Re-Inventory of Fishes in Kings Mountain National Military Park

James J. English[1*], W. Kyle Lanning[2], Shepard McAninch[3], LisaRenee English[1]

Abstract

A resurvey of fish in streams on Kings Mountain National Military Park (KIMO) was conducted following a prolonged period of record-setting temperatures and regional drought, with special attention given to Carolina Darter, *Etheostoma collis*, the species of highest conservation priority to South Carolina. This resurvey compares findings to a previous survey (Scott 2006) that was conducted in comparable fashion. In general, overall fish abundance, species richness and species diversity declined when considering KIMO as a whole or comparing individual streams, with few exceptions. Several species that were present in the 2006 survey were not found in the resurvey, and a few additional species were found. Comparing the 2006 and 2011 surveys found that, in general, common species became more common and rare species became rarer. Variability in temperature and pH values may be useful in predicting survivability or relative success, as species found under a greater range of these variables were more likely to be in high numbers (greater than 5% of the overall community) and were more likely to have increased in abundance between the two surveys. Carolina Darters were found under a wide temperature and pH value range, and increased in abundance compared to the 2006 survey. Included is a specific description of a complex of microhabitat conditions consistently present in each Carolina Darter finding.

1 Lipscomb University Institute for Sustainable Practice, Nashville, TN
2 Gardner-Webb University, Boiling Springs, NC
3 NPS Cumberland/Piedmont Network Ecologist and Data Manager
* Corresponding author: englishjamesj@gmail.com

Introduction

One of the most detrimental factors affecting population survival and species richness of fish communities is drought. Drought affects fish in many ways, often with several related and/or exacerbating factors, as many abiotic variables are correlated (Reid 1961, Foltz 1982): drought conditions may increase water temperature, reduce oxygen levels, change ambient light profiles and water clarity, concentrate pollutants and change water chemistry, further compounding environmental stresses on fish. Drought also affects fish mobility which reduces refuge availability, changes predator-prey dynamics and causes populations to more readily exhaust their resources.

In 2006, a fish survey was conducted by Scott (Scott 2006) of the streams on Kings Mountain National Military Park (KIMO) located in the Piedmont Region of the Southern Appalachian Mountains near Blacksburg, South Carolina, 2.5 miles south of I-85 and 25 miles west of Gastonia, North Carolina. The Kings Mountain range is a rocky spur of the Blue Ridge Mountains that rises 46m above the surrounding area. The northern boundary of the park is located approximately one mile south of the North Carolina / South Carolina state line and the Park is situated in both York and Cherokee Counties, South Carolina, abutting Cleveland and Gaston Counties, North Carolina. KIMO's water resources are part of the Broad River drainage that empties into the Santee River system. Kings Creek and Long Branch are the main stream systems in KIMO fed by numerous smaller streams, though Dellingham Branch, Garner Branch and Stonehouse Creek are also significant. While Kings Creek originates off-site, drains private lands and crosses under I-85, KIMO protects the headwaters of Long Branch. There are no known impounded waters or substantial springs capable of supporting fishes on KIMO property.

The 2006 survey was an effort to inventory at least 90% of the expected fish species present as well as to calculate species richness, distribution, and abundance while documenting habitat variables. Since that survey was conducted, the region experienced an extended drought including the year of the most severe drought recorded for this area, 2007 (NCDM 2008). It was therefore of interest to re-survey the streams on KIMO to determine the effects these prolonged drought conditions have had on the fish community.

Previous Study: The South Carolina Department of Natural Resources Freshwater Fisheries staff inventoried freshwater fishes during May and June 2006 for the National Park Service in four Cumberland Piedmont Network parks in South Carolina and North Carolina including Kings Mountain National Military Park (Scott 2006).

Fish sampling was conducted using a backpack electrofishing technique in the wadeable streams. Sampled stream lengths varied among sites, and were equivalent to at least 30 times the average stream width (per Angermeier & Smogor 1995) with one pass from downstream toward upstream, with thorough effort to collect all encountered fishes in all habitats (Scott 2006). The study found a total of 1,328 individual fish from 19 species representing 5 families. Six of these species were listed in South Carolina's Comprehensive Wildlife Conservation Strategy as priority conservation species: Highback Chub (*Hybopsis hypsinotus*), Greenfin Shiner (*Cyprinella chloristia*), and Flat Bullhead (*Ameiurus platycephalus*) were moderate priority species; Seagreen Darter (*Etheostoma thalassinum*) and Carolina Fantail Darter (*Etheostoma flabellare*) were high conservation priority; Carolina Darter *(Etheostoma collis*) was considered highest conservation priority (SCDNR 2005). One species collected was exotic to the Broad River drainage: Smallmouth Bass (Warren et al. 2000), all other species are considered native.

Regional Drought: Since 2006, Cleveland & Gaston counties in North Carolina and York & Cherokee counties in South Carolina (as well as other counties in the Piedmont region) experienced a period of significant drought that drastically lowered the water levels of many ponds, lakes, streams, and rivers in the area. This drought began summer 2006 and lasted until 2009, and included the most severe drought (and highest temperatures) ever recorded in the area during 2007 (NCDM 2008). One of the main reasons for conducting the resurvey was to compare the species richness from the 2006 survey to the results gained in the current study, with the implication being that the major drought could have altered the species richness of the park. It was fortuitous that the 2006 survey was conducted immediately before the drought began so it could serve as a natural 'pre-drought survey' to compare the present 'post-drought survey'.

Because six of the documented species were on South Carolina's Comprehensive Wildlife Conservation Strategy as species of conservation priority, it was of interest to determine if this drought affected species diversity, and in particular, those species already in danger of extinction. Because Carolina Darter is of highest conservation priority, it was of importance to pay special attention to this species.

Carolina Darter: Darters (Family Percidae) are small perch-like fish that inhabit freshwater streams in North America and include members of four Genera: *Ammocrypta*, *Crystallaria*, *Etheostoma* and *Percina.* Some darters are widespread throughout North America, but others are restricted to single streams, leaving them vulnerable to extinction. Carolina Darter, *Etheostoma collis*, is a small insectivorous fish native to southeastern United States (Hubbs & Cannon 1935) and is listed as a species of special concern in South Carolina and is considered vulnerable in North Carolina, imperiled in Virginia, and vulnerable to imperilment among southeastern freshwater fishes (Rohde et al. 1994, Warren et al. 2000, SCDNR 2005, NatureServe 2010).

Carolina Darter eyes are almost on top of the head and they have an elongate, somewhat compressed body with incomplete lateral line, terminal highly arched mouth and short, rounded nose (Kuehne & Barbour 1983). The body is yellow-brown with dark blotches and speckles. The brown-spotted sides are marked with a medial dark stripe that breaks into blotches on the peduncle. A primary basicaudal spot has two spots of lesser intensity above and below (Rohde et al. 1994). The caudal fin is rounded and it, as well as the dorsal fins, may include rusty coloring while other fins are clear or pale yellow. The head is rather small and may have green and yellow iridescence. Adults average 25-40 mm standard length but can reach a length of 60 mm (Rohde et al. 1994). Breeding males do not develop bright colors but may have breeding tubercles on the pelvic fin spine and rays as well as anal fin rays (Kuehne & Barbour 1983). Carolina Darters are typically found in warm pools and slower runs in streams and are seemingly most camouflaged when swimming over sand and gravel. The fish becomes sexually mature by age 1-2 years and spawning occurs from March to April. Like many other freshwater fish in a lotic environment, Carolina Darter eggs attach to gravel on the bottom of the stream and are externally fertilized. Though some reproductive ecology has been documented in recent years, relative fecundity of Carolina Darter is unknown (NatureServe 2010).

Methods

In order to duplicate the 2006 survey as closely as possible, we used a similar electroshocker (Smith-Root LR-24 backpack electrofisher) with comparable methods as used by Scott (2006) and surveyed the same stream systems with only 2 differences. Scott (2006) surveyed fish on KIMO in May - June, while the resurvey was conducted in June - July of 2011 due to the availability dates of the electro-fishing unit. Secondly, the 2006 survey searched a length of each stream equivalent to at least 30 times the average stream width (per Angermeier & Smogor 1995) in a single pass from downstream toward upstream, with thorough effort to collect all encountered fishes in all habitats along the surveyed portion of the stream (Scott 2006). We also conducted a single downstream-to-upstream pass but in an effort for completeness and to account for the dryer conditions, we surveyed all potential habitats along the entire stream length while on KIMO property. Fish were caught using dipnets and were identified, counted and released in the downstream direction. The number of individuals and species found was recorded for each sample location. Fish were identified to species level with the following exception. During breeding season when they could be easily differentiated, Bluehead Chub (*Nocomis leptocephalus*) and Creek Chub (*Semotilus atromaculatus*) were found in roughly equal numbers (22%, 19% of overall catch, respectively). However, outside breeding season, these species could not reliably be differentiated in the field. As the 2011 stream resurvey was conducted during their non-breeding season, we identified both of these species into an aggregate group during field work and assigned individual counts to these species based on their relative ratio during breeding season (53.5 % Bluehead Chub, 46.5% Creek Chub).

Eight streams and tributaries were studied in the 2006 survey of Kings Mountain National Military Park: Dellingham Branch, Garner Branch, Kings Creek, Kings Creek Tributary, Long Branch, Long Branch Tributary 1, Long Branch Tributary 2, and Stonehouse Creek. In this 2011 resurvey of KIMO, we surveyed each of those streams or tributaries studied in 2006. For analysis purposes, this report consolidates findings from minor tributaries with the larger streams, thus creating the following five streams with total stream length in parentheses: Dellingham Branch (2,712 m), Garner Branch (5,883 m), Kings Creek (1,197 m), Long Branch (7,400 m), Stonehouse Creek (4,859 m). For some comparisons, data for all streams were pooled to give abundance and relative abundance by species for the entire park. For comparison of commonly found species to rare species for analysis purposes, a species was considered *Common* if the species was found to constitute more than 5% of the overall fish community in the survey and considered *Uncommon* if found to constitute less than 5% of the overall fish community. *Common* and *Uncommon* label assignment was done independently for each survey (2006, 2011), so it was possible for a species of fish to be *Common* in one survey and *Uncommon* in the other.

Stream characteristics were collected at multiple locations within each stream and include average wetted width (m, taken from water edge to water edge), average stream depth (cm), average water temperature (C°), average pH, a categorical description of the substrate (clay-mud-silt, detritus, detritus-mud, detritus-rock, mud-silt-rock, rock-sand) and water clarity category (1 = clear, 2 = moderately turbid, 3 = opaque).

Species diversity was determined for the original 2006 survey (based on data published in Scott 2006) and compared to index values calculated for the 2011 resurvey using Simpson's Diversity Index as it is one of the most meaningful, intuitive and robust diversity measures available and useful for a variety of applications (May 1975, Krebs 1989, Magurran 2011) and is probably more effective than species accumulation curves (Lande *et al*. 2000). Simpson's Diversity Index (1-D) shares the same two features as most Diversity Indices: 1) they account for abundance of individuals within species as well as number of different species, and 2) larger numbers usually correspond to relatively more diverse communities. Simpson's Index is calculated ($D = \Sigma (P_i^2)$) where P_i is the proportion of individuals belonging to the i^{th} species. When using Simpson's Index (D) often Simpson's Diversity Index (1-D) is reported as it is more intuitive: values range from 0-1 with greater values representing greater species diversity, or, alternatively, greater probability that two individuals chosen at random are different species.

Data analysis was conducted in JMP 7.0 for PC/Windows (SAS Institute, Inc. 2007).

Results

In the 2006 survey, Scott found a total of 1,328 individuals including 19 Species (Scott 2006), delivering overall Simpson's Diversity Index (1-D) = 0.81874. The resurvey found 1,111 individuals including 18 Species, delivering an overall Simpson's Diversity Index (1-D) = 0.74042 (Table 1).

Several species identified in the 2006 survey were not found in the 2011 resurvey: Flat Bullhead, Tessellated Darter, Seagreen Darter and Striped Jumprock were all present in relatively low numbers (all *Uncommon* species) in 2006 but were absent in the 2011 resurvey while three *Uncommon* species of shiners (Tennessee Shiner, Silver Shiner and Swallowtail Shiner) were found in 2011 that were not found in 2006 (Table 1).

Table 2 contains species occurrence (individual numbers and relative abundance) for each stream searched in both surveys (2006 vs 2011). This data is combined in Figure 1 showing number and percent total of individual fish found in each stream as well as the number of species in each stream (Figure 1). Simpson's Diversity Index values for individual stream communities are calculated for each survey and presented in Table 2. As with the overall diversity trend, most streams decreased in diversity between the 2006 and 2011 survey, with exeptions being Garner Branch and Stonehouse Creek, which increased slightly (Table 2). In both surveys, King's Creek showed the most diversity, closely followed by Long Branch and Stonehouse Creek, while Dellingham Branch was consistently the least diverse (Table 2). No significant relationships were found when conducting linear regression on stream length in relation to Diversity Index ($P = 0.9706$), species richness ($P = 0.7132$), fish abundance ($P = 0.2717$), or percentage of the fish that were *Uncommon* species ($P = 0.6861$).

Table 3 shows the percentage of *Uncommon* species that were found in each stream, and compares these findings between surveys. In 2006 more *Uncommon* individuals were found in each stream except Dellingham Branch; In 2006 only *Common* species were found in

Dellingham Branch, while in 2011, just over 4% of the fish found in this stream were *Uncommon* species (Table 3). Aside from this one stream, *Uncommon* fish became less common in 2011; combining all streams, 13.48% of the fish found in 2006 were *Uncommon* species, and in 2011 only 3.96% of the fish were *Uncommon* species. Kings Creek contained the most fish from *Uncommon* species in each survey; in 2006, 37.48% of the fish in Kings Creek were *Uncommon* species and in 2011, 13.55% of the fish found in Kings Creek were *Uncommon* species (Table 3).

Mean depth (cm), width (m), clarity, pH, and temperature (C°) for each stream are presented in Table 4 and can be compared to 2006 parameters where both measures are available and/or comparable. Mean stream width was found to be wider in 2011 for Dellingham Branch, Long Branch and Garner Branch, though the difference was only slight in Stonehouse Creek, and Kings Creek was less wide in 2011 (Table 4). Mean pH in 2011 was lower in each stream except Dellingham Branch, which was nearly unchanged, and 2011 mean temperatures were between 2-5°C warmer in each stream (Table 4). Overall (all streams combined per survey), mean water temperatures in 2011 were significantly warmer (mean 2006 = 18.42°C ± 0.0431, mean 2011 = 22.45 ± 0.0555; $P < 0.0001$) and had a significantly lower pH (mean 2006 = 6.91 ± 0.0179, mean 2011 = 5.36 ± 0.0277; $P < 0.0001$).

Fish of *Uncommon* species were, on average, found in significantly wider streams in both surveys (2006 mean stream width: *Common* 2.71 m ± 0.0477, *Uncommon* 4.79 m ± 0.1210, $P < 0.0001$; 2011 mean stream width: *Common* 3.23 m ± 0.0486 , *Uncommon* 4.14 ± 1.314, $P = 0.0002$) (Table 5). Similarly, *Common* fish species were, on average, found in water with significantly lower pH (2006: *Common* 6.83 ± 0.0165, *Uncommon* 7.40 ± 0.0418, $P < 0.0001$; 2011: *Common* 5.35 ± 0.0338, *Uncommon* 5.74 ± 0.1448, $P = 0.0081$) (Table 5). *Uncommon* fish were also found in warmer water in 2006 (*Common* 18.19C° ± 0.0360, *Uncommon* 19.82 C° ± 0.0913; $P < 0.0001$) though there was no significant difference between average temperature of *Common* and *Uncommon* fish species in 2011 (*Common* 22.46 C° ± 0.0686, *Uncommon* 22.39 C° ± 0.2992; $P = 0.8354$) (Table 5). Finally, for the 2011 survey, no significant difference in average depth was found between *Common* and *Uncommon* fish (*Common* 20.97 cm ± 0.9317, *Uncommon* 17.88 cm ± 4.2787; $P = 0.4811$; all analysis Student's T-test) (Table 5).

While mean values may be important in explaining fish presence/absence, abundance, richness and diversity, the range of values a species can tolerate is also important (Shelford 1911, Krebs 2008). It was therefore of interest to consider the range of values where species were found. Species of fish with multiple values (more than one fish of a species was found) were grouped into either *Common* or *Uncommon* species for which the range of temperatures and pH values were compared. Student's T-test found *Common* and *Uncommon* fish species had different ranges of these parameters. *Common* species were found in a significantly wider range of conditions (temperature, $P = 0.0005$; pH, $P = 0.0134$; Table 6). Additionally, species were classified by the difference in relative abundance between the surveys (Success Classes: MORE = species that moved from being Absent or *Uncommon* to *Common*, SAME = species that didn't change from one level to another, LOWER = species that were *Common* and became *Uncommon*, LOST = species that were found in the 2006 survey but not found in the 2011 resurvey (Table 7). Comparing the temperature range and pH range of Success Classes, LOST species had significantly lower ranges than species that became more abundant (MORE) ($P < 0.05$). Table 7 shows differences between these relative abundance categories of fish and shows a trend of increased ranges in both parameters (temperature and pH) with increased levels of success between the surveys (MORE > SAME > LOWER > LOST), though not all differences were significant (Table 7).

Carolina Darter, *Etheostoma collis*, is a species of highest conservation priority according to South Carolina's Comprehensive Wildlife Conservation Strategy (SCDNR 2005). In the 2006 survey, one Carolina Darter was found in Long Branch. In the 2011 resurvey, 11 Carolina Darters were found in Long Branch and one was found in Stonehouse Creek, a stream where this species was not previously found on KIMO. The only stream attribute that seems significant in describing differences in the 2006 vs 2011 surveys relating to Carolina Darters involves water temperature. The single Carolina Darter found in 2006 was found in a stream (Long Branch) with a temperature of 18.4C°. In 2011, Carolina Darters were again mostly found in Long Branch (11 of 12), however Long Branch was significantly warmer in the resurvey than in 2006 (2011 mean: 23.67C° ± 0.290, $P < 0.0005$) and was the warmest stream in the survey ($P < 0.0001$).

Discussion

The 2011 fish resurvey of streams on Kings Mountain National Military Park found fewer fish species and fewer individuals even though more stream distance was surveyed. The

2006 survey found 1,328 fish from 19 species and the 2011 resurvey found 1,111 fish from 18 species. Several fish species that were found in low numbers in 2006 were absent from the 2011 (Flat Bullhead, Tessellated Darter, Seagreen Darter and Striped Jumprock) (Table 1). On the other hand, three species of shiners (Tennessee Shiner, Silver Shiner and Swallowtail Shiner) were found in low numbers in 2011 that were not found in 2006 (Table 1). However, the few individuals found of these three species are within the projected error inherent in the methods used in the 2006 survey (Angermeier & Smogor 1995, Scott 2006); because the additional species found in the 2011 resurvey occurred in such low numbers, it is possible that these additional species could have been missed in the 2006 survey. Less easily explained is the finding that Redbreast Sunfish and Smallmouth Bass were both *Uncommon* (less than 5% of the overall community) in 2006 but were found *Common* (greater than 5% of the overall community) in the resurvey (Table 1).

In general, species diversity decreased from the 2006 survey to the 2011 resurvey. Simpson's Diversity Index (1-D) shows a decrease in overall fish diversity on KIMO from 0.81874 in 2006 to 0.74042 in 2011 (Table 1). When considering each stream seperately, the same overall trend was found with the exceptions of Garner Branch and Stonehouse Creek, which increased slightly (Table 2). Although there was an increase in species richness (more species were found) in Dellingham Branch in 2011, there were few individuals of those species, yeilding a lower species diversity index in 2011 (Table 2, Figure 1). Long Branch is the longest stream on KIMO property and had high diversity in each survey year, however, Kings Creek is the shortest stream on KIMO property and also had high diversity; when comparing all streams, stream length was not useful for predicting relative abundance, species richness, diversity or commonness of species (linear regression all $P > 0.1$).

Another general trend that speaks to the loss of diversity is that rare fish in 2006 (*Uncommon* species) became more rare in 2011 (after the drought that occurred between the survey years). In 2006, 14 of the 19 species found in the survey were *Uncommon* species (Table 1) with an average across streams of 13.48% of the fish caught being *Uncommon* species (Table 3). In 2011, 12 of the 18 species were *Uncommon* (about the same percentage), but there were far fewer rare fish species found in 2011 – an average across streams of only 3.96% of the fish community being *Uncommon* species (Table 1, Table 3).

In both surveys, *Uncommon* species were found in significantly wider streams (2006, $P < 0.0001$; 2011, $P = 0.0002$) and in streams with higher (closer to neutral) pH (2006, $P < 0.0001$; 2011, $P = 0.0081$) (Table 5). *Uncommon* fish were also found in warmer water in 2006 ($P < 0.0001$) though this difference was not found in 2011 ($P = 0.8354$) (Table 5). It is likely that *Uncommon* species are found in wider streams more often because these streams offer more complex microhabitats (Gorman & Karr 1978, Foltz 1982, Schlosser 1982, Heithaus & Grame 1997) which tend to promote greater species diversity (Tramer & Rogers 1973, Gorman & Karr 1978, Foltz 1982, Angermeier 1987). In fact, though our data collection was not designed specifically to test this hypothesis, the only stream that was found narrower in 2011, Kings Creek (Table 4), saw the greatest decline in diversity (Table 2) and greatest loss in percentage of *Uncommon* fish (Table 3); Additionally, the stream that increased in mean width the most in 2011, Dellingham Branch (Table 4), was one of the only streams that increased in diversity (Table 2) and percentage of *Uncommon* fish (Table 3).

The loss of diversity between the two surveys may be due to stress brought about by the drought that occurred between the survey periods. Between 2006 and 2009, this region had been repeatedly under the most severe drought conditions and the warmest average temperatures on record (NCDM 2008). While mean water temperature was significantly warmer ($P < 0.0001$) and mean pH was significantly lower ($P < 0.0001$) (Table 4) in the resurvey, the differences seen between these serveys may not be direct consequences still remaining as a result of the 2006-2009 drought. Rather, these differences could be a product of normal inter-annual differences and/or due to the resurvey being conducted in June and July, a month later into summer than the 2006 survey. Rather, the overall reduction in species diversity is likely a result of the severe conditions that occurred during the drought; the drought put stress ‘hurdles’ in place that not all individuals could pass.

When looking at the range of temperature and pH values where individuals of different species were found, an important, but not necessarily suprising observation can be made. *Common* fish species were found in a significantly wider range of conditions than *Uncommon* fish (temperature $P = 0.0005$, pH $P = 0.0134$; Table 6). Similarly, when comparing the relative fate of fish species across the drought (between the 2006 & 2011 surveys), a difference was found where those species that did better (became more abundant) were found in a significantly greater range of temperature and pH variables than those that became absent from the survey (P

< 0.05; Table 7). While significant differences were not found between each pair of success classes, a general trend was found where relative success of a species between surveys was related to the average range of values where the fish were found (MORE > SAME > LOWER > LOST; Table 7). In general, fish species that were found in a wider temperature range and pH levels were more likely to be *Common* fish species and had greater success between surveys than fish species found in a narrower range of conditions (Table 6, Table 7). Because *Uncommon* fish species were generally found in a lower range of environmental parameters (temperature and pH) than *Common* fish species, it is likely that the observed loss of species diversity is the result of severe and prolonged drought conditions that occurred between the two surveys.

Of particular interest in this study was the fate of Carolina Darters. Already an extremely rare fish on KIMO (and of highest conservation priority), we were concerned that the species might become extirpated, or at least be in numbers so low as to not find any in the resurvey. As it turned out, because we encountered this species so often, we were able to characterize commonalities in the locations it was found and develop a microhabitat attribute description for this species. As others have noted, we found this fish in pools about half a meter deep, usually occurring at bends in the creek immediately downstream of runs with higher current velocity (Lee et al. 1980, Burkhead & Jenkins 1991, Jenkins & Burkhead 1994). Substrate was usually small pebbles and sand with detritus buildup and the area had moderate ambient light (neither fully exposed nor fully shadowed by bank tree foliage).

In each case, this species was found in an area where a group of sticks, brush, or fallen limbs had gathered, collecting leaves and other organic debris. Also in every case, the stick-and-debris complex was partly submerged but also extended out of the water and always located at a bend severe enough to accumulate sticks and debris or else in an area where a small tree fell over the correct substrate type, lighting conditions, water velocity and depth. If an area lacked any of these features, we failed to find this species. We also found one individual Carolina Darter in Stonehouse Creek under the same descriptive conditions.

Carolina Darters found in the 2011 resurvey were found in water with moderate pH (mean pH: 5.52 ± 0.280) and relatively warm water (mean temperature: 23.48 ± 0.529 C°) compared to the overall averages (2006 mean pH: 6.91 ± 0.018, mean temperature: 18.41 ± 0.043 C°; 2011 mean pH: 5.36 ± 0.028, mean temperature: 22.45 ± 0.055 C°). It is important to note that the temperature range (6.90 C°) and pH range (2.36) that Carolina Darters were found were relatively high, especially considering this is an *Uncommon* species (compare to Table 6 and Table 7). If these findings could serve to adequately and reliably describe this species' tolerances, and if the specific microhabitat conditions are adequate descriptors of Carolina Darter habitat requirements, it could be concluded that this species is relatively robust in its water temperature and pH range tolerability, and are limited more by the specific suite of requirements involved in making a suitable microhabitat complex.

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Literature Cited

Angermeier, P.L. 1987. Spatiotemporal Variation in Habitat Selection by Fishes in Small Illinois Streams. In (W. Mathews and Heins D, ed.) Community and Evolutionary Ecology of North American Stream Fishes. Univ Oklahoma Press. Norman, OK.

Angermeier, P.L., and R.A. Smogor. 1995. Estimating Number of Species and Relative Abundances in Stream-fish Communities: Effects of Sampling Effort and Discontinuous Spatial Distributions. *Can. J. Fish. Aquat. Sci*. 52:936-949.

Burkhead, N. M., and R.E. Jenkins. 1991. Fishes. In (K. Terwilliger, coordinator) Virginia's Endangered Species: Proceedings of a Symposium. McDonald and Woodward Publishing Company, Blacksburg, Virginia.

Foltz, J.W. 1982. Fish Species Diversity and Abundance in Relation to Stream Habitat Characteristics. *Proceedings of the Annual Conference of Southeast Association of Fish and Wildlife Agencies* 36:305-311.

Gorman, O.T. and J.R. Karr. 1978. Habitat Structure and Stream Fish Communities. *Ecology* 59: 507-515.

Heithaus, M.R. and C. Grame. 1997. Fish Communities of the Vermilion River Watershed: Comparison of the Main Channel and Tributaries. *Ohio Journal of Science* 97(5) 98-102.

Hubbs, C.L. and M.D. Cannon. 1935. The Darters of the Genera *Hololepis* and *Villora*. *Misc. Publications of the Museum of Zoology* University of Michigan (30): 1-93.

Jenkins, R.E and N.M. Burkhead. 1994. Freshwater Fishes of Virginia. American Fisheries Society. Bethesda, Maryland.

Krebs, C.J. 1989. Ecological Methodology. New York: Harper Collins Publishers.

Krebs, C.J. 2008. The Ecological World View. University of California Press, Berkeley, CA.

Kuehne, R.A., and R.W. Barbour. 1983. The American Darters. University Press of Kentucky. Lexington, Kentucky.

Lande, R, P.J. DeVries, and T. Walla 2000. When Species Accumulation Curves Intersect: Implications for Ranking Diversity Using Small Samples. *Oikos* 76, 5-13.

Lee, D.S., C.R. Gilbert, C.H. Hocutt, R.E. Jenkins, D.E. McAllister, and J.R. Stauffer, Jr. 1980. Atlas of North American Freshwater Fishes. North Carolina State Museum of Natural History. Raleigh, North Carolina.

Magurran, A.E. 2011. Measuring Biological Diversity. Blackwell Publishing. Malden, MA.

May, R.M. 1975. Patterns of Species Abundance. In (M.L. Cody and Diamond, J.M, ed.) Diversity in Ecology and Evolution of Communities. Harvard Univ. Press. Cambridge, MA.

Meiman, J. 2005. Water Quality Monitoring Protocol Cumberland Piedmont Network, National Park Service, Mammoth Cave, KY.

NatureServe. 2010. NatureServe Explorer: Online Encyclopedia of Life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available www.natureserve.org/explorer/servlet/NatureServe?searchName=Etheostoma+collis

NCDM 2008. North Carolina Drought Management Advisory Council Activities Report, December, 2008. North Carolina Division of Water Resources, Department of Environment and Natural Resources. Available http://www.ncdrought.org/documents/2008_annual_report.pdf

Page, L.M. and B.M. Burr. 1991. A Field Guide to Freshwater Fishes of North America North of Mexico. Houghton Mifflin Company. Boston, MA.

Reid, G.K. 1961. The Ecology of Inland Waters and Estuaries. Reinhold Publishing. NY, NY.

Rhodes, R.J., W.J. Keith, P. Eldridge and V.G. Burrell, Jr. 1977. An Empirical Evaluation of the Leslie-Delury Method to Estimating Hard Clam, *Mercenaria mercenaria*, Abundance in the Santee River Estuary, *South Carolina. Proc. Natl. Shellf. Assoc*. 67:44-52.

Rohde, F.C., R.G. Arndt, D.G. Lindquist and J.F. Parnell. 1994. Freshwater Fishes of the Carolinas, Virginia, Maryland, and Delaware. University of NC Press. Chapel Hill, NC.

SCDNR 2005. The 2005 Comprehensive Wildlife Conservation Strategy, South Carolina Department of Natural Resources, Available http://www.dnr.sc.gov/cwcs/plan/Chapter2.pdf

Schlosser, I.J. 1982. Fish Community Structure and Function Along two Habitat Gradients in a Headwater Stream. *Ecol. Monogr*. 52:395-414.

Scott, Mark C. November, 2006. Inventory of Fishes in Kings Mountain National Military Park. National Park Service, Kings Mountain National Park.

Shelford, V.E. 1911. Physiological Animal Geography. *Journal of Morphology* 22:551-618.

Tramer, E.J. and P.M. Rogers. 1973. Diversity and Longitudinal Zonation in Fish Populations of Two Streams Entering a Metropolitan Area. *Amer. Mid. Nat*. 90: 366-374.

Warren, M.L. Jr., B.M. Burr, S.J. Walsh, H.L. Bart Jr., R.C. Cashner, D.A. Etnier, B.J. Freeman, B.R. Kuhajda, R.L. Mayden, H.W. Robison, S.T. Ross, and W.C. Starnes. 2000. Diversity, Distribution, and Conservation Status of the Native Freshwater Fishes of the Southern United States. *Fisheries* 25(10):7-31.

Appendix I: Tables

Species	Common Name	2006 Count	2006 %	2011 Count	2011 %	State Conservation Status	2006 / 2011
Ameiurus platycephalus	Flat Bullhead	1	0.075	0	0	Moderate	Uncommon/Absent
Catostomus commersoni	White Sucker	5	0.377	4	0.360		Uncommon/Uncommon
Clinostomus funduloides	Rosyside Dace	359	27.033	499	44.914		Common/Common
Cyprinella chloristia	Greenfin Shiner	4	0.301	1	0.090	Moderate	Uncommon/Uncommon
Etheostoma collis	Carolina Darter	1	0.075	12	1.080	Highest (High)	Uncommon/Uncommon
Etheostoma flabellare	Carolina Fantail Darter	11	0.828	1	0.090	High	Uncommon/Uncommon
Etheostoma olmstedi	Tessellated Darter	26	1.958	0	0		Uncommon/Absent
Etheostoma thalassinum	Seagreen Darter	6	0.452	0	0	High	Uncommon/Absent
Hybopsis hypsinotus	Highback Chub	79	5.949	1	0.090	Moderate	Common/Uncommon
Hypentelium nigricans	Northern Hogsucker	17	1.280	6	0.540		Uncommon/Uncommon
Lepomis auritus	Redbreast Sunfish	64	4.819	100	9.001		Uncommon/Common
Lepomis macrochirus	Bluegill	2	0.151	9	0.810		Uncommon/Uncommon
Micropterus dolomieui	Smallmouth Bass	1	0.075	76	6.841		Uncommon/Common
Nocomis leptocephalus	Bluehead Chub	296	22.289	167*	15.024*		Common/Common
Notropis leuciodus	Tennessee Shiner	0	0	3	0.270	Moderate	Absent/Uncommon
Notropis lutipinnis	Yellowfin Shiner	158	11.898	80	7.201		Common/Common
Notropis photogenis	Silver Shiner	0	0	1	0.090		Absent/Uncommon
Notropis procne	Swallowtail Shiner	0	0	1	0.090		Absent/Uncommon
Notropis scepticus	Sandbar Shiner	21	1.581	1	0.090		Uncommon/Uncommon
Noturus insignis	Margined Madtom	11	0.828	4	0.360		Uncommon/Uncommon
Scartomyzon rupiscartes	Striped Jumprock	9	0.678	0	0		Uncommon/Absent
Semotilus atromaculatus	Creek Chub	257	19.352	145*	13.050*		Common/Common

Table 1. Species occurrence data from all KIMO streams surveyed, comparing 2006 survey findings to 2011 survey findings.
2006 Total: 19 Species, 1,328 individuals; Simpson's Diversity Index (1-D): 0.81874.
2011 Total: 18 Species, 1,111 individuals; Simpson's Diversity Index (1-D): 0.74042.
* Creek Chub and Bluehead Chub could not be differentiated in the field outside of breeding season (during the 2011 resurvey). Species assignment of fish from this group in the resurvey is based on relative abundance of these two species during breeding season,: 312 individuals found were either Bluehead Chub or Creek Chub, thus giving 167 Bluehead Chub and 145 Creek Chub (53.5% Bluehead Chub / 46.5% Creek Chub).

These are priority levels according to chapter 2 of South Carolina’s Comprehensive Wildlife Conservation Strategy. Is this list dated, and does Mark’s priority “Highest” reflect more current data?

Species	Common Name	Dellingham '06	Dellingham '11	Garner '06	Garner '11	Kings '06	Kings '11	Long '06	Long Branch '11	Stonehouse '06	Stonehouse '11
Ameiurus platycephalus	Flat Bullhead					1/0.3%					
Catostomus commersoni	White Sucker					5/1.6%			4/0.8%		
Clinostomus funduloides	Rosyside Dace	36/45%	148/71%	55/50%	48/37.7%	47/15%	8/13.5%	213/29%	214/42%	8/8%	81/38%
Cyprinella chloristia	Greenfin Shiner					4/1.3%	1/1.7%				
Etheostoma collis	Carolina Darter							1/0.1%	11/2%		1/0.5%
Etheostoma flabellare	Car. Fantail Darter			1/1%	1/0.7%	5/1.6%		1/0.1%		4/4%	
Etheostoma olmstedi	Tessellated Darter					12/4%		14/1.9%			
Etheostoma thalassinum	Seagreen Darter					6/1.9%					
Hybopsis hypsinotus	Highback Chub			1/1%		4/1.3%		74/10%	1/0.2%		
Hypentelium nigricans	Northern Hogsucker					17/5.5%	3/5%		3/0.6%		
Lepomis auritus	Redbreast Sunfish		1/0.4%	1/1%	2/1.5%	34/11%	7/11.8%	29/4%	71/14%		19/9%
Lepomis macrochirus	Bluegill		6/2.9%			2/0.6%			2/0.4%		1/0.5%
Micropterus dolomieui	Smallmouth Bass		13/6.3%			1/0.3%			51/10%		12/5.7%
Nocomis leptocephalus	Bluehead Chub	1/1%	17/8%	12/11%	40/31.5%	82/26.7%	19/32.6%	158/21%	55/11%	43/44%	35/17%
Notropis leuciodus	Tennessee Shiner		3/1.4%								
Notropis lutipinnis	Yellowfin Shiner		4/1.9%	9/8%	1/0.7%	20/6.5%		94/12.8%	43/8.5%	35/36%	32/15%
Notropis photogenis	Silver Shiner						1/1.7%				
Notropis procne	Swallowtail Shiner						1/1.7%				
Notropis scepticus	Sandbar Shiner					21/6.8%	1/1.7%				
Noturus insignis	Margined Madtom					7/2.3%	1/1.7%	4/0.5%	3/0.6%		
Scartomyzon rupiscartes	Striped Jumprock			4/4%				5/0.7%			
Semotilus atromaculatus	Creek Chub	43/54%	15/7%	26/24%	35/27.5%	39/12.7%	17/28.4%	141/19%	49/9.5%	8/8%	30/14%
	Simpson's (1-D)	**0.5084**	**0.4714**	**0.6679**	**0.6816**	**0.8615**	**0.7768**	**0.8039**	**0.7632**	**0.6649**	**0.7705**
	Stream length (m)		**2,712**		**5,883**		**1,197**		**7,400**		**4,859**

Table 2. Species occurrence, by number and percent, broken down by stream for each survey (2006 survey data from Scott 2006) and Simpson Diversity Index (1-D) for each stream in each survey.

Watershed	2006 % Uncommon	2011 % Uncommon
Stonehouse	**4.08**	**0.95**
Long	**7.36**	**4.73**
Kings	**37.46**	**13.55**
Garner	**5.50**	**0.78**
Dellingham	**0**	**4.35**
Average	*13.48*	*3.96*

Table 3. Percentage of fish from *Uncommon* species in each stream.

Stream Parameter	Dellingham '06	Dellingham '11	Garner '06	Garner '11	Kings '06	Kings '11	Long '06	Long '11	Stonehouse '06	Stonehouse '11
Mean Depth (cm)		8.97		20.3		13.0		22.18		24.11
Mean Width (m)	1.8	3.29	1.5	2.0	4.65	2.0	2.83	4.25	1.70	1.9
Clarity		1		1		3		1.21		1.03
Mean pH	5.54	5.87	7.29	5.32	7.18	6.52	7.02	4.97	5.98	5.66
Mean Temp. (C°)	16.25	18.9	19.80	20.30	19.57	22.3	18.21	23.66	16.54	20.1

Table 4. Stream parameters (2006 data from Scott 2006).

Stream Parameter	2006 Common	2006 Uncommon	P value	2011 Common	2011 Uncommon	P value
Mean Depth (cm)				20.97	17.88	0.4811
Mean Width (m)	2.71	4.79	<0.0001	3.23	4.14	0.0002
Mean pH	6.83	7.40	<0.0001	5.35	5.74	0.0081
Mean Temp. (C°)	18.19	19.82	<0.0001	22.46	22.39	0.8354

Table 5. Mean stream parameters for *Common* and *Uncommon* fish species for both survey years (2006 data from Scott 2006).

Mean Temp Range for *Common* and *Uncommon* Species

Level	Number	Mean Range C°	Std Error	
Common	6	7.51000	0.71294	
Uncommon	11	3.57182	0.52654	P = 0.0005

Mean pH Range for *Common* and *Uncommon* Species

Level	Number	Mean Range pH	Std Error	
Common	6	3.22833	0.40401	
Uncommon	11	1.82000	0.29838	P = 0.0134

Table 6. Comparison of Temperature and pH range between *Common* and *Uncommon* species. Only species with repeated measures used. Student's T-test.

Level			Temp Range	Std Error
MORE	A		6.9033333	1.3385
SAME	A	B	5.4822222	0.7728
LOWER	A	B	3.1350000	1.6393
LOST		B	2.6766667	1.3385

Level			pH Range	Std Error
MORE	A		3.1066667	0.56776
SAME	A		2.6433333	0.32779
LOWER	A	B	1.8950000	0.69536
LOST		B	0.8300000	0.56776

Table 7. Mean temperature range and pH range of species groups that were *Uncommon* in 2006 and became *Common* in 2011 (MORE), species that showed relatively little change in relative abundance between surveys (SAME), species that were *Common* in 2006 but became *Uncommon* in 2011 (LOWER) and species that were present in 2006 but absent in 2011 (LOST). Only species with multiple readings are used. Levels not connected by same letter are significantly different, Student's T-test ($P<0.05$).

Appendix II: Figures

2006 Distribution by Stream **2011 Distribution by Stream**

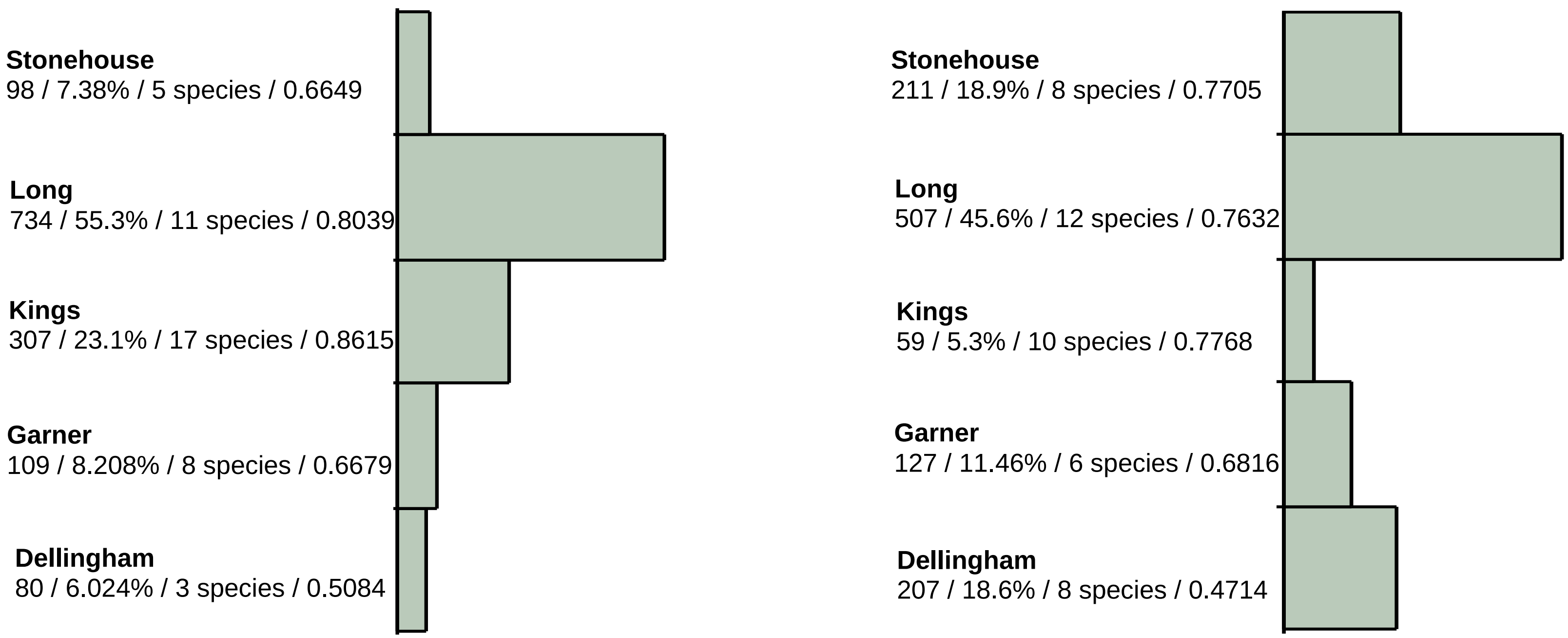

Figure 1. Comparison of Pre-Drought and Post-Drought Fish Surveys. Number of individual fish per stream / Percent of the total fish found in the stream / Number of species found in the stream / Simpson Diversity Index (1-D). Bars represent fish numbers per stream.