	3.1	3.2	1.9	3.9	4.0	2.7				3.13	1.7	4.1	0.0310
	Sep	2.6	100.0	3.2	1.7	1.8	1.6	2.0	2.9	4.1	2.1	2.2	1.8	1.0				2.22	1.0	4.1	0.0222

* The initial stream width was measured at the downstream net and then at 10-m intervals to the upper net. The last interval was of variable length to accommodate net placement.

Table 2. Scientific and common names, pollution tolerance rating, trophic status, number, and percent composition of fish species collected in London Creek, Cherokee County, SC, during March and September, 2008 – 2009.

				2008				2009			
				March		September		March		September	
Scientific name	Common name	Tolerance rating	Trophic guild of adults	no	%	no	%	no	%	no	%
Cyprinidae											
Clinostomus funduloides	Rosyside dace	Intermediate	Insectivore	21	2.96%	70	5.12%	68	9.41%	42	4.35%
Cyprinella nivea	Whitefin shiner	Intermediate	Insectivore			34	2.49%	24	3.32%		
Hybopsis hypsinotus	Highback chub	Intolerant	Insectivore	59	8.31%	62	4.53%	13	1.80%	37	3.83%
Nocomis leptocephalus	Bluehead chub	Intermediate	Omnivore	267	37.61%	144	10.53%	68	9.41%	171	17.72%
Notropis chlorocephalus	Greenhead shiner	Intermediate	Insectivore	68	9.58%	14	1.02%	6	0.83%	10	1.04%
Notropis scepticus	Sandbar shiner	Intermediate	Insectivore	31	4.37%	30	2.19%	30	4.15%	70	7.25%
Semotilus atromaculatus	Creek chub	Tolerant	Insectivore	18	2.54%	225	16.45%	154	21.30%	99	10.26%
Catostomidae											
Catostomus commersoni	White sucker	Tolerant	Omnivore			17	1.24%	15	2.07%	65	6.74%
Hypentelium nigricans	Northern hog sucker	Intermediate	Insectivore					1	0.14%	2	0.21%
Scartomyzon rupiscartes	Striped jumprock	Intermediate	Insectivore					4	0.55%	3	0.31%
Scartomyzon sp.	Brassy jumprock	Intermediate	Insectivore			5	0.37%				
Ictaluridae											
Ameiurus platycephalus	Flat bullhead	Tolerant	Insectivore	2	0.28%	4	0.29%	10	1.38%	26	2.69%
Poeciliidae											
Gambusia holbrooki	Eastern mosquitofish	Tolerant	Insectivore	29	4.08%	219	16.01%	7	0.97%	38	3.94%
Centrarchidae											
Lepomis auritus	Redbreast sunfish	Tolerant	Insectivore	169	23.80%	241	17.62%	117	16.18%	144	14.92%
Lepomis cyanellus	Green sunfish	Tolerant	Insectivore	1	0.14%	213	15.57%	139	19.23%	140	14.51%
Lepomis gibbosus	Pumpkinseed	Intermediate	Insectivore							4	0.41%
Lepomis gulosus	Warmouth	Intermediate	Insectivore			58	4.24%	36	4.98%	7	0.73%
Lepomis hybrid	Hybrid sunfish	Tolerant	Insectivore			2	0.15%	9	1.24%		
Lepomis macrochirus	Bluegill	Intermediate	Insectivore			14	1.02%			15	1.55%
Lepomis microlophus	Redear sunfish	Intermediate	Insectivore							2	0.21%
Micropterus salmoides	Largemouth bass	Intermediate	Piscivore			2	0.15%			51	5.28%
Percidae											
Etheostoma olmstedi	Tessellated darter	Intermediate	Insectivore	45	6.34%	14	1.02%	22	3.04%	39	4.04%
Total				710	100.00%	1,368	100.00%	723	100.00%	965	100.00%

Table 3. Fish species electrofished by SCDNR from 10 streams in the South Carolina portion of the Broad River basin near London Creek during 2003 – 2004. Data courtesy of Jason Bettinger, SCDNR.

				SCDNR Location # Stream name										
Scientific name	Common name	Tolerance rating	Trophic guild of adults	132003 Guyon-Moore	142003 Wolf	192004 Gilkey	10573 Gilkey	202004 Cowcastle	342004 Kings	2512 Thicketty	66 Thicketty	65 L. Thicketty	150 Cherokee	Present in the region
Cyprinidae														
Clinostomus funduloides	Rosyside dace	Intermediate	Insectivore		X	X					X	X	X	X
Cyprinella chloristia	Greenfin shiner	Intermediate	Insectivore	X	X		X		X	X				X
Cyprinella nivea	Whitefin shiner	Intermediate	Insectivore						X	X				X
Hybognathus regius	Eastern silvery minnow	Intermediate	Herbivore	X	X		X		X	X				X
Hybopsis hypsinotus	Highback chub	Intolerant	Insectivore	X	X	X	X	X	X	X	X	X		X
Nocomis leptocephalus	Bluehead chub	Intermediate	Omnivore	X	X	X	X	X	X	X	X	X	X	X
Notemigonus crysoleucas	Golden shiner	Tolerant	Omnivore							X				X
*Notropis chlorocephalus**	Greenhead shiner	Intermediate	Insectivore	X	X	X	X	X	X	X	X	X	X	X
Notropis hudsonius	Spottail shiner	Intermediate	Omnivore	X	X			X	X	X				X
Notropis petersoni	Coastal shiner	Intermediate	Insectivore									X		X
Notropis procne	Swallowtail shiner	Intermediate	Insectivore						X					X
Notropis scepticus	Sandbar shiner	Intermediate	Insectivore	X	X	X	X	X	X	X		X		X
Semotilus atromaculatus	Creek chub	Tolerant	Insectivore		X	X		X	X		X	X	X	X
Catostomidae														
Catostomus commersoni	White sucker	Tolerant	Omnivore	X				X	X		X	X		X
Erimyzon oblongus	Creek chubsucker	Intermediate	Insectivore	X	X		X							X
Hypentelium nigricans	Northern hog sucker	Intermediate	Insectivore		X	X	X	X	X	X				X
Moxostoma collapsum	Notchlip redhorse	Intermediate	Insectivore						X					X
Scartomyzon sp.	Brassy jumprock	Intermediate	Insectivore						X	X				X
Scartomyzon rupiscartes	Striped jumprock	Intermediate	Insectivore	X	X	X	X	X	X	X	X	X	X	X
Ictaluridae														
Ameiurus brunneus	Snail bullhead	Intermediate	Insectivore							X				X
Ameiurus natalis	Yellow bullhead	Tolerant	Omnivore							X				X
Ameiurus platycephalus	Flat bullhead	Tolerant	Insectivore	X	X		X	X	X	X				X
Noturus insignis	Margined madtom	Intermediate	Insectivore	X		X	X	X	X	X	X			X
Poeciliidae														
Gambusia holbrooki	Eastern mosquitofish	Tolerant	Insectivore				X		X				X	X
Centrarchidae														
Lepomis auritus	Redbreast sunfish	Tolerant	Insectivore	X	X	X	X	X	X	X	X	X	X	X
Lepomis gulosus	Warmouth	Intermediate	Insectivore				X	X	X	X				X
Lepomis macrochirus	Bluegill	Intermediate	Insectivore	X			X	X	X	X	X	X	X	X
Lepomis microlophus	Redear sunfish	Intermediate	Insectivore						X					X
Micropterus dolomieu	Smallmouth bass	Intolerant	Piscivore						X					X
Micropterus salmoides	Largemouth bass	Intermediate	Piscivore	X	X		X	X	X	X	X	X	X	X
Pomoxis nigromaculatus	Black crappie	Intermediate	Piscivore				X			X				X
Percidae														
Etheostoma olmstedi	Tessellated darter	Intermediate	Insectivore	X	X	X	X	X	X	X	X	X		X
Etheostoma flabellare	Fantail darter	Intermediate	Insectivore		X				X		X			X
Etheostoma thalassinum	Seagreen darter	Intolerant	Insectivore			X	X	X	X	X				X
Percina crassa	Piedmont darter	Intolerant	Insectivore						X					X
Total				16	17	12	19	17	28	23	13	13	9	35

* Based on information in Rohde et al. (2009), the yellowfin shiners reported by Bettinger are called greenhead shiners in this table.

Table 4. Population statistics of fishes collected during depletion sampling at London Creek, Cherokee County, SC at Location 0.9 on March 12, 2008. Location length = 102.0 m, area = 0.039 ha, temp. = 7.1 °C (44.8 °F), and DO = 10.5 mg/L.

Scientific name	Common name	Total no of fish collected	Total wt of fish collected (g)	Population estimate	Pop. est. (95% confidence intervals)*	Density (no/ 100 m)	Density (no/ ha)**	Est. wt of pop. (kg)**	Biomass (kg/ ha)**
Cyprinidae									
Clinostomus funduloides	Rosyside dace	2	4.3	2	(- , -)	2	52	0.004	0.111
Hybopsis hypsinotus	Highback chub	4	3.2	4	(4 , 5)	4	103	0.003	0.082
Nocomis leptocephalus	Bluehead chub	25	27.4	25	(25 , 27)	25	644	0.027	0.706
Semotilus atromaculatus	Creek chub	3	2.9	3	(3 , 6)	3	77	0.003	0.075
Ictaluridae									
Ameiurus platycephalus	Flat bullhead	1	15.2	1	(- , -)	1	26	0.015	0.392
Poeciliidae									
Gambusia holbrooki	Eastern mosquitofish	29	6.4	29	(29 , 31)	28	747	0.006	0.165
Centrarchidae									
Lepomis auritus	Redbreast sunfish	9	23.4	9	(9 , 10)	9	232	0.023	0.603
Lepomis cyanellus	Green sunfish	1	6.5	1	(- , -)	1	26	0.007	0.168
Percidae									
Etheostoma olmstedi	Tessellated darter	1	2.4	1	(- , -)	1	26	0.002	0.062
Total		75	91.7	75		74	1,933	0.092	2.363

* Confidence intervals denoted by (- , -) were not calculated due to non-descending removal pattern, collection of just one fish, or collection of all fish on the first pass.

** Estimates of total density, total weight of the population, and total biomass may vary insignificantly from the sum of the individual values due to rounding.

Table 5. Population statistics of fishes collected during depletion sampling at London Creek, Cherokee County, SC at Location 1.7 on March 12, 2008. Location length = 102.6 m, area = 0.041 ha, temp. = 11.1 °C (52.0 °F), and DO = 9.0 mg/L.

Scientific name	Common name	Total no of fish collected	Total wt of fish collected (g)	Population estimate	Pop. est. (95% confidence intervals)*	Density (no/ 100 m)	Density (no/ ha)**	Est. wt of pop. (kg)**	Biomass (kg/ ha)**
Cyprinidae									
Clinostomus funduloides	Rosyside dace	19	14.5	19	(19 , 20)	19	468	0.015	0.357
Hybopsis hypsinotus	Highback chub	55	37.2	55	(55 , 55)	54	1,355	0.037	0.916
Nocomis leptocephalus	Bluehead chub	242	180.2	242	(242 , 244)	236	5,961	0.180	4.438
Notropis chlorocephalus	Greenhead shiner	68	38.0	68	(68 , 68)	66	1,675	0.038	0.936
Notropis scepticus	Sandbar shiner	31	30.8	31	(31 , 32)	30	764	0.031	0.759
Semotilus atromaculatus	Creek chub	11	6.9	11	(- , -)	11	271	0.007	0.170
Ictaluridae									
Ameiurus platycephalus	Flat bullhead	1	2.1	1	(- , -)	1	25	0.002	0.052
Centrarchidae									
Lepomis auritus	Redbreast sunfish	160	298.6	162	(160 , 166)	158	3,990	0.302	7.447
Percidae									
Etheostoma olmstedi	Tessellated darter	44	37.8	45	(44 , 49)	44	1,108	0.039	0.952
Total		631	646.1	634		619	15,616	0.651	16.027

* Confidence intervals denoted by (- , -) were not calculated due to non-descending removal pattern, collection of just one fish, or collection of all fish on the first pass.

** Estimates of total density, total weight of the population, and total biomass may vary insignificantly from the sum of the individual values due to rounding.

Table 6. Population statistics of fishes collected during depletion sampling at London Creek, Cherokee County, SC at Location 2.6 on March 13, 2008. Location length = 99.3 m, area = 0.028 ha, temp. = 7.2 °C (45.0 °F), and DO = 10.9 mg/L.

Scientific name	Common name	Total no of fish collected	Total wt of fish collected (g)	Population estimate	Pop. est. (95% confidence intervals)	Density (no/ 100 m)	Density (no/ ha)	Est. wt of pop. (kg)	Biomass (kg/ ha)
Cyprinidae									
Semotilus atromaculatus	Creek chub	4	34.4	4	(4 , 5)	4	144	0.034	1.242
Total		4	34.4	4		4	144	0.034	1.242

Table 7. Population statistics of fishes collected during depletion sampling at London Creek, Cherokee County, SC at Location 0.9 on September 24, 2008. Location length = 100.0 m, area = 0.038 ha, temp. = 17.0 °C (62.6 °F), and DO = 9.3 mg/L.

Scientific name	Common name	Total no of fish collected	Total wt of fish collected (g)	Population estimate	Pop. est. (95% confidence intervals)*	Density (no/ 100 m)	Density (no/ ha)**	Est. wt of pop. (kg)**	Biomass (kg/ ha)**
Cyprinidae									
Clinostomus funduloides	Rosyside dace	8	6.4	8	(- , -)	8	213	0.006	0.171
Cyprinella nivea	Whitefin shiner	33	39.9	33	(33 , 33)	33	880	0.040	1.064
Hybopsis hypsinotus	Highback chub	8	9.5	8	(8 , 11)	8	213	0.010	0.253
Nocomis leptocephalus	Bluehead chub	50	177.2	50	(50 , 51)	50	1,333	0.177	4.725
Notropis chlorocephalus	Greenhead shiner	6	4.8	6	(6 , 8)	6	160	0.005	0.128
Notropis scepticus	Sandbar shiner	12	7.6	12	(12 , 13)	12	320	0.008	0.203
Semotilus atromaculatus	Creek chub	17	48.4	17	(17 , 18)	17	453	0.048	1.291
Catostomidae									
Catostomus commersoni	White sucker	17	61.0	17	(17 , 18)	17	453	0.061	1.627
Scartomyzon sp.	Brassy jumprock	5	8.8	5	(- , -)	5	133	0.009	0.235
Ictaluridae									
Ameiurus platycephalus	Flat bullhead	3	5.8	3	(3 , 6)	3	80	0.006	0.155
Poeciliidae									
Gambusia holbrooki	Eastern mosquitofish	219	71.8	233	(221 , 245)	233	6,213	0.076	2.037
Centrarchidae									
Lepomis auritus	Redbreast sunfish	54	94.4	55	(54 , 58)	55	1,467	0.096	2.564
Lepomis cyanellus	Green sunfish	197	332.5	215	(200 , 230)	215	5,733	0.363	9.677
Lepomis gulosus	Warmouth	34	60.8	34	(34 , 36)	34	907	0.061	1.621
Lepomis hybrid	Hybrid sunfish	2	18.8	2	(2 , 15)	2	53	0.019	0.501
Lepomis macrochirus	Bluegill	1	1.0	1	(- , -)	1	27	0.001	0.027
Micropterus salmoides	Largemouth bass	1	2.9	1	(- , -)	1	27	0.003	0.077
Percidae									
Etheostoma olmstedi	Tessellated darter	9	3.4	9	(9 , 11)	9	240	0.003	0.091
Total		676	955.0	709		709	18,907	0.992	26.446

* Confidence intervals denoted by (- , -) were not calculated due to non-descending removal pattern, collection of just one fish, or collection of all fish on the first pass.

** Estimates of total density, total weight of the population, and total biomass may vary insignificantly from the sum of the individual values due to rounding.

Table 8. Population statistics of fishes collected during depletion sampling at London Creek, Cherokee County, SC at Location 1.7 on September 24, 2008. Location length = 124.0 m, area = 0.033 ha, temp. = 16.5 °C (61.7 °F), and DO = 9.7 mg/L.

Scientific name	Common name	Total no of fish collected	Total wt of fish collected (g)	Population estimate	Pop. est. (95% confidence intervals)*	Density (no/ 100 m)	Density (no/ ha)**	Est. wt of pop. (kg)**	Biomass (kg/ ha)**
Cyprinidae									
Clinostomus funduloides	Rosyside dace	43	78.9	43	(43 , 44)	35	1,287	0.079	2.362
Hybopsis hypsinotus	Highback chub	51	51.7	51	(51 , 52)	41	1,527	0.052	1.548
Nocomis leptocephalus	Bluehead chub	61	198.1	61	(61 , 62)	49	1,826	0.198	5.931
Notropis chlorocephalus	Greenhead shiner	4	5.4	4	(- , -)	3	120	0.005	0.162
Notropis scepticus	Sandbar shiner	18	50.7	18	(18 , 19)	15	539	0.051	1.518
Semotilus atromaculatus	Creek chub	12	60.3	12	(12 , 13)	10	359	0.060	1.805
Ictaluridae									
Ameiurus platycephalus	Flat bullhead	1	12.0	1	(- , -)	1	30	0.012	0.359
Centrarchidae									
Lepomis auritus	Redbreast sunfish	176	365.4	189	(177 , 201)	152	5,659	0.392	11.748
Lepomis cyanellus	Green sunfish	16	99.6	31	(16 , 90)	25	928	0.193	5.778
Lepomis gulosus	Warmouth	15	31.6	22	(15 , 46)	18	659	0.046	1.388
Lepomis macrochirus	Bluegill	10	18.8	10	(10 , 11)	8	299	0.019	0.563
Micropterus salmoides	Largemouth bass	1	1.6	1	(- , -)	1	30	0.002	0.048
Percidae									
Etheostoma olmstedi	Tessellated darter	4	3.7	4	(4 , 6)	3	120	0.004	0.111
Total		412	977.8	447		361	13,383	1.113	33.321

* Confidence intervals denoted by (- , -) were not calculated due to non-descending removal pattern, collection of just one fish, or collection of all fish on the first pass.

** Estimates of total density, total weight of the population, and total biomass may vary insignificantly from the sum of the individual values due to rounding.

Table 9. Population statistics of fishes collected during depletion sampling at London Creek, Cherokee County, SC at Location 2.6 on September 23, 2008. Location length = 99.0 m, area = 0.023 ha, temp. = 18.5 °C (65.3 °F), and DO = 7.7 mg/L.

Scientific name	Common name	Total no of fish collected	Total wt of fish collected (g)	Population estimate	Pop. est. (95% confidence intervals)*	Density (no/ 100 m)	Density (no/ ha)**	Est. wt of pop. (kg)**	Biomass (kg/ ha)**
Cyprinidae									
Clinostomus funduloides	Rosyside dace	19	16.4	19	(19 , 21)	19	823	0.016	0.710
Cyprinella nivea	Whitefin shiner	1	4.3	1	(- , -)	1	43	0.004	0.186
Hybopsis hypsinotus	Highback chub	3	5.6	3	(3 , 9)	3	130	0.006	0.242
Nocomis leptocephalus	Bluehead chub	33	48.5	33	(33 , 35)	33	1,429	0.049	2.100
Notropis chlorocephalus	Greenhead shiner	4	4.5	4	(4 , 9)	4	173	0.005	0.195
Semotilus atromaculatus	Creek chub	196	205.5	201	(196 , 207)	203	8,701	0.211	9.123
Centrarchidae									
Lepomis auritus	Redbreast sunfish	11	26.0	11	(11 , 12)	11	476	0.026	1.126
Lepomis gulosus	Warmouth	9	22.0	9	(9 , 10)	9	390	0.022	0.952
Lepomis macrochirus	Bluegill	3	3.8	3	(3 , 4)	3	130	0.004	0.165
Percidae									
Etheostoma olmstedi	Tessellated darter	1	2.2	1	(- , -)	1	43	0.002	0.095
Total		280	338.8	285		287	12,338	0.344	14.894

* Confidence intervals denoted by (- , -) were not calculated due to non-descending removal pattern, collection of just one fish, or collection of all fish on the first pass.

** Estimates of total density, total weight of the population, and total biomass may vary insignificantly from the sum of the individual values due to rounding.

Table 10. Population statistics of fishes collected during depletion sampling at London Creek, Cherokee County, SC at Location 0.9 on March 25, 2009. Location length = 108.5 m, area = 0.048 ha, temp. = 12.7 °C (54.9 °F), and DO = 9.8 mg/L.

Scientific name	Common name	Total no of fish collected	Total wt of fish collected (g)	Population estimate	Pop. est. (95% confidence intervals)*	Density (no/ 100 m)	Density (no/ ha)**	Est. wt of pop. (kg)**	Biomass (kg/ ha)**
Cyprinidae									
Clinostomus funduloides	Rosyside dace	14	35.0	14	(14 , 15)	13	295	0.035	0.737
Cyprinella nivea	Whitefin shiner	24	44.1	24	(24 , 25)	22	505	0.044	0.928
Hybopsis hypsinotus	Highback chub	7	6.8	7	(7 , 9)	6	147	0.007	0.143
Nocomis leptocephalus	Bluehead chub	41	115.9	41	(41 , 43)	38	863	0.116	2.440
Notropis chlorocephalus	Greenhead shiner	2	1.2	2	(- , -)	2	42	0.001	0.025
Notropis scepticus	Sandbar shiner	30	48.4	30	(30 , 32)	28	632	0.048	1.019
Semotilus atromaculatus	Creek chub	14	67.4	17	(14 , 28)	16	358	0.082	1.723
Catostomidae									
Catostomus commersoni	White sucker	14	128.2	14	(14 , 15)	13	295	0.128	2.699
Hypentelium nigricans	Northern hog sucker	1	140.0	1	(- , -)	1	21	0.140	2.947
Scartomyzon rupiscartes	Striped jumprock	4	9.3	4	(- , -)	4	84	0.009	0.196
Ictaluridae									
Ameiurus platycephalus	Flat bullhead	9	97.4	9	(9 , 12)	8	189	0.097	2.051
Poeciliidae									
Gambusia holbrooki	Eastern mosquitofish	7	3.8	7	(7 , 9)	6	147	0.004	0.080
Centrarchidae									
Lepomis auritus	Redbreast sunfish	31	119.4	32	(31 , 36)	29	674	0.123	2.595
Lepomis cyanellus	Green sunfish	136	418.7	161	(138 , 184)	148	3,389	0.496	10.435
Lepomis gulosus	Warmouth	13	39.1	13	(13 , 14)	12	274	0.039	0.823
Lepomis macrochirus	Bluegill	3	46.1	3	(3 , 6)	3	63	0.046	0.971
Percidae									
Etheostoma olmstedi	Tessellated darter	4	5.1	4	(- , -)	4	84	0.005	0.107
Total		354	1,325.9	383		353	8,063	1.421	29.919

* Confidence intervals denoted by (- , -) were not calculated due to non-descending removal pattern, collection of just one fish, or collection of all fish on the first pass.

** Estimates of total density, total weight of the population, and total biomass may vary insignificantly from the sum of the individual values due to rounding.

Table 11. Population statistics of fishes collected during depletion sampling at London Creek, Cherokee County, SC at Location 1.7 on March 25, 2009. Location length = 101.0 m, area = 0.037 ha, temp. = 11.8 °C (53.2 °F), and DO = 10.5 mg/L.

Scientific name	Common name	Total no of fish collected	Total wt of fish collected (g)	Population estimate	Pop. est. (95% confidence intervals)*	Density (no/ 100 m)	Density (no/ ha)**	Est. wt of pop. (kg)**	Biomass (kg/ ha)**
Cyprinidae									
Clinostomus funduloides	Rosyside dace	1	1.7	1	(- , -)	1	27	0.002	0.046
Hybopsis hypsinotus	Highback chub	6	9.0	6	(6 , 8)	6	163	0.009	0.245
Nocomis leptocephalus	Bluehead chub	10	65.0	10	(10 , 11)	10	272	0.065	1.766
Semotilus atromaculatus	Creek chub	3	13.2	3	(- , -)	3	82	0.013	0.359
Ictaluridae									
Ameiurus platycephalus	Flat bullhead	1	50.0	1	(- , -)	1	27	0.050	1.359
Centrarchidae									
Lepomis auritus	Redbreast sunfish	80	206.0	86	(80 , 95)	85	2,337	0.221	6.018
Lepomis cyanellus	Green sunfish	3	27.4	3	(3 , 8)	3	82	0.027	0.745
Lepomis gulosus	Warmouth	16	74.2	16	(16 , 18)	16	435	0.074	2.016
Lepomis macrochirus	Bluegill	6	17.0	6	(- , -)	6	163	0.017	0.462
Percidae									
Etheostoma olmstedi	Tessellated darter	15	27.9	15	(15 , 16)	15	408	0.028	0.758
Total		141	491.4	147		146	3,995	0.507	13.773

* Confidence intervals denoted by (- , -) were not calculated due to non-descending removal pattern, collection of just one fish, or collection of all fish on the first pass.
** Estimates of total density, total weight of the population, and total biomass may vary insignificantly from the sum of the individual values due to rounding.

Table 12. Population statistics of fishes collected during depletion sampling at London Creek, Cherokee County, SC at Location 2.6 on March 24, 2009. Location length = 98.4 m, area = 0.030 ha, temp. = 13.7 °C (56.7 °F), and DO = 9.1 mg/L.

Scientific name	Common name	Total no of fish collected	Total wt of fish collected (g)	Population estimate	Pop. est. (95% confidence intervals)*	Density (no/ 100 m)	Density (no/ ha)**	Est. wt of pop. (kg)**	Biomass (kg/ ha)**
Cyprinidae									
Clinostomus funduloides	Rosyside dace	53	108.4	53	(53 , 54)	54	1,797	0.108	3.675
Nocomis leptocephalus	Bluehead chub	17	163.9	17	(17 , 18)	17	576	0.164	5.556
Notropis chlorocephalus	Greenhead shiner	4	10.9	4	(- , -)	4	136	0.011	0.369
Semotilus atromaculatus	Creek chub	137	279.0	137	(137 , 138)	139	4,644	0.279	9.458
Catostomidae									
Catostomus commersoni	White sucker	1	9.1	1	(- , -)	1	34	0.009	0.308
Centrarchidae									
Lepomis auritus	Redbreast sunfish	6	22.2	6	(6 , 6)	6	203	0.022	0.753
Lepomis gulosus	Warmouth	7	40.5	7	(7 , 8)	7	237	0.041	1.373
Percidae									
Etheostoma olmstedi	Tessellated darter	3	5.8	3	(3 , 4)	3	102	0.006	0.197
Total		228	639.8	228		231	7,729	0.640	21.688

* Confidence intervals denoted by (- , -) were not calculated due to non-descending removal pattern, collection of just one fish, or collection of all fish on the first pass.
** Estimates of total density, total weight of the population, and total biomass may vary insignificantly from the sum of the individual values due to rounding.

Table 13. Population statistics of fishes collected during depletion sampling at London Creek, Cherokee County, SC at Location 0.9 on September 10, 2009. Location length = 100.0 m, area = 0.036 ha, temp. = 19.8 °C (67.6 °F), and DO = 7.9 mg/L.

Scientific name	Common name	Total no of fish collected	Total wt of fish collected (g)	Population estimate	Pop. est. (95% confidence intervals)*	Density (no/ 100 m)	Density (no/ ha)**	Est. wt of pop. (kg)**	Biomass (kg/ ha)**
Cyprinidae									
Clinostomus funduloides	Rosyside dace	21	104.0	21	(21 , 21)	21	588	0.104	2.913
Hybopsis hypsinotus	Highback chub	13	33.9	13	(13 , 14)	13	364	0.034	0.950
Nocomis leptocephalus	Bluehead chub	56	248.2	56	(56 , 57)	56	1,569	0.248	6.952
Notropis scepticus	Sandbar shiner	37	128.3	37	(37 , 38)	37	1,036	0.128	3.594
Semotilus atromaculatus	Creek chub	38	293.7	38	(38 ,40)	38	1,064	0.294	8.227
Catostomidae									
Catostomus commersoni	White sucker	19	403.7	19	(19 , 21)	19	532	0.404	11.308
Hypentelium nigricans	Northern hog sucker	2	7.8	2	(2 , 7)	2	56	0.008	0.218
Scartomyzon rupiscartes	Striped jumprock	3	40.6	3	(- , -)	3	84	0.041	1.137
Ictaluridae									
Ameiurus platycephalus	Flat bullhead	20	221.9	27	(20 , 46)	27	756	0.300	8.391
Poeciliidae									
Gambusia holbrooki	Eastern mosquitofish	36	13.3	41	(36 , 51)	41	1,148	0.015	0.424
Centrarchidae									
Lepomis auritus	Redbreast sunfish	58	407.0	58	(58 , 60)	58	1,625	0.407	11.401
Lepomis cyanellus	Green sunfish	135	1102.0	148	(135 , 161)	148	4,146	1.208	33.841
Lepomis gulosus	Warmouth	4	49.0	4	(4 , 6)	4	112	0.049	1.373
Lepomis macrochirus	Bluegill	6	61.0	6	(6 , 6)	6	168	0.061	1.709
Micropterus salmoides	Largemouth bass	12	63.8	12	(12 , 12)	12	336	0.064	1.787
Percidae									
Etheostoma olmstedi	Tessellated darter	23	25.3	25	(23 , 31)	25	700	0.028	0.770
Total		483	3,203.5	510		510	14,286	3.391	94.995

* Confidence intervals denoted by (- , -) were not calculated due to non-descending removal pattern, collection of just one fish, or collection of all fish on the first pass.

** Estimates of total density, total weight of the population, and total biomass may vary insignificantly from the sum of the individual values due to rounding.

Table 14. Population statistics of fishes collected during depletion sampling at London Creek, Cherokee County, SC at Location 1.7 on September 10, 2009. Location length = 99.0 m, area = 0.031 ha, temp. = 19.8 °C (67.6 °F), and DO = 7.4 mg/L.

Scientific name	Common name	Total no of fish collected	Total wt of fish collected (g)	Population estimate	Pop. est. (95% confidence intervals)*	Density (no/ 100 m)	Density (no/ ha)**	Est. wt of pop. (kg)**	Biomass (kg/ ha)**
Cyprinidae									
Clinostomus funduloides	Rosyside dace	19	101.0	19	(19 , 19)	19	613	0.101	3.258
Hybopsis hypsinotus	Highback chub	18	45.5	18	(18 , 18)	18	581	0.046	1.468
Nocomis leptocephalus	Bluehead chub	79	283.1	79	(79 , 79)	80	2,548	0.283	9.132
Notropis scepticus	Sandbar shiner	33	132.3	33	(33 , 33)	33	1,065	0.132	4.268
Semotilus atromaculatus	Creek chub	15	248.0	15	(15 ,16)	15	484	0.248	8.000
Catostomidae									
Catostomus commersoni	White sucker	46	402.1	46	(46 , 47)	46	1,484	0.402	12.971
Ictaluridae									
Ameiurus platycephalus	Flat bullhead	6	63.6	6	(6 , 7)	6	194	0.064	2.052
Centrarchidae									
Lepomis auritus	Redbreast sunfish	82	673.6	84	(82 , 88)	85	2,710	0.690	22.259
Lepomis cyanellus	Green sunfish	5	60.0	5	(5 , 8)	5	161	0.060	1.935
Lepomis gibbosus	Pumpkinseed	4	41.2	4	(4 , 5)	4	129	0.041	1.329
Lepomis gulosus	Warmouth	1	28.0	1	(- , -)	1	32	0.028	0.903
Lepomis macrochirus	Bluegill	3	18.2	3	(- , -)	3	97	0.018	0.587
Lepomis microlophus	Redear sunfish	2	21.6	2	(- , -)	2	65	0.022	0.697
Micropterus salmoides	Largemouth bass	19	106.4	19	(19 , 20)	19	613	0.106	3.432
Percidae									
Etheostoma olmstedi	Tessellated darter	8	12.9	8	(8 , 9)	8	258	0.013	0.416
Total		340	2,237.5	342		344	11,032	2.254	72.707

* Confidence intervals denoted by (- , -) were not calculated due to non-descending removal pattern, collection of just one fish, or collection of all fish on the first pass.

** Estimates of total density, total weight of the population, and total biomass may vary insignificantly from the sum of the individual values due to rounding.

Table 15. Population statistics of fishes collected during depletion sampling at London Creek, Cherokee County, SC at Location 2.6 on September 9, 2009. Location length = 100.0 m, area = 0.022 ha, temp. = 20.3 °C (68.5 °F), and DO = 6.9 mg/L.

Scientific name	Common name	Total no of fish collected	Total wt of fish collected (g)	Population estimate	Pop. est. (95% confidence intervals)*	Density (no/ 100 m)	Density (no/ ha)**	Est. wt of pop. (kg)**	Biomass (kg/ ha)**
Cyprinidae									
Clinostomus funduloides	Rosyside dace	2	8.3	2	(- , -)	2	90	0.008	0.374
Hybopsis hypsinotus	Highback chub	6	13.0	6	(- , -)	6	270	0.013	0.586
Nocomis leptocephalus	Bluehead chub	36	125.8	36	(36 , 37)	36	1,622	0.126	5.667
Notropis chlorocephalus	Greenhead shiner	10	16.8	10	(10 , 10)	10	450	0.017	0.757
Semotilus atromaculatus	Creek chub	46	335.5	46	(46 , 47)	46	2,072	0.336	15.113
Poeciliidae									
Gambusia holbrooki	Eastern mosquitofish	2	0.4	2	(2 , 15)	2	90	0.000	0.018
Centrarchidae									
Lepomis auritus	Redbreast sunfish	4	16.5	4	(4 , 7)	4	180	0.017	0.743
Lepomis gulosus	Warmouth	2	41.0	2	(2 , 7)	2	90	0.041	1.847
Lepomis macrochirus	Bluegill	6	19.6	6	(6 , 6)	6	270	0.020	0.883
Micropterus salmoides	Largemouth bass	20	62.9	20	(20 , 22)	20	901	0.063	2.833
Percidae									
Etheostoma olmstedi	Tessellated darter	8	11.0	8	(- , -)	8	360	0.011	0.495
Total		142	650.8	142		142	6,396	0.651	29.315

* Confidence intervals denoted by (- , -) were not calculated due to non-descending removal pattern, collection of just one fish, or collection of all fish on the first pass.

** Estimates of total density, total weight of the population, and total biomass may vary insignificantly from the sum of the individual values due to rounding.

Table 16. Summary pollution tolerance rating and trophic guild status of fish collected at three sampling locations on London Creek, Cherokee County, SC, in March and September, 2008 – 2009.

	2008		2009	
	Mar	Sep	Mar	Sep
Pollution tolerance				
Intolerant	8.31%	4.53%	1.80%	3.83%
Intermediate	60.85%	28.14%	37.07%	43.11%
Tolerant	30.84%	67.33%	61.13%	53.06%
Trophic Guild				
Herbivore	0.00%	0.00%	0.00%	0.00%
Insectivore	62.39%	88.08%	88.52%	70.26%
Omnivore	37.61%	11.77%	11.48%	24.46%
Piscivore	0.00%	0.15%	0.00%	5.28%

Table 17. Number and total length ranges of centrarchids collected at three sampling locations on London Creek, Cherokee County, SC, during 2008 – 2009.

		2008		2009	
Scientific name	Common name	no	Range (mm)	no	Range (mm)
Lepomis auritus	Redbreast sunfish	410	18 - 121	261	24 - 144
Lepomis cyanellus	Green sunfish	214	27 - 124	279	30 - 148
Lepomis gibbosus	Pumpkinseed			4	71 - 87
Lepomis gulosus	Warmouth	58	30 - 91	43	41 - 110
Lepomis macrochirus	Bluegill	14	40 - 57	24	22 - 119
Lepomis microlophus	Redear sunfish			2	76 - 99
Micropterus salmoides	Largemouth bass	2	52 - 61	51	55 - 95

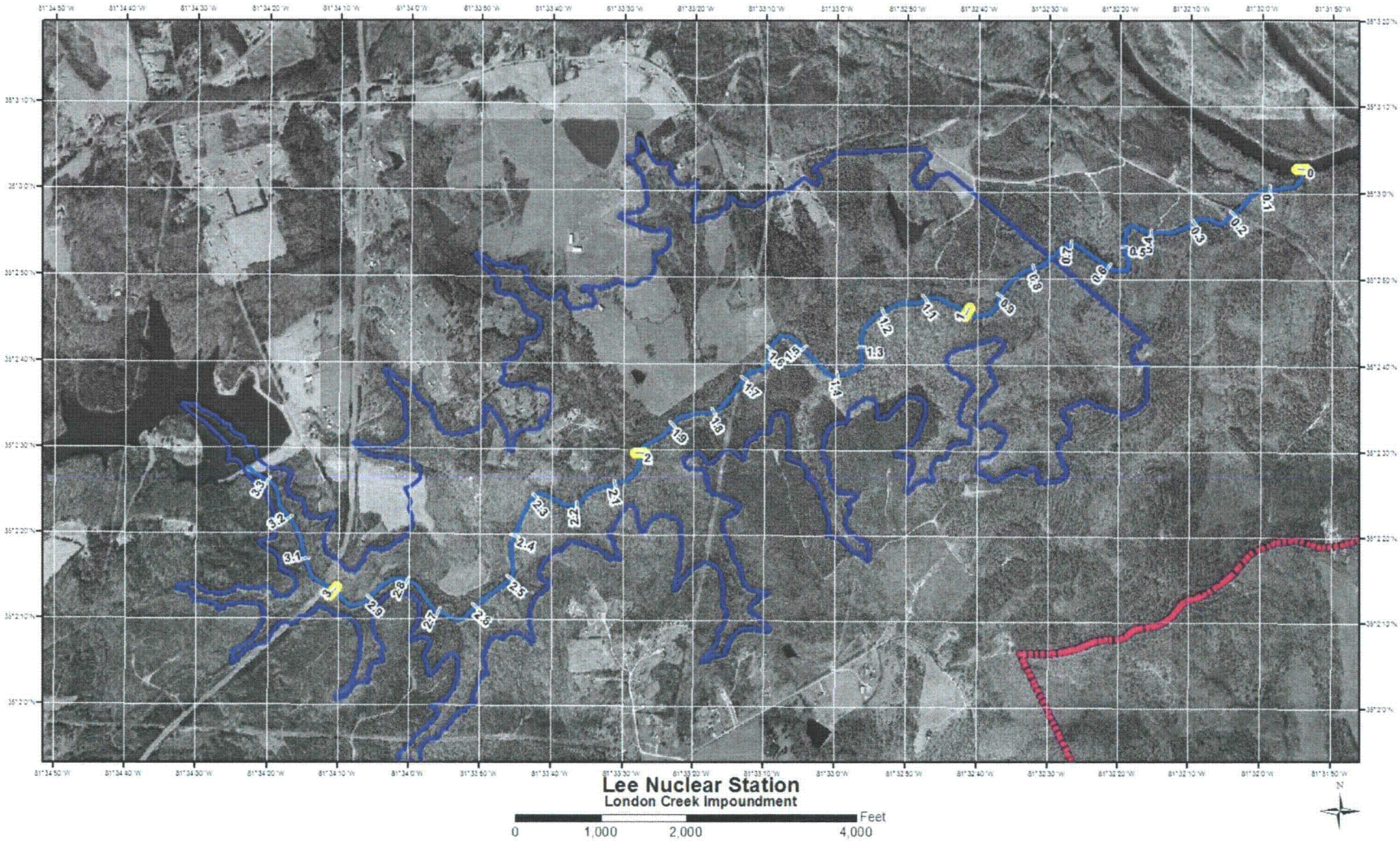


Figure 1. Aerial photograph of the London Creek, Cherokee County, SC, watershed. The Broad River is in the upper right corner and Lake Cherokee is at the left. The outline of the proposed reservoir (Make-Up Pond C) is in blue, London Creek is teal colored, and the Lee Nuclear Station Project boundary is in pink. Distances on London Creek are approximate river miles upstream from the Broad River and are denoted in tenths of a mile.

Figure 2. Photographs of three fish sampling locations on London Creek, Cherokee County, SC, from downstream to upstream. Location 0.9 (A and B), Location 1.7 (C and D), and Location 2.6 (E and F).

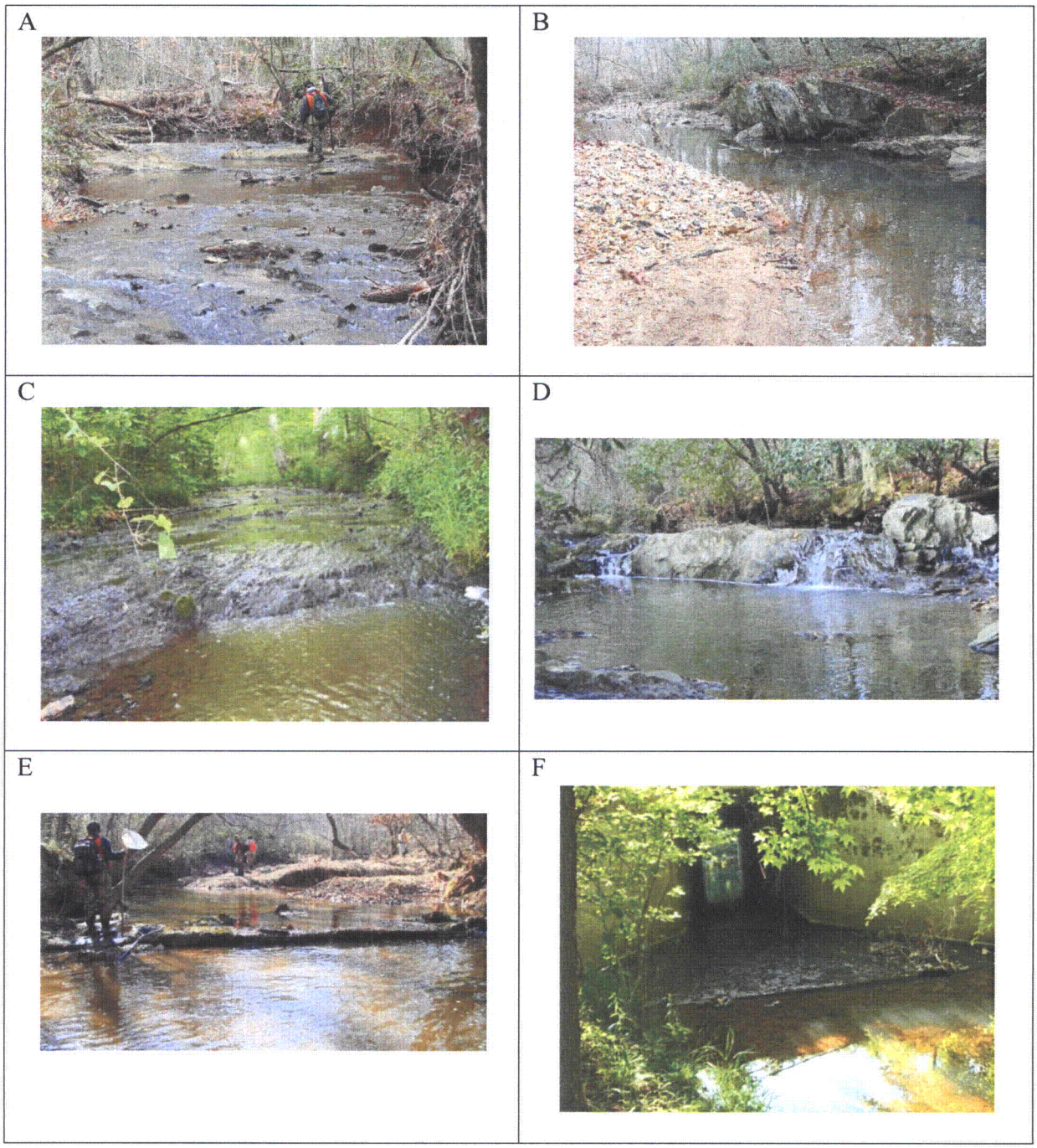


Figure 3. Photographs of additional reaches of London Creek, Cherokee County, SC, surveyed in 2009. Stream segments between Locations 0.9 and 1.7 (A and B) and between Hwy 329 and Lake Cherokee (C). Possible barriers to fish movement in London Creek during low flow periods located between Locations 0.9 and 1.7 (D), between Locations 1.7 and 2.6 (E), and at the upstream edge of the Hwy 329 culvert (F).

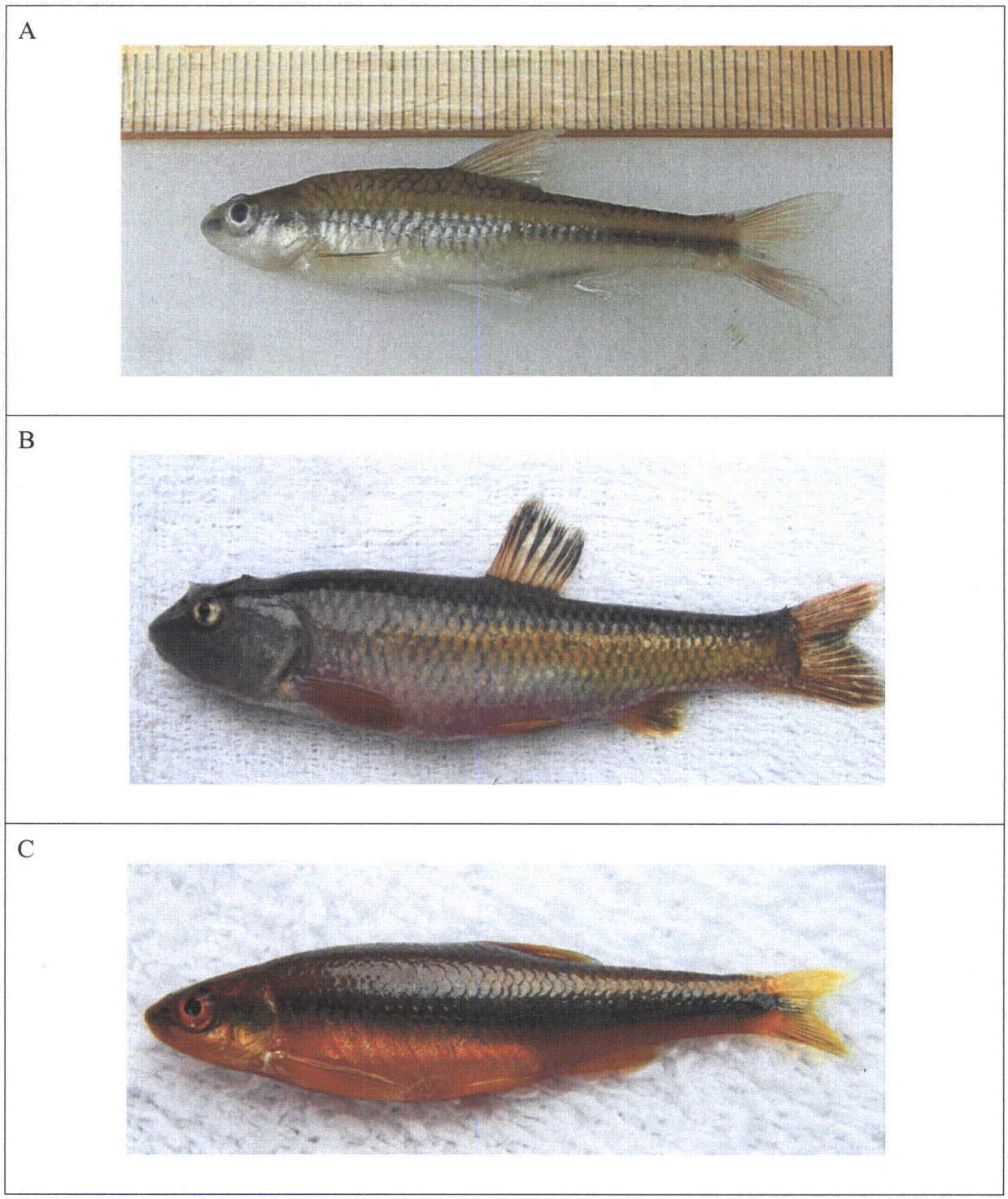


Figure 4. Photographs of selected London Creek fishes – highback chub *Hybopsis hypsinotus* (A), bluehead chub *Nocomis leptocephalus* (B), and greenhead shiner *Notropis chlorocephalus* (C).

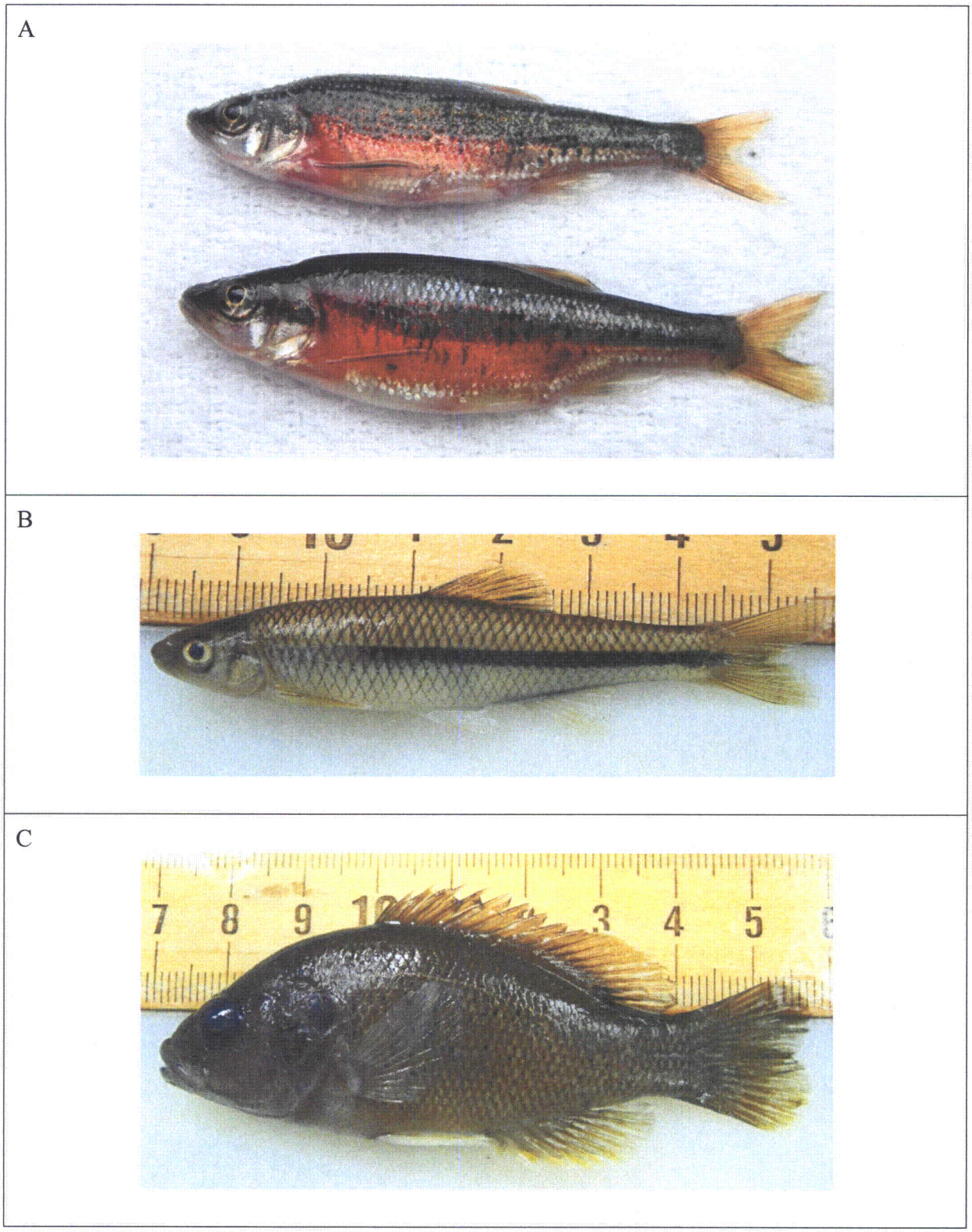


Figure 5. Photographs of selected London Creek fishes – rosyside dace *Clinostomus funduloides* (A), whitefin shiner *Cyprinella nivea* (B), and green sunfish *Lepomis cyanellus* (C).

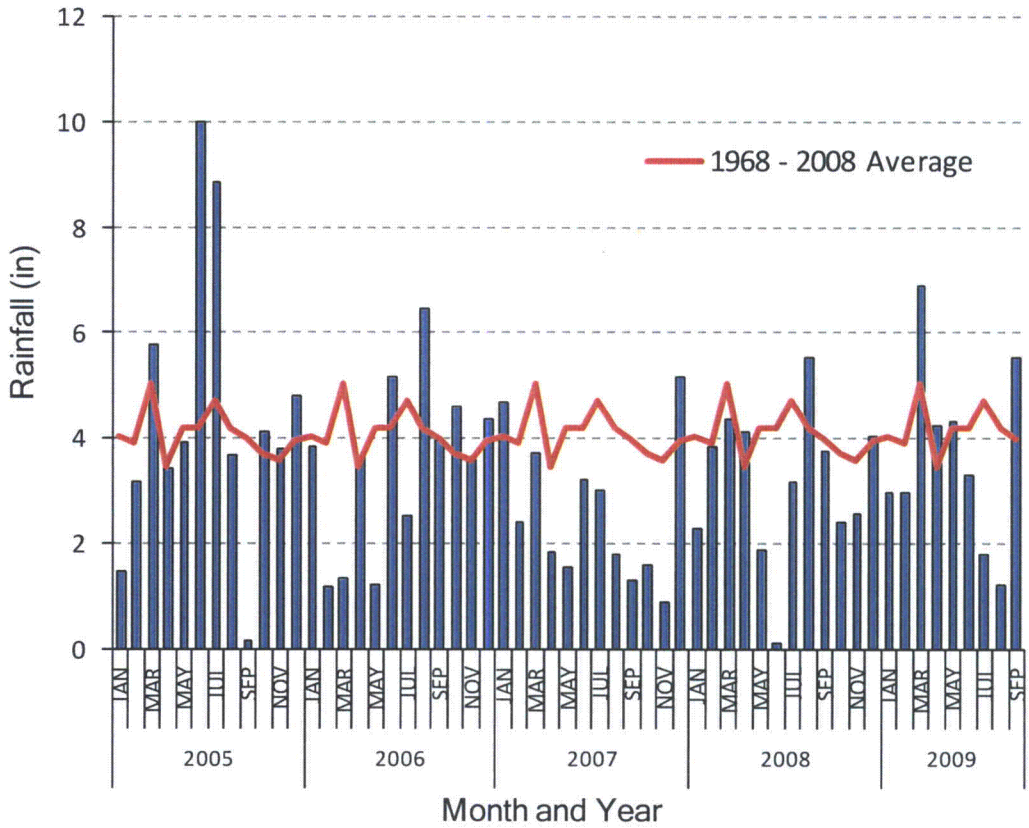
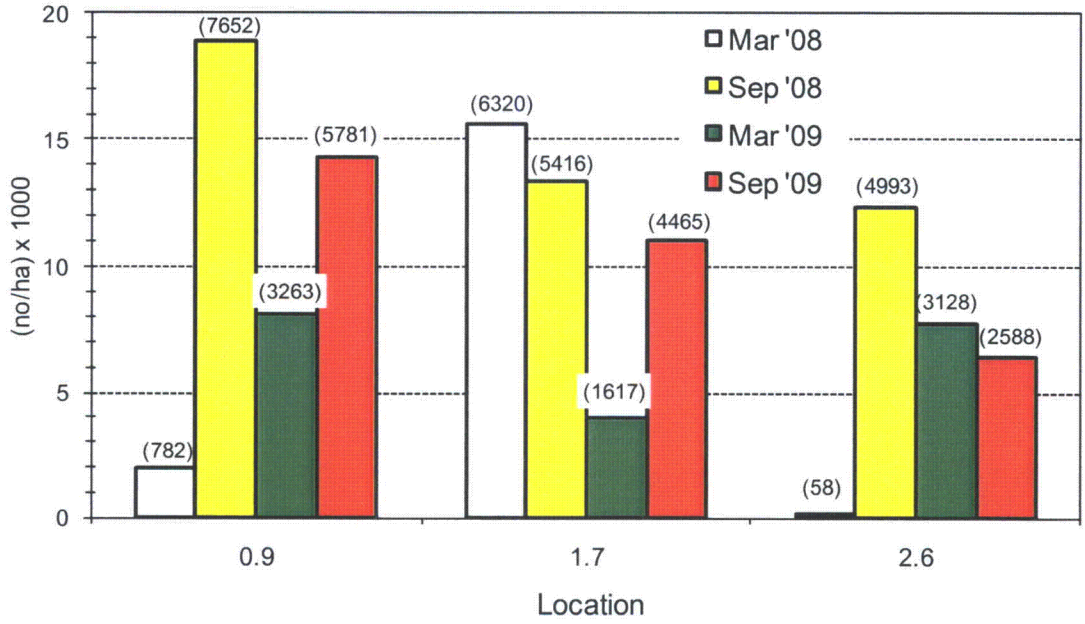


Figure 6. Monthly rainfall totals at the Greenville-Spartanburg Airport in Greer, SC, from January 2005 through September 2009 and the average monthly rainfall totals 1968 – 2008 (NCDC 1997, 2008, and 2009).

A



B

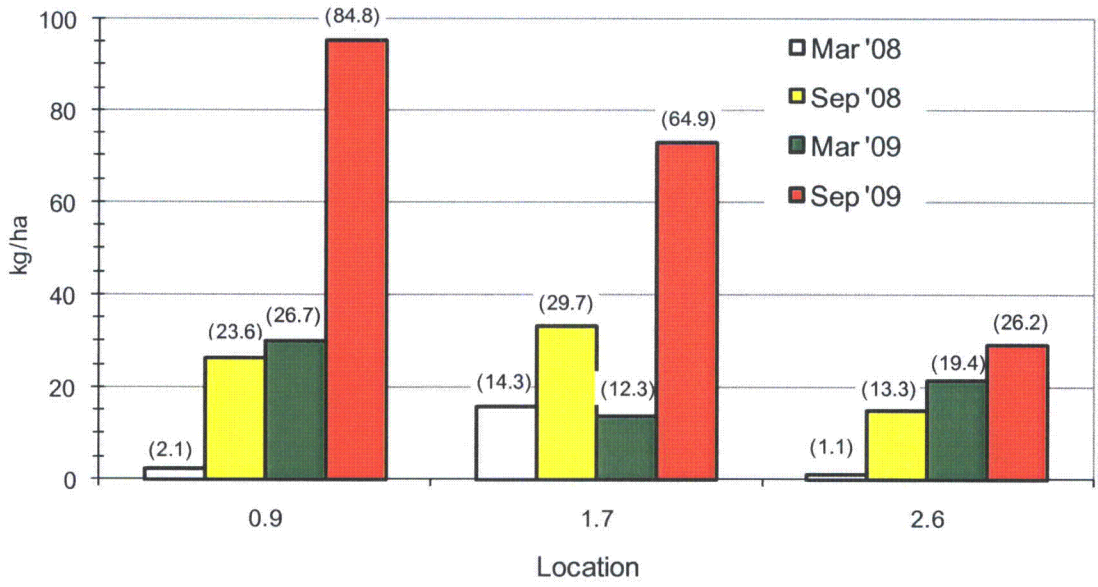


Figure 7. Fish density (A, values in parentheses are no/ac) and biomass (B, values in parentheses are lb/ac) estimates at three locations in London Creek, Cherokee County, SC, during March and September, 2008 – 2009.

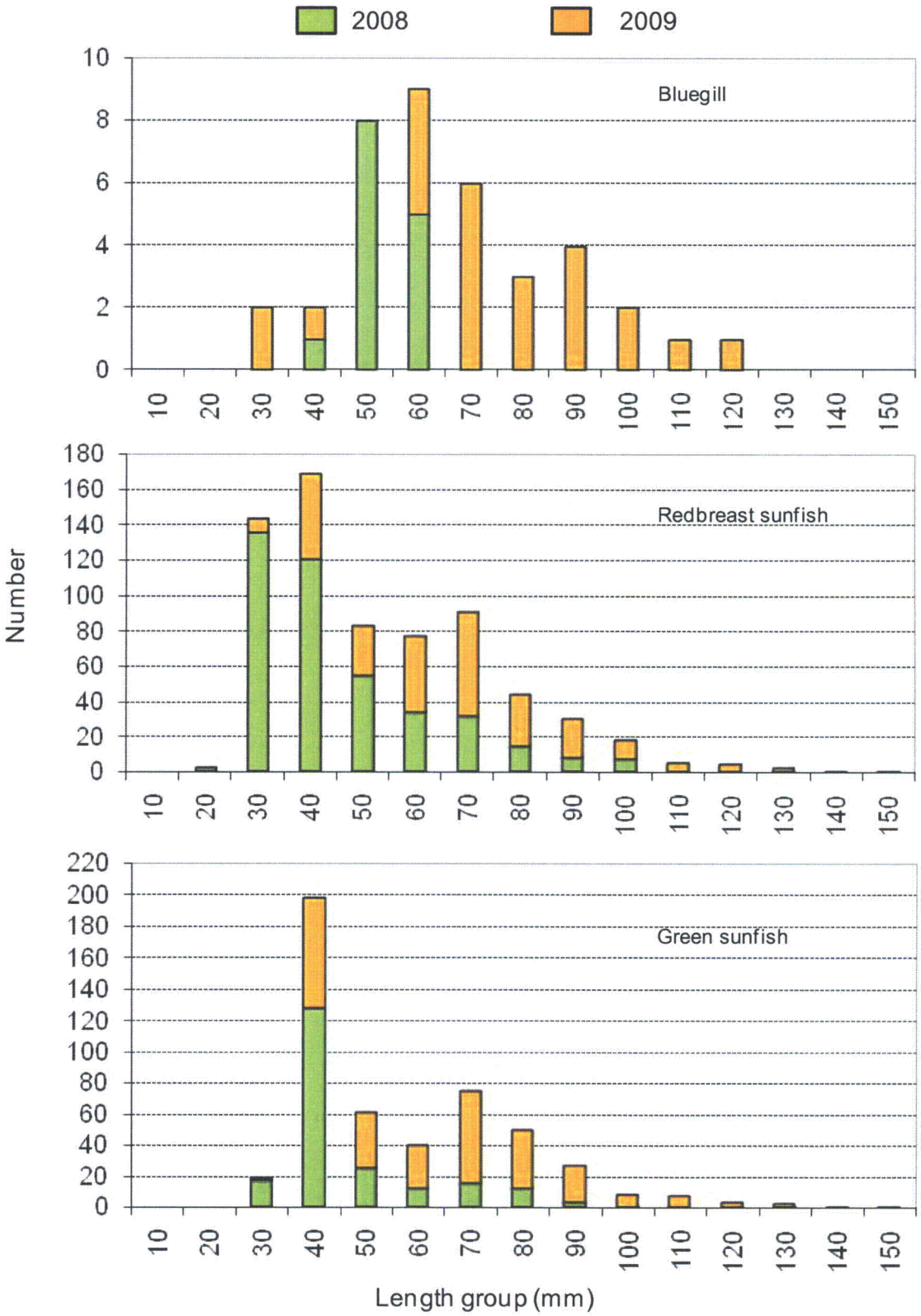


Figure 8. Length frequency distribution of bluegill, redbreast sunfish, and green sunfish collected at three locations in London Creek, Cherokee County, SC, during 2008 – 2009.

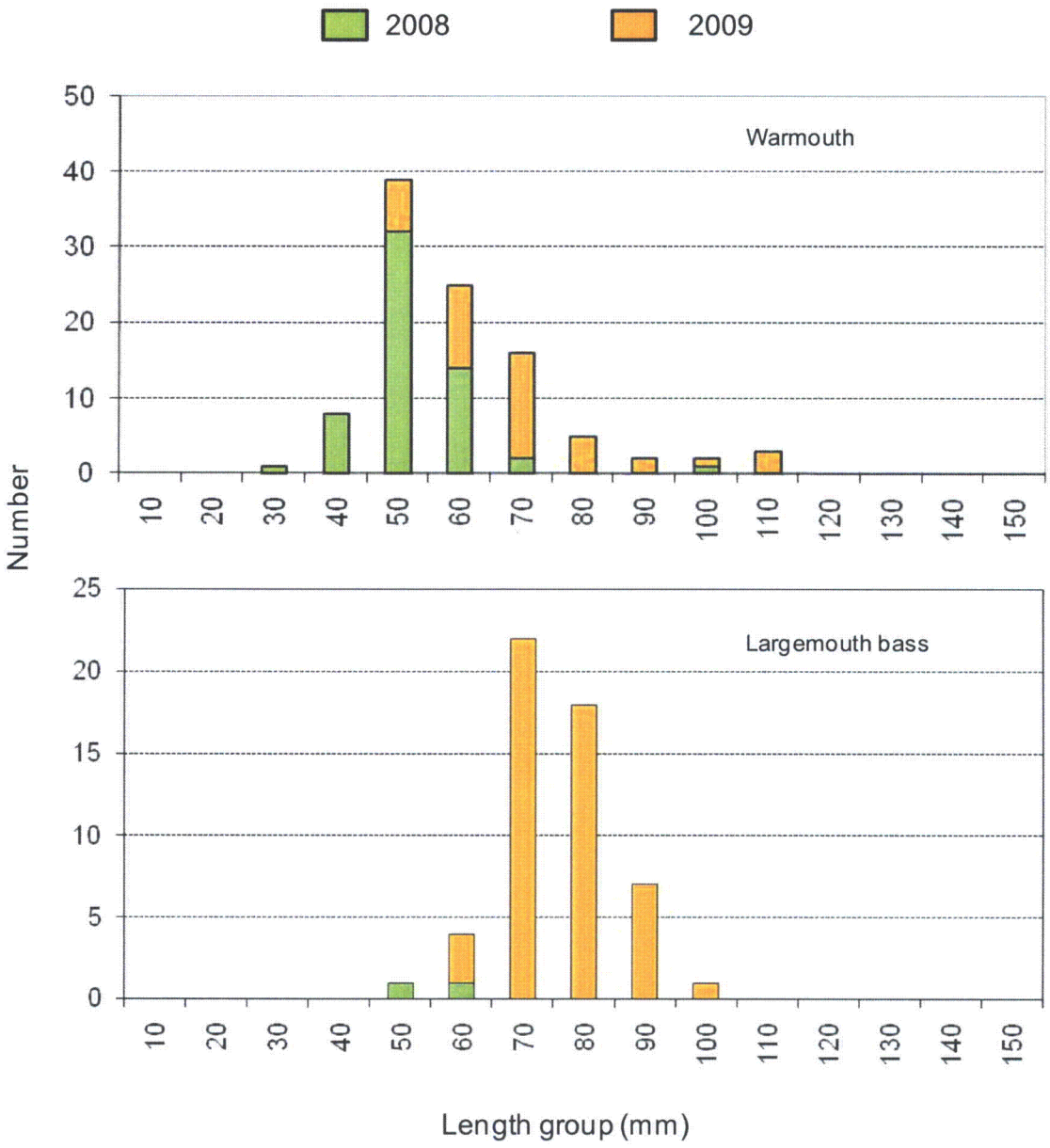


Figure 9. Length frequency distribution of warmouth and largemouth bass collected at three locations in London Creek, Cherokee County, SC, during 2008 – 2009.