Southeastern Fishes Council Proceedings

Volume 1
Number 56 *Number 56*

Article 1

October 2016

Intensive, Regular Sampling and Removal of Modest Numbers of Fishes Shows No Measurable Impact on Fish Populations in Three Streams of North Georgia

Steven L. Powers
Roanoke College, powers@roanoke.edu

Intensive, Regular Sampling and Removal of Modest Numbers of Fishes Shows No Measurable Impact on Fish Populations in Three Streams of North Georgia

Abstract

Recent publications and restrictions on collecting by state fish and game managers indicate a growing concern regarding the impact of field sampling on native fish populations. To evaluate the validity of these concerns, data from five life-history studies conducted in Cherokee County, Georgia were examined to test the hypothesis that regular sampling has a negative impact on fish populations. Number of individuals collected was divided by time collecting to calculate catch per unit effort (CPUE) as an indicator of relative abundance for each species. The collecting sequence (i.e. the number of times a species had previously been sampled) was regressed against CPUE for each of the five species. Despite monthly electrofishing and removing up to hundreds of individuals of each species, there was no significant relationship between CPUE and the collecting sequence (r^2 = 0.1%, P = 0.82). Only one species, the imperiled *Etheostoma scotti,* Cherokee Darter, showed a negative correlation (-0.1) between CPUE and collecting sequence, but the association was weak (r^2= 0.1%) and not significant (P = 0.76). These data suggest that even intensive, regular sampling and removal of modest numbers of individuals from the same reach of a small stream (< 10 m wide) had no measurable long-term impact on stream fish populations. Therefore, concerns regarding of the impact of collectors on stream fish populations may not be consistent with the actual impact of collectors.

Keywords

electroshocking, endangered species, Etheostoma scotti

Cover Page Footnote

I would like to thank S.D. Barton, K.M. Edberg, D.S. Holder, D.M. Jolly, and C.T. O'Kelley for assistance with field work for this project. Thanks also to Reinhardt College for equipment used during field work for this project. All fishes were collected under Georgia Scientific Collecting number 16494 and US Fish and Wildlife Service Federal Fish and Wildlife Permit number TE136747-0 issued to S.L. Powers.

INTRODUCTION

Recent research, discussions within the ichthyology and fisheries communities, and increased restrictions on field work by state fish and game agencies indicate a growing concern regarding the impact of field sampling on native fishes. Sampling methods such as snorkel surveys, video analyses, and fin clipping released fishes for tissues to be used in genetic analyses are often seen as more desirable methods as they are less intrusive than methods like electrofishing and retaining voucher specimens (George et al. 2006, Thurow et al. 2006, Roberts 2011, Ellender et al. 2012). In recent years, several state fish and game agencies have increased restrictions on fish sampling by biologists by restricting collections in streams containing imperiled species (personal observation, B.R. Kuhajda, personal communication). While increased restrictions on sampling are clearly well intended attempts to minimize threats to native fishes, all management strategies should be based on empirical research to ensure their effectiveness. A major concern that has initiated investigation is the impact of electrofishing. Injuries and mortality of fishes following exposure to electrical current is well documented in recent literature (Bohl et al. 2009, Clément and Cunjak 2010, Miranda and Kidwell 2010, Janáč and Jurajda 2011). However, lab controlled experiments such as those performed by Bohl et al. (2009) in which fish embryos in 1L pans were exposed to electrical current for 20 seconds are unlikely representations of actual field use of electrofishing equipment. Electrofishing units are rarely held stationary for more than a few seconds and are generally moved upstream during field work prohibiting exposures like those in Bohl et al. (2009). The documentation of mortality and injury in fishes collected from streams using electrofishing by Clément and Cunjak (2010) and Janáč and Jurajda (2011) is a more realistic assessment of the impacts of electrofishing, but as it exclusively examines fishes collected by electrofishing, it inherently biases the samples due to ignoring all the fishes in a population not coming in contact with the electrical field. As effective conservation requires the long-term persistence and proliferation of a population, long-term investigations of the impacts of electrofishing on populations are likely to provide more useful information to managers and field researchers than lab experiments or analyses of single electrofishing events. Despite the utility of long-term studies examining the impacts of electrofishing on a population over many generations, such studies are wanting. Miranda and Kidwell (2010) noted the lack of empirical research on the long-term impacts of electrofishing on populations of fishes and suggested such a study be undertaken to guide the use of electrofishing in streams with imperiled species of nongame fishes.

Not only are studies investigating the impacts of electrofishing on populations wanting, few investigations have demonstrated long-term negative

impacts of scientific collecting on populations of non-game fishes. Several studies have demonstrated essentially indistinguishable fish communities before and after complete defaunation of stream reaches (Charles 1957, Meffe and Sheldon 1990, Sheldon and Meffe 1995). To the contrary, empirical studies attributing the decline of populations of fishes due to habitat degradation are extensive (Weaver and Garman 1994, Anderson et al. 1995, Onorato et al. 2000). With widespread habitat alteration for stream fishes, anecdotal accounts of collector impacts, unrealistic lab experiments and samples unrepresentative of populations provide a poor foundation for policies regarding field work. Furthermore, it is nearly impossible to tease out any impacts of research sampling from those due to long-term habitat degradation. This is especially true in large streams with a variety of impacts upstream of sampling sites. Investigations of collector impacts, therefore, would be most useful conducted over relatively short time periods in small streams in order to reduce impacts of human activity upstream and changes in watersheds over decades. If electrofishing and regular removal of specimens from streams negatively impacts fish populations, then we should see measurable declines in fish populations in areas that are intensively sampled repeatedly. To test the hypothesis that electrofishing and removal of large numbers of specimens will negatively impact populations, data from five life-history studies conducted in Cherokee County, Georgia were examined. The five species used in this study represent a wide variety of taxa, life-history strategies, and relative abundances. One species, *Etheostoma scotti* (Cherokee Darter), is also protected by the United States Fish and Wildlife Service as a "threatened" species under the Endangered Species Act.

METHODS

Study Sites

The study areas encompassed Shoal and Moore creeks upstream of their confluence (34.3240°N, 84.5636°W), near Waleska and Hickory Log Creek at Fate Conn Road (34.2930°N, 84.4650°W), near Canton in Cherokee County, Georgia (Figure 1). Shoal Creek is an upland fourth order tributary of the Etowah River like many streams in this area. Near the mouth of Moore Creek, Shoal Creek is between 5.3 and 9.8 m wide and less than 1.5 m deep at normal flows. Substrate is primarily gravel to cobble with sporadic bedrock in riffles, gravel to sand in runs, and sand and silt in pools. Moore Creek is a second order stream at its mouth between 3.1 and 6.4 m wide and less than 1.0 m deep at normal flows. Substrate is similar to that of Shoal Creek. Hickory Log Creek is an upland second-order tributary of the Etowah River between 2.9 and 6.1 m wide and less than 1.0 m deep at normal flows. Substrate is primarily gravel to cobble in riffles, gravel to sand in runs, and sand and silt in pools. Upstream of the study area, the Hickory Log Creek watershed is mostly forested with moderate residential development. Species richness of fishes

within the study reaches is relatively high with 34 species (32 native) representing nine different families collected during this study (see O'Kelley and Powers, 2007 for complete list). *Hypentelium etowanum* (Alabama Hogsucker) was collected from Shoal and Moore creeks. *Notropis xaenocephalus* (Coosa Shiner), *Notropis chrosomus* (Rainbow Shiner), *Fundulus stellifer* (Southern Studfish), and "captured-and-released" data for *E. scotti* were collected from Moore Creek. *Etheostoma scotti* "kill" data were collected from Hickory Log Creek.

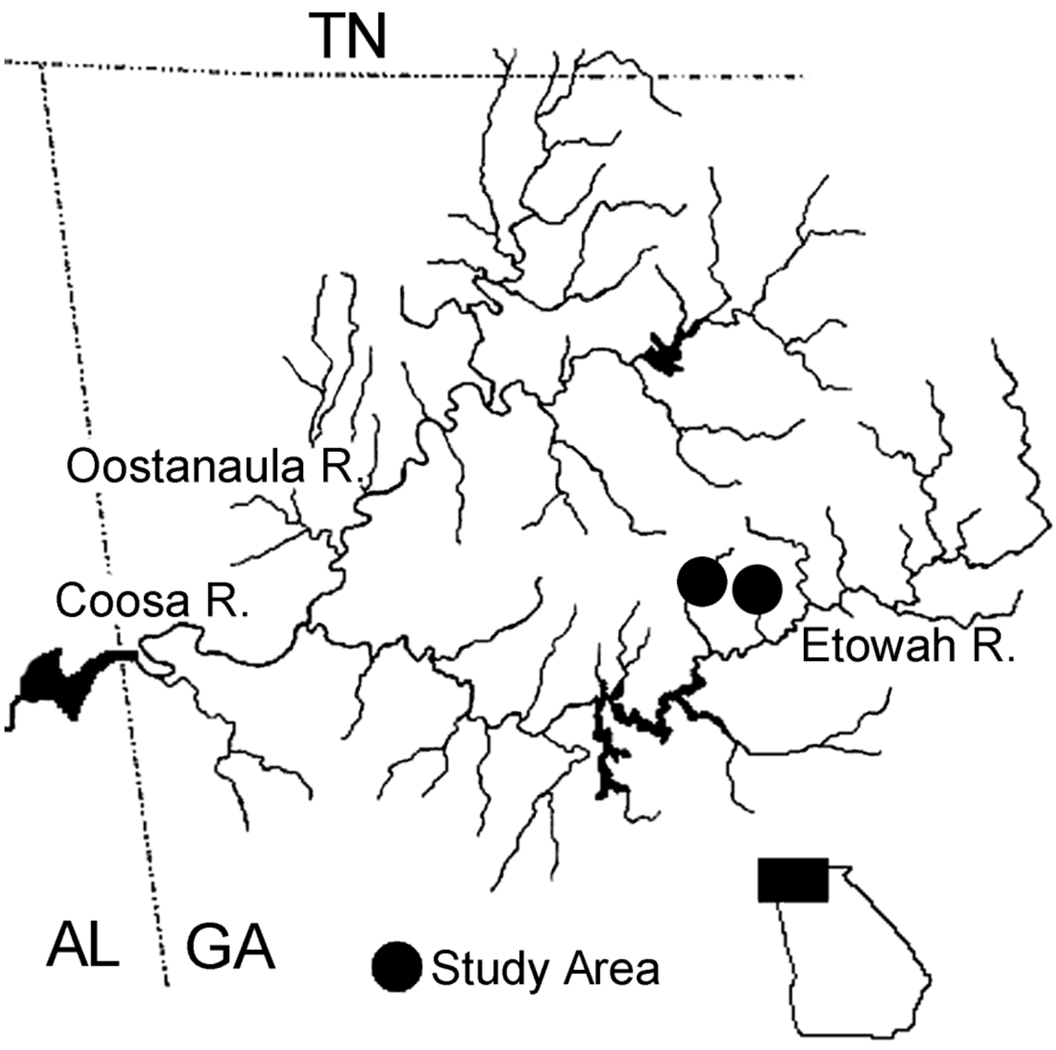

Figure 1. Localities from which fishes were collected in Shoal and Moore creeks upstream of their confluence (34.3240ºN, 84.5636ºW), near Waleska and Hickory Log Creek at Fate Conn Road (34.2930ºN, 84.4650ºW), near Canton in Cherokee County, Georgia from August 2004 to January 2008.

Field Collection and Data Analysis

Fishes were collected by monthly sampling during the following periods: *H. etowanum* and *N. xaenocephalus* from August 2004 to July 2005; *N. chrosomus* from January to December 2006; *F. stellifer* from February 2006 to January 2007; and *E. scotti* from February 2007 to January 2008. Captured-and-released data for *E. scotti* was recorded throughout the collection of *H. etowanum*, *N. xaenocephalus*, *N. chrosomus*, and *F. stellifer*. Collections were made during daylight hours near the end of each month using a 3.3m x 1.3m seine and a Smith-Root model 24 backpack electrofisher and retained specimens were accessioned into the University of Alabama Ichthyological Collection (UAIC). A total of 184 *H. etowanum* (UAIC 14729-14740), 305 *N. xaenocephalus* (UAIC 14729-14740) , 200 *N. chrosomus* (UAIC 15027-15038), 240 *F. stellifer* (UAIC 15028-15039), 226 *E. scotti* (UAIC 15015-15026) were collected, preserved in 10% formalin, rinsed with water, and transferred into 70% EtOH for long term storage. A total of 253 Cherokee Darters were captured and released from Moore Creek. Number of individuals collected each month was recorded as was the time spent collecting. Number of individuals collected was divided by minutes spent collecting to calculate catch per unit effort (CPUE) as an indicator of relative abundance for each species. A value for "collecting sequence" was assigned as the number of times a species had previously been sampled (e.g. the first month's collection for a particular species was assigned a one, the second month for a particular species was assigned a two, etc.). For captured-and-released *E. scotti* from Moore Creek, the collecting sequence value of the species being targeted when they were collected was recorded. Collecting sequence was regressed against CPUE for each species and collectively. Pearson product moment correlations between collecting sequence and CPUE were also calculated. All statistical analyses were performed using Data Desk 6.0 (Data Description, Inc., Ithaca, NY) with alpha equal to 0.05.

RESULTS

The data from all species analyzed together (Figure 2), showed a low correlation (0.031) and no significant relationship between combined CPUE and the collecting sequence (r^2 = 0.1%, P = 0.82). For data analyzed separately for each species, the only species to show a negative correlation (-0.10) between collecting sequence and CPUE was *E. scotti*, but this relationship also was not significant (r^2 = 1.0%, P = 0.76). The greatest correlation (0.653) between collecting sequence and CPUE was for *H. etowanum*, but this relationship was not significant (r^2 = 42.6%, P = 0.16). *Fundulus stellifer* and captured-and-released *E. scotti* showed moderate correlations (0.475 and 0.452, respectively) between collecting sequence and CPUE, but these relationships were not significant (r^2 = 22.6%, P = 0.16; r^2 = 20.4%, P = 0.12, respectively). *Notropis chrosomus* showed a low correlation

(0.197) between collecting sequence and CPUE and no significant relationship (r^2 = 3.9%, P = 0.58). *Notropis xaenocephalus* showed the lowest correlation (0.062) of any single species between collecting sequence and CPUE and no significant relationship (r^2 = 0.4%, P = 0.92).

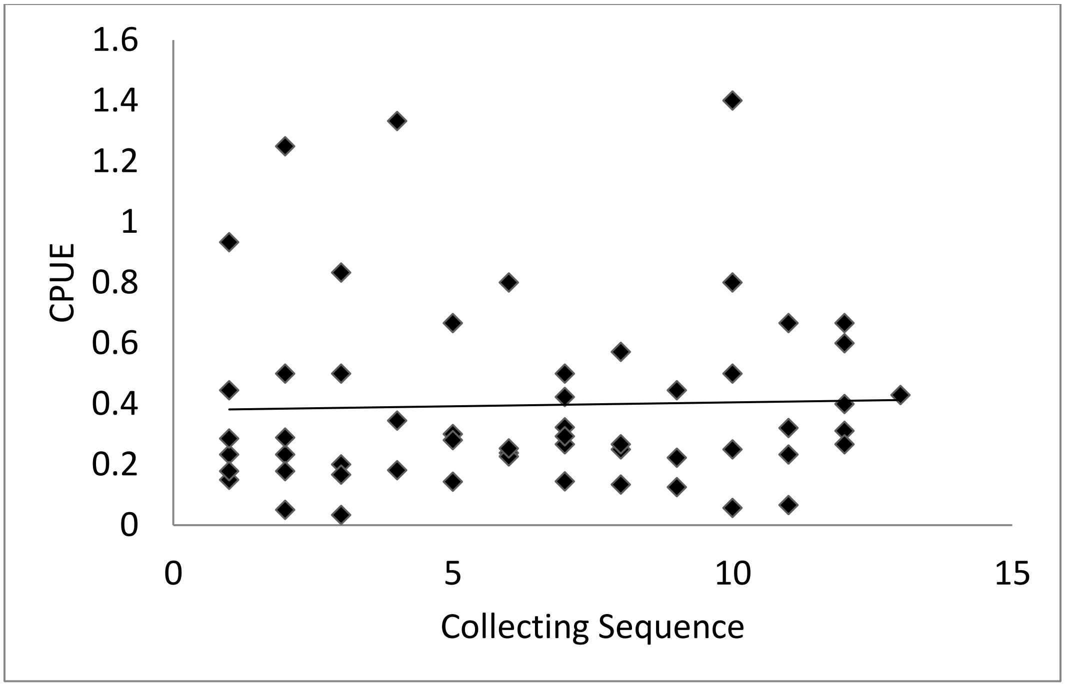

Figure 2. Catch per unit effort (CPUE) of five species collected between August 2004 and January 2008 plotted over the number of times that species had previously been sampled (Collecting Sequence).

DISCUSSION

These analyses suggest that repeated removal of modest numbers of non-imperiled species has little impact on their populations. This may be explained by considering the number of individuals removed during sampling within the context of the life-history and abundance of stream fishes. In a study of the life-history of the Snubnose Darter, *Etheostoma simoterum* complex, Page and Mayden (1981) reported a density of 5.38 individuals per m^2 of bedrock pool habitat. Powers and Mayden (2007) extrapolated this estimate across available habitat nearby and suggested more than 50,000 individuals in a single km of stream and noted instances of hundreds of individuals in collections sampling only 50 m of linear habitat from nearby streams. For the species examined directly in this study, removing between 184 and 305 individuals of each species initially appears to represent a large number of individuals. However, a single female of each of these

species may produce more than that number of eggs in a single spawning season (O'Kelley and Powers 2007, Jolly and Powers 2008, Barton and Powers 2010, Edberg and Powers 2010, Holder and Powers 2010). The reproductive potential of most fishes is high, making them able to replenish depleted populations rapidly providing the foundation for the management of fisheries for decades (Beverton and Holt 1957). This reproductive potential is apparent in their rapid recolonization and repopulation of streams following droughts (Larimore et al. 1959) and experimental eradication (Charles 1957). The data presented herein, did not however, suggest that the number of specimens being removed depleted populations to the point where this high reproductive potential was being tapped. For each species, sampling occurred within a single year. This did not allow for an increased survival of young-of-the-year specimens to contribute substantially to our calculations of CPUE as most small fishes (<25 mm SL) pass through the holes in the nets used to collect them (O'Kelley and Powers 2007, Jolly and Powers 2008, Barton and Powers 2010, Edberg and Powers 2010 Holder and Powers 2010). Rather, the sampling in this study appears to be removing such a small proportion of the fishes in the stream throughout the duration of the study, that depletion of these natural populations was undetectable.

There is also a long history of research that shows little long-term differences following defaunation of stream reaches. Experimentally depleted short reaches of coastal plain streams were statistically indistinguishable from control reaches within a matter of days (Meffe and Sheldon 1990, Sheldon and Meffe 1995). More large-scale efforts to experimentally manipulate fish assemblages by eradication of fishes from over 100 km of streams in Kentucky with rotenone proved equally ineffective at having long-term impacts on these assemblages (Charles 1957). During the current study, there was never an attempt to completely defaunate the stream. Rather, samples large enough to provide some level of statistical confidence in data were removed monthly for detailed life-history studies. Therefore, the simplest explanation of the lack of relationship between collection sequence and CPUE is that such a low proportion of the population was removed with each collection, it was undetectable. Perhaps the clearest illustration of how ineffective conventional collecting methods are is presented by Larimore (1961) in an attempted experimental census of a small Illinois stream using an electric seine. Electric seines produce a field of electricity nearly 10 m wide with anodes spaced less than 1m moving continuously downstream. This electric seine sampling would be comparable to 10 backpack electrofishers working side by side. Despite this intense effort in a stream less than 8m wide, Larimore (1961) collected only 51% of the fish within the experimental reach with shiners, darters and madtoms showing some of the lowest capture rates. As collections rarely target every square meter of stream within a collecting reach, the proportion of fish within

a given reach actually collected by researchers is likely to be very small. Larimore (1961) estimated that 100 square yards of shallow water stream habitat contained 513 fish, and deep water stream habitat contained 324 fish for the same area. This area represents less than a 10 m reach of a stream approximately 10 m wide. As this width would be typical of a fourth order stream, an extrapolation of these estimates would suggest tens of thousands of fish per river km in such habitats. Therefore, even the removal of hundreds of individuals would not represent a large proportion of a fishes in a stream.

Repeated removal of modest numbers of individuals of *E. scotti*, an imperiled species, also appears to have no measurable impact on its population size. This also is not surprising due to most imperiled fishes being narrowly endemic species with relatively high fecundity and annual mortality rates threatened primarily by habitat degradation (Warren et al. 2000, Jelks et al. 2008). Two important direct impacts of habitat degradation on fishes are the decrease of habitat and food (see Helfman 2007). The availability of habitat and food act as density-dependent influences on populations. While there is far from a consensus on the role of density-dependent controls on natural populations of fishes (see Matthews and Heins 1987), several studies have demonstrated decreased recruitment and/or growth of juveniles in high-density populations (Jones 1987a, 1987b; Forrester 1990, 1995). Therefore, removal of individuals from these study populations may reduce natural mortality caused by density-dependent variables leading to no net change in populations. This suggests that removal of modest numbers of individuals from populations of an imperiled nongame surface stream fish species is unlikely to negatively impact its survival. This conclusion is further supported by a recent summary of 12 especially imperiled freshwater fishes of the Southeast (Kuhajda et al. 2009) for which only five of these species had total population estimates. Four of those were surface water fishes, and of those, three had populations estimated between 1,667 and 31,293 individuals. While all of these species are threatened by habitat degradation, none of the accounts mention scientific or educational collection as a threat.

The captured-and-released *E. scotti* data provide an opportunity to test whether electrofishing has any measurable impacts on an imperiled species not targeted during research, but simply shocked inadvertently while other species are targeted. This concern provided the impetus for the study by Bohl et al. (2009) and Holliman et al. (2007) and has in part led to restrictions on electrofishing in waters containing imperiled species. The positive correlation (0.45) and insignificant relationship ($P = 0.12$) fail to reject the null hypothesis that electrofishing has no impact on imperiled species inadvertently shocked by efforts to collect other target species. This is not a surprising result given the usually rapid recovery of fishes

following a shocker pass and the low mortality and incidence of injury reported by Janáč and Jurajda (2011) and Clément and Cunjak (2010). These findings are also consistent with those of Larimore (1961) where only 51% of fish present in a small stream were able to be collected in attempts to census a stream using an electric seine. While it is difficult to demonstrate the lack of an effect, these data suggest that any impact electrofishing has on fish populations is incapable of being measured by these methods, and thus does not support the hypothesized negative impacts on fish populations. This also suggests that restrictions of electrofishing in streams housing imperiled species appear unwarranted due to a lack of evidence that electrofishing has measurable negative impacts on fish populations.

Given the sum of this information, it appears that collections for ichthyological research such as systematic, genetic, and ecological studies have little chance of harming wild populations of fishes. Given the demonstrated effectiveness of electrofishing as a collecting technique (Korman et al. 2010), restricting the use of this technique may be counterproductive to conservation efforts as having more information about distribution, abundance, and ecology of fishes allows us to identify species prone to extinction and be more proactive in conservation efforts (Angermeier 1995, Helfman 2007).

LITERATURE CITED

Anderson, A., A. C. Hubbs, K. O. Winemiller, and R. J. Edwards. 1995. Texas freshwater fish assemblages following three decades of environmental change. Southwest Naturalist 40:314–321.

Angermeier, P. L. 1995. Ecological attributes of extinction-prone species: loss of freshwater fishes of Virginia. Conservation Biology 9:143–158.

Barton, S. D., and S. L. Powers. 2010. Life-history aspects of the Cherokee Darter, *Etheostoma scotti* (Actinopterygii: Percidae), an imperiled species in northern Georgia. Southeastern Naturalist 9(4):687–698.

Beverton, R. J. H. and S. J. Holt. 1957. On the dynamics of exploited fish populations. U.K. Ministry of Agriculture and Fisheries Investigations Series 2. No. 19 533pp.

Bohl, R. J., T. B. Henry, R. J. Strange, and P. L. Rakes. 2009. Effects of electroshock on cyprinid embryos: implications for threatened and endangered fishes. Transactions of the American Fisheries Society 138:768–776.

Charles, J. R. 1957. Final report on population manipulation studies in three Kentucky streams. Fisheries Bulletin 22. Kentucky Department of Fish and Wildlife Resources. 45pp.

Clément, M., and R. A. Cunjak. 2010. Physical injuries in juvenile Atlantic Salmon, Slimy Sculpin, and Blacknose Dace attributable to electrofishing. North American Journal of Fisheries Management 30:840–850.

Edberg, K. M., and S. L. Powers. 2010. Life-history aspects of the Southern Studfish, *Fundulus stellifer* (Actinopterygii: Fundulidae) in northern Georgia. Southeastern Naturalist 9(1):119–128.

Ellender, B. R., A. Becker, O. L. F. Weyl, and E. R. Swartz. 2012. Underwater video analysis as a non-destructive alternative to electrofishing for sampling imperiled headwater stream fishes. Aquatic Conservation: Marine and Freshwater Ecosystems 22:58–65.

Forrester, G. E. 1990. Factors influencing the juvenile demography of a coral reef fish. Ecology 71:1666–1681.

Forrester, G. E. 1995. Strong density-dependent survival and recruitment regulate the abundance of a coral reef fish. Oecologia 103:275–282.

George, A. L., D. A. Neely, and R. L. Mayden. 2006. Conservation genetics of an imperiled riverine fish from eastern North America, the Blotchside Logperch, *Percina burtoni* (Teleostei: Percidae). Copeia 2006:585–594.

Helfman, G. S. 2007. Fish Conservation: A guide to understanding and restoring global aquatic biodiversity and fishery resources. Island Press. Washington.

Holder, D. S., and S. L. Powers. 2010. Life-history aspects of the Rainbow Shiner, *Notropis chrosomus* (Actinopterygii: Cyprinidae) in northern Georgia. Southeastern Naturalist 9(2):347–358.

Holliman, F. M., T. J. Kwak, W. G. Cope, and J. F. Levine. 2007. Exposure of unionid mussels to electric current: assessing risks associated with electrofishing. Transactions of the American Fisheries Society 136:1593–1606.

Janáč, M., and P. Jurajda. 2011. Mortality induced by electrofishing and handling in five young-of-the-year cyprinids: effect of the fish size, species and anode size. Journal of Applied Ichthyology 27:990–994.

Jelks, H. L., S. J. Walsh, N. M. Burkhead, S. Contreras-Balderas, E. Diaz-Pardo, D. A. Hendrickson, J. Lyons, N. E. Mandrak, F. McCormick, J. S. Nelson, S. P. Platania, B. A. Porter, C. B. Renaud, J. J. Schmitter-Soto, E. B. Taylor, and M. L. Warren, Jr. 2008. Conservation status of imperiled North American freshwater and diadromous fishes. Fisheries 33(8):372–407.

Jolly, D. M., and S. L. Powers. 2008. Life-history aspects of the Coosa Shiner, *Notropis xaenocephalus* (Actinopterygii: Cyprinidae) in northern Georgia. Southeastern Naturalist 7(3):449–458.

Jones, G. P. 1987a. Competitive interactions among adults and juveniles in a coral reef fish. Ecology 68:1534–1547.

Jones, G. P. 1987b. Some interactions between residents and recruits in two coral reef fishes. Journal of Experimental Marine Biology and Ecology 114:169–182.

Korman, J., A. S. Decker, B. Mossop, and J. Hagen. 2010. Comparison of electrofishing and snorkeling mark-recapture estimation of detection probability and abundance of juvenile steelhead in a medium-sized river. North American Journal of Fisheries Management 30:1280–1302.

Kuhajda, B. R., A. L. George, and J. D. Williams. 2009. The desperate dozen: southeastern freshwater fishes on the brink. Southeastern Fishes Council Proceedings 51:10–25.

Larimore, R. W. 1961. Fish population and electrofishing success in a warm-water stream. Journal of Wildlife Management 25(1):1–12.

Larimore, R. W., W. F. Childers, and C. Heckrotte. 1959. Destruction and reestablishment of stream fish and invertebrates affected by drought. Transactions of the American Fisheries Society 88:261–285.

Matthews, W. J., and D. C. Heins. 1987. Community and Evolutionary Ecology of North American Stream Fishes. Norman, OK, University of Oklahoma Press.

Meffe, G. K., and A. L. Sheldon. 1990. Post-defaunation recovery of fish assemblages in southeastern blackwater streams. Ecology 71: 657–667.

Miranda, L. E., and R. H. Kidwell. 2010. Unintended effects of electrofishing on nongame fishes. Transactions of the American Fisheries Society 139:1315–1321.

O’Kelley, C. T., and S. L. Powers. 2007. Life-history aspects of the Alabama Hog Sucker, *Hypentelium etowanum* (Actinopterygii: Catostomidae) in northern Georgia. Southeastern Naturalist 6(3):479–490.

Onorato, D., R. A. Angus, and K. R. Marion. 2000. Historical changes in the ichthyofaunal assemblages of the upper Cahaba River in Alabama associated with extensive urban development in the watershed. Journal of Freshwater Ecology 15:47–63.

Page, L. M., and R. L. Mayden. 1981. The life history of Tennessee Snubnose Darter, *Etheostoma simoterum*, in Brush Creek, Tennessee. Illinois Natural History Survey Biological Notes 117:1–11.

Powers, S. L., and R. L. Mayden. 2007. Evolution, systematics and biogeography of the *Etheostoma simoterum* species complex (Percidae: subgenus *Ulocentra*). Bulletin of the Alabama Museum of Natural History 25:1–23.

Roberts, J. H. 2011. First observation of a natural hybrid between endangered Roanoke Logperch (*Percina rex*) and Chainback Darter (*Percina nevisense*). Southeastern Fishes Council Proceedings 53:21–28.

Sheldon, A. L., and G. K. Meffe. 1995. Short-term recolonization by fishes of experimentally defaunated pools in a coastal plain stream. Copeia 1995:828–837.

Thurow, R. F., J. T. Peterson, J. W. Guzevich. 2006. Utility and validation of day and night snorkel counts for estimating bull trout abundance in first- to third-order streams. North American Journal of Fisheries Management 26:217–232.

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 25:7–29.

Weaver, L. A., and G. C. Garman. 1994. Urbanization of a watershed and historical changes in stream fish assemblage. Transactions of the American Fisheries Society 123:162–172.