Changes in Black Bass Population Characteristics after the Introduction of Alabama Bass in Lake Norman, North Carolina

Lawrence G. Dorsey, *North Carolina Wildlife Resources Commission, 1721 Mail Service Center, Raleigh, NC 27699*

Michael A. Abney, *Duke Energy Carolinas. Water Strategy. Hydro Licensing and Lake Services, 562 S. Church St., Charlotte, NC 28202*

Abstract: Lake Norman, North Carolina, has a popular fishery for largemouth bass (*Micropterus salmoides*), but in 2001, annual surveys by Duke Energy documented the unauthorized introduction of Alabama bass (*M. henshalli*). Concerns over the effects of this introduction on the existing largemouth bass fishery prompted this study, the objective of which was to use the existing standardized sampling program to document expansion of the Alabama bass population and describe changes in the population characteristics of largemouth bass in Lake Norman. Following Alabama bass introduction, the species quickly spread throughout the main channel of the reservoir, with a concomitant decline in largemouth bass abundance, although mean total length of largemouth bass increased. While the sampling protocol used was effective at documenting the changes in the main reservoir channel population characteristics between the two species, it did not document population characteristics in all areas of the reservoir. Additional samples collected in 2010 and 2013 by the North Carolina Wildlife Resources Commission in the upper area of the reservoir indicated that largemouth bass remained dominant in creek and cove areas but not along the main reservoir channel. This study illustrates that, while standardized sampling is a sound method for comparing black bass population characteristics between specific areas of interest, the addition of other habitat areas may be necessary to address specific questions regarding whole reservoir changes in their population characteristics. Further, this study serves as a cautionary tale of the unintended consequences of illegal unauthorized introductions of non-native species on native congeners.

Key words: Alabama bass, largemouth bass, standardized sampling, introductions

Journal of the Southeastern Association of Fish and Wildlife Agencies 3:161–166

Introductions of new fish species often yield results counter to their intended effect (Moyle et al. 1986, Courtenay 2007, Cucherousset and Olden 2011). This has been particularly true for black bass (*Micropterus* spp.) fisheries across the United States in recent years (Shaw 2015). While recent introductions of black bass have garnered the attention of fisheries professionals, similar introductions have occurred over the last 20 years across the southeastern United States (Pierce and Van Den Ayvle 1997, Long and Fisher 2005, Barwick et al. 2006, Moyer et al. 2014). Research efforts on these introductions have focused mostly on the genetic implications of hybridization between existing and introduced sympatric species, but few studies have documented changes that have occurred in an existing reservoir black bass population after the introduction of a new black bass (Pierce and Van Den Ayvle 1997, Long and Fisher 2005). While preservation of genetic integrity is important, fisheries managers are also responsible for managing fisheries yielding quality fishing experiences, and this is especially true given the economic importance of black bass angling across the United States (Shaw 2015).

Lake Norman, an approximately 13,000-ha mainstem impoundment of the Catawba River just north of Charlotte, North Carolina, was impounded in 1963 to provide water for multiple power generating facilities (Siler et al. 1986). Largemouth bass (*Micropterus salmoides*) is the sole native black bass species in the reservoir, as the species is native to the Catawba River Basin (Claussen 2015). Alabama bass (*M. henshalli*), native to the Mobile River Basin in Alabama, Georgia, and Mississippi (Rider and Maceina 2015), were first discovered in Lake Norman in 2000 by Duke Energy personnel (Godbout et al. 2009). Like other large reservoirs, Lake Norman exhibits an upstream-downstream productivity gradient (Siler et al. 1986). Buynak et al. (1989) observed that native largemouth bass and spotted bass (*M. punctulatus*) catch rates in Cave Run Lake, Kentucky, were linked to the productivity gradient in that reservoir. In their study, spotted bass were found in areas of low primary productivity while largemouth bass were found in areas of higher primary productivity. Reservoir managers were concerned about the effect Alabama bass would have on the existing largemouth bass fishery, but no published information existed on the effects of Alabama bass introduced into a black bass fishery containing only largemouth bass.

Standardized sampling is often used by management agencies to conduct long-term fisheries studies (Bonar et. al 2009) to address specific questions. This type of sampling design is well suited to collect data over an extended time period because effort is consistent and site-specific habitat remains fairly constant. However, these protocols may not accurately assess fish populations if all habitat types are not sampled in proportion to their abundance (Miranda and Boxrucker 2009). This is particularly true for black bass in reservoirs where habitat use of each species may be different (Sammons and Bettoli 1999). The objective of this study was to use an existing standardized sampling program to document changes in the population characteristics of largemouth bass in Lake Norman following introduction and establishment of Alabama bass.

Methods

In 1993, Duke Energy initiated an annual standardized electrofishing protocol to specifically monitor the effects of heated power facility effluent on reservoir fish populations in Lake Norman. The littoral sites used in this protocol were all associated with the main channel of the reservoir and were selected either to target areas influenced by heated effluent or as non-influenced control areas. Lake Norman was initially divided into three zones: upper forebay, lower forebay, and mid-lake (Figure 1). Black bass were collected annually from these zones during spring 1993 to 2013 with the exception of 1998. An additional area (upper main lake zone) was established in the upper area of the reservoir and sampled in 1999, 2005, 2010, and 2013 (Figure 1). In each zone, ten 300-m, fixed transects were sampled. An additional five transects (also 300-m in length) were sampled in 2010 and 2013 to represent the upper coves area of the reservoir.

Black bass were collected from littoral habitat during daylight hours using a Smith-Root boat-mounted electrofisher when surface water temperatures were typically 15–20 C (i.e., late March and early April). All black bass were collected and identified to species. Prior to 2008, if a fish could not be identified as an Alabama bass or largemouth bass through existing meristic identification methods, it was labeled as an Alabama bass x largemouth bass hybrid. In 2008, Godbout et al. (2009) developed a key for visually identifying hybrid black bass specifically in Lake Norman and this key was used for the remainder of our study. All black bass were measured for total length (TL, mm) and weighed (g). Relative weight values (*Wr*) were calculated for largemouth bass using the equation derived in Henson (1991). No relative weight equation currently exists for Alabama bass. Instead, the relative weight equation for spotted bass (Wiens et al. 1996) was used as Alabama bass were once classified as a subspecies of spotted bass. The CPUE values were calculated as number of fish collected 300 m^{-1}.

Mean CPUE, mean *Wr*, and mean TL were analyzed for largemouth bass (1993–2013) and for Alabama bass (2001–2013) by year and zone. Catch rates for largemouth bass and Alabama bass were ln-transformed for normality and analyzed using a Poisson linear mixed model with zone, year, and the zone by year interaction as fixed factors and a random year effect within each transect

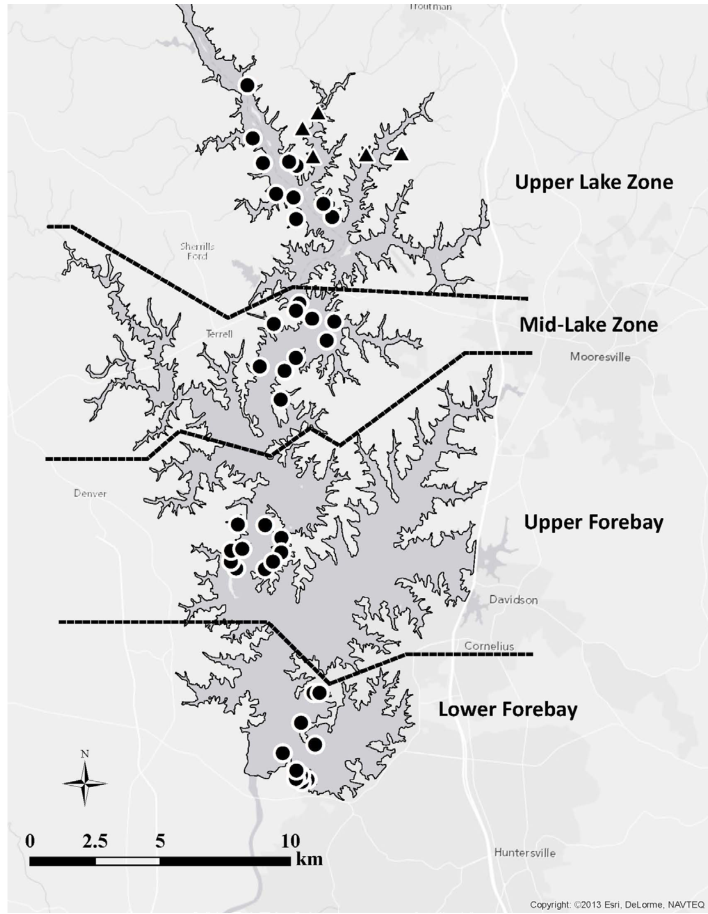

Figure 1. Map of Lake Norman, North Carolina, with electrofishing transects and zones that were sampled during 1993-2013. In the upper lake zone, circles represent the upper main channel electrofishing sites while triangles represent the upper coves zone electrofishing sites.

to model the within transect repeated measure covariance structure (McCullagh and Nelder 1989, Skrondal and Rabe-Hesketh 2004). To examine changes in catch rates of each species following introduction of Alabama bass, data from 2001–2013 were used in an analysis of covariance model regarding year as a continuous covariate to analyze the changes in mean total catch rates of both species by zone over the entire study. Similar analyses were conducted for mean *Wr* and mean TL. Regression lines were plotted for each variable in each year and zone combination to illustrate trends.

Similar analyses were repeated on the upper main channel and upper coves area data for surveys conducted in 2010 and 2013 in order to test for differences in abundance by year and area for each species. Catch rates for largemouth bass and Alabama bass were analyzed using a Poisson linear mixed model using the same model structure described above. Differences in mean catch rates (ln-transformed), TL, and *Wr* were examined between years and zones. All statistical tests were conducted using SAS (SAS 2012) and were considered significant at the $P \leq 0.05$ level.

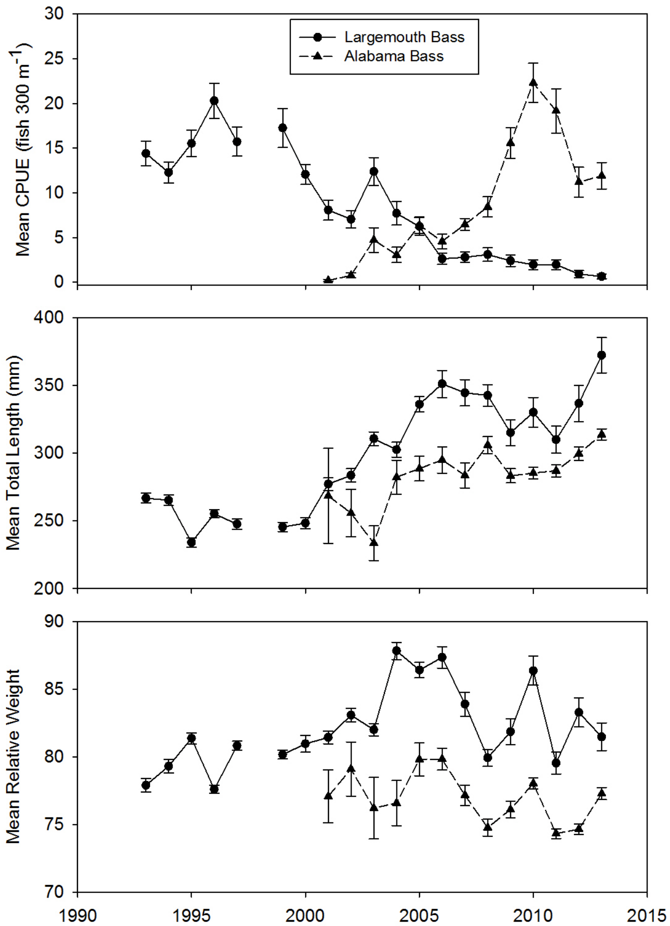

Figure 2. Mean CPUE, total length, and relative weight of largemouth bass and Alabama bass collected from Lake Norman, North Carolina, during spring 1993–2013. Error bars indicate 1 SE of the mean.

Results

A total of 5452 largemouth bass, 3240 Alabama bass, and 150 hybrids were collected from Lake Norman during this 20-yr study period. Overall, largemouth bass CPUE declined over the course of the study, while Alabama bass CPUE increased (Figure 2). In the first seven years, largemouth bass mean CPUE varied from a high of 21.9 fish 300 m^{-1} (SE = 2.0) to a low of 13.3 fish 300 m^{-1} (SE = 1.1). However, from 2003 through 2013, mean CPUE declined from 13.7 fish 300 m^{-1} (SE = 1.6) to 1.0 fish 300 m^{-1} (SE = 0.3). Alabama bass were first collected in 2001, and abundance subsequently increased from an initial CPUE of 0.2 fish 300 m^{-1} (SE = 0.1) in 2001 to 22.3 fish 300 m^{-1} (SE = 2.2) in 2010 (Figure 2). Catch rates declined over the next two years but were still an order of magnitude higher than largemouth bass CPUE by the end of this study.

Largemouth bass mean CPUE decreased significantly over the study period (Poisson linear mixed model ANCOVA: Zone: $F = 0.63$, df = 2, 88.16, $P = 0.536$; Year: $F = 109.54$, df = 1, 113.5, $P < 0.001$; Year*Zone: $F = 2.48$, df = 2, 111.1, $P = 0.088$). The model indicated that largemouth bass CPUE declined similarly in each zone (Table 1) and was predicted to approximate zero by the end of the study in the lower forebay and mid-lake zones (Figure 3). Alabama bass CPUE increased in all three zones during the study (Zone: $F = 10.98$, df = 2, 113.1, $P < 0.001$; Year: $F = 148.15$, df = 1, 113.5, $P < 0.001$; Year*Zone: $F = 8.24$, df = 2, 112.2, $P < 0.001$), but increased less rapidly in the lower forebay compared to the other two zones (Table 1, Figure 3).

Largemouth bass mean TL increased significantly over the study period (Poisson linear mixed model ANCOVA: Zone: $F = 0.66$, df = 2, 80, $P = 0.521$; Year: $F = 36.71$, df = 1, 105, $P < 0.001$; Year*Zone: $F = 1.28$, df = 2, 101, $P = 0.283$). Mean TL of Alabama bass also increased significantly during the study period (Zone: $F = 1.09$, df = 2, 110, $P = 0.340$; Year: $F = 16.34$, df = 1, 107.2, $P < 0.001$; Year*Zone: $F = 1.87$, df = 2, 105.1, $P = 0.1593$). Models indicated that mean TL of both species similarly increased in all three zones, despite varying slopes across zones (Table 1, Figure 3).

Mean *Wr* values of both species were variable over the study period (Figure 2) and ANCOVA failed to detect any differences in *Wr* of largemouth bass following introduction of Alabama bass (Zone: $F = 0.31$, df = 2, 117.3, $P = 0.732$; Year: $F = 1.98$, df = 1, 150.2, $P = 0.162$; Year*Zone: $F = 0.27$, df = 2, 142.4, $P = 0.767$). In contrast, mean *Wr* of Alabama bass declined following their introduction (Zone: $F = 0.42$, df = 2, 191.6, $P = 0.656$; Year: $F = 16.60$, df = 1, 174.0, $P < 0.001$; Year*Zone: $F = 0.20$, df = 2, 170.9, $P = 0.821$), although these declines appeared to be more severe in the lower forebay and mid-lake zones (Table 1, Figure 3).

Table 1. ANCOVA results for largemouth bass and Alabama bass by zone for mean CPUE, mean total length, and mean relative weight scores following establishment of Alabama bass in 2001 in Lake Norman, North Carolina.

Species	Parameter	Zone	Slope	Pr > |t|
Largemouth bass	CPUE	Lower Forebay	–0.233	< 0.001
		Upper Forebay	–0.235	< 0.001
		Mid-Lake	–0.147	< 0.001
	Total length	Lower Forebay	9.476	0.001
		Upper Forebay	6.709	0.002
		Mid-Lake	4.996	0.002
	Relative weight	Lower Forebay	–0.078	0.715
		Upper Forebay	–0.254	0.173
		Mid-Lake	–0.105	0.412
Alabama bass	CPUE	Lower Forebay	0.141	< 0.001
		Upper Forebay	0.315	< 0.001
		Mid-Lake	0.314	< 0.001
	Total length	Lower Forebay	2.104	0.239
		Upper Forebay	7.833	0.002
		Mid-Lake	4.839	0.022
	Relative weight	Lower Forebay	–0.441	0.001
		Upper Forebay	–0.304	0.133
		Mid-Lake	–0.452	0.008

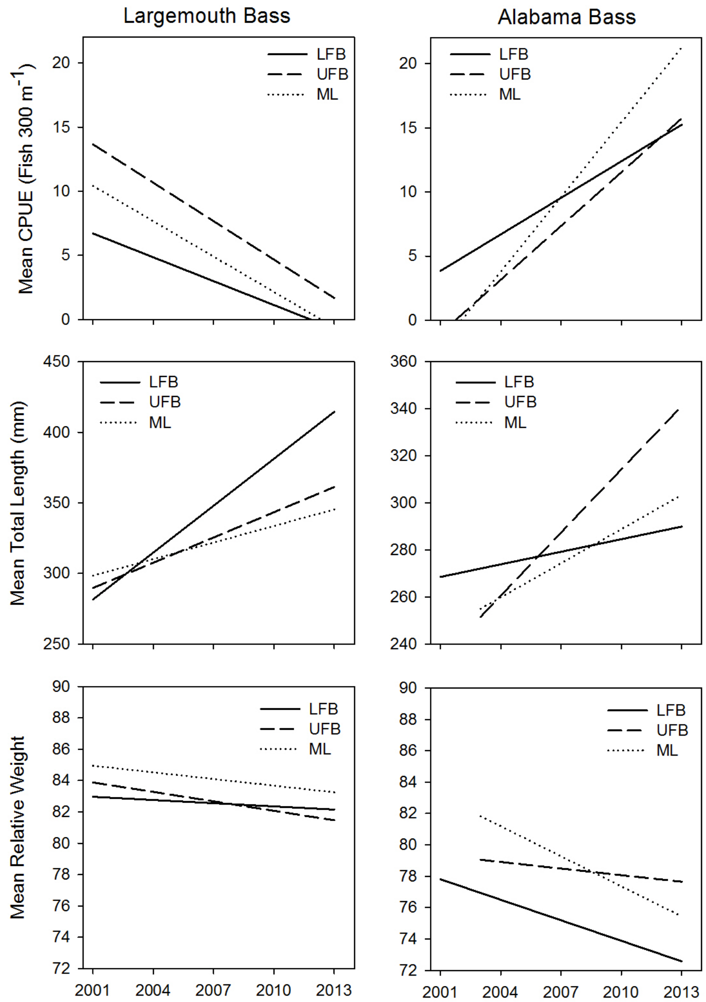

Figure 3. Regression lines calculated by ANCOVA analysis showing trends in mean CPUE, total length, and relative weight of largemouth bass and Alabama bass collected from three areas in Lake Norman, North Carolina, during spring 2001–2013. Areas sampled include the lower forebay (LFB), upper forebay (UFB), and mid lake (ML).

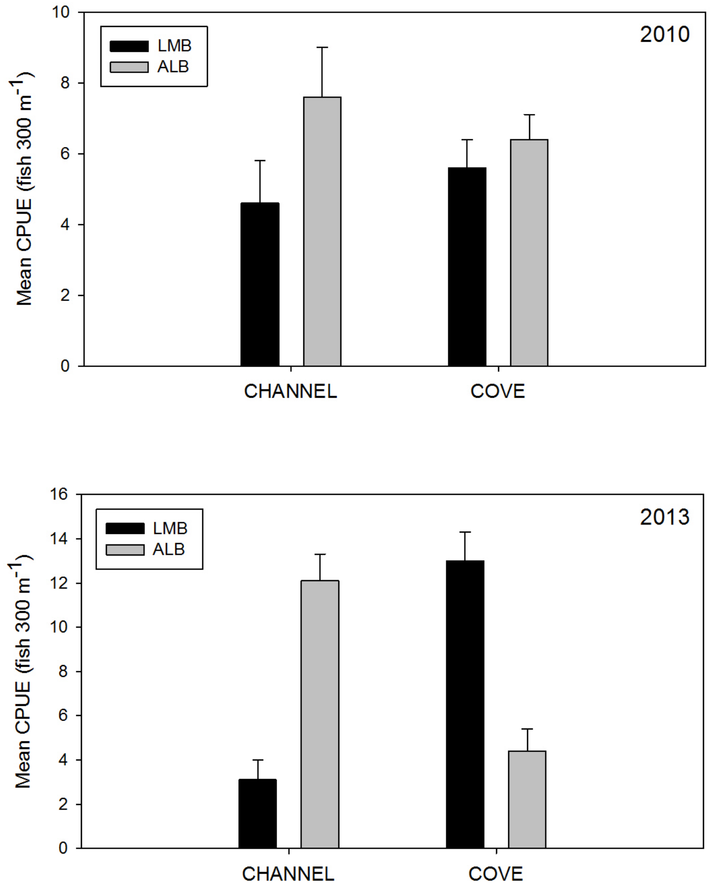

Figure 4. Mean relative weight scores of largemouth bass (LMB) and Alabama bass (ALB) collected from Lake Norman, North Carolina, during spring 1993–2013. Error bars indicate 1 SE of the mean.

Although not sampled annually during the study, black bass CPUE in the upper main channel zone followed similar trends in terms of changes in relative abundance over time. Alabama bass were already present in this zone in 2005 and their CPUE increased from 0.4 fish 300 m^{-1} (SE = 0.3) in 2005 to 12.1 fish 300 m^{-1} (SE = 1.2) by 2013. Largemouth bass CPUE exhibited a concomitant decline from 23.7 fish 300 m^{-1} in 1999 to 13.5 fish 300^{-1} in 2005 and 3.1 fish 300 m^{-1} by 2013. However, largemouth bass were slightly more abundant than Alabama bass in the upper coves zone in 2010, and were more than three times as abundant in 2013 (Figure 4). Largemouth bass CPUE was higher in the upper coves than the main channel zone in both years (Poisson linear mixed model: Zone: $F = 8.95$, df = 1, 11, $P = 0.001$; Year: $F = 0.03$, df = 1, 10, $P = 0.873$; Zone*Year: $F = 2.69$, df = 1, 10, $P = 0.132$). Conversely, Alabama bass were more abundant in the upper main channel zone than in the cove zone in both years (Zone: $F = 9.20$, df = 1, 11, $P = 0.011$; Year: $F = 0.46$, df = 1, 16, $P = 0.509$; Zone*Year: $F = 1.62$, df = 1, 16, $P = 0.221$).

Discussion

The introduction of Alabama bass in Lake Norman caused a dramatic shift in the composition of the black bass fishery. Prior to the introduction of Alabama bass, largemouth bass mean CPUE was variable but never declined more than two consecutive years. After the introduction of Alabama bass, largemouth bass abundance declined over the next 10 years and never returned to the abundances documented prior to the introduction of Alabama bass. Only one published study documented the interactions of native largemouth bass and introduced Alabama bass (Pierce and Van Den Ayvle 1997) and it found no relationship between Alabama bass and largemouth bass CPUE. However, introduced *Micropterus* species have been suspected to reduce native congeners by several authors (e.g., Barwick et al. 1996, Pierce and Van Den Avyle 1997, Stormer and Maceina 2008, Bean et al. 2013). Long and Fisher (2005) found that introduced smallmouth bass (*M. dolomieu*) had a similar effect on native spotted bass in an Oklahoma reservoir. It is apparent that the introduction of a new black bass species into a system already containing a congener can cause substantial changes in the population and genetic structure of the resident species.

Alabama bass mean CPUE remained low for the first five years after discovery and then increased substantially over the next four years before ultimately declining to levels between peak values and initial values. The rate of increase in abundance of a newly introduced species is usually exponential (Crooks and Soulè 1999) and this type of population expansion is common with introduced fish species (Moyle et al. 1986, Cucherousset and Olden 2011). Factors governing the rate of increase for an introduced species include the amount of habitat present that is suitable for the introduced species and the level of competition with established species (Crooks and Soulè 1999). Although it is not possible to isolate the most influential of these two factors as they relate to the introduction of Alabama bass, it is clear that the habitat present in the main lake portions of the reservoir is well suited to Alabama bass and that in these habitats they have been able to outcompete the well-established largemouth bass population. Maceina and Bayne (2001) documented that largemouth bass abundance decreased and spotted bass abundance increased after reduction in nutrient input into West Point Lake, Alabama-Georgia. Similarly, Greene and Maceina (2000) determined that oligotrophic conditions favored adult and juvenile Alabama bass over largemouth bass in several Alabama reservoirs. Given the low productivity of Lake Norman, much of the reservoir likely constitutes better habitat for introduced Alabama bass than native largemouth bass; thus, the black bass fishery will likely be dominated by Alabama bass for the foreseeable future.

While the abundance of largemouth bass decreased after the introduction of Alabama bass, mean TL values for largemouth bass increased. The inverse relationship between abundance and average size was not surprising since both species have similar prey requirements throughout their life histories and fewer largemouth bass in the population would reduce intraspecific competition for food resources. The increase in Alabama bass mean TL can be attributed to the expansion of age classes in the population over time. As the population expanded in size and in age, more adult fish relative to the number of juvenile fish in the population shifted mean TL higher. None of the small number of published studies documenting the introduction of a new black bass species on an existing black bass population in reservoirs reported changes in average size for either the existing or introduced black bass species. However, the concept of carrying capacity and density-dependence in black bass populations are summarized in Miranda and Dibble (2002) and these concepts accurately describe the changes in average size of both black bass species in Lake Norman observed during this study. Trends in mean *Wr* values were not consistent over time or between zones and did not appear to be linked to changes in abundance of size structure of either species.

The standard sampling protocol designed to study the impacts of heated power plant effluent on fish populations within specific areas of Lake Norman was critical in documenting the introduction and subsequent spread of Alabama bass in the reservoir while concurrently documenting the corresponding decline in largemouth bass abundance. However, the transect selection was restricted to areas on or near the main channel of the Catawba River and was not intended to monitor changes in the black bass fishery within the entire reservoir. While Alabama bass are now likely the dominant black species in the main basin of Lake Norman, largemouth bass remain more abundant than Alabama bass in the upper coves zone and it is unclear if this pattern exists in other areas of the reservoir that have not been sampled historically. Sammons and Bettoli (1999) noted that largemouth bass were often more abundant in coves than other native congeners in a Tennessee reservoir. Thus, additional surveys in Lake Norman may be needed in creek and cove habitats to gain a better understanding of the distribution and relative abundance of both black bass species.

The practice of adding ancillary sampling sites to support an existing standardized sampling protocol should be considered whenever primary objectives confine sampling to reduced areas of a reservoir (Miranda and Boxrucker 2009). While non-native species introductions are unpredictable, the increasing frequency of these introductions warrants consideration when designing standardized surveys. In the case of this protocol, additional sample sites were added to capture population trends in other areas of the reservoir not typically sampled.

Fisheries managers are often unsure about the length of time before an introduced population achieves its peak abundance and subsequently settles into its equilibrium abundance. In this study, well over a decade passed before the peak and decline in Alabama bass abundance occurred, but the equilibrium abundance of this species has likely not been reached in this system. Similarly, the new equilibrium abundance of largemouth bass has not yet been achieved, but will obviously be much lower than it was prior to the illegal unauthorized introduction of Alabama bass and will likely be concentrated in cove and creek areas of Lake Norman where mesotrophic conditions are most prevalent (Siler et al. 1986). This study serves as a cautionary tale of the unintended consequences of introductions of non-native species on native congeners.

Acknowledgments

We would like to thank all of the Duke Energy and North Carolina Wildlife Resources Commission employees who participated in field data collections. We would also like to thank Dr. Qiang Wu of East Carolina University for his assistance with statistical analyses and interpretation.

Literature Cited

Barwick, D.H., K.J. Oswald, J.M. Quattro, and R.D. Barwick. 2006. Redeye bass (*Micropterus coosae*) and Alabama spotted bass (*M. punctulatus henshalli*) hybridization in Keowee Reservoir. Southeastern Naturalist 5(4):661–668.

Bean, P.T., D.J. Lutz-Carrillo, and T. H. Bonner. 2013. Rangewide survey of the introgressive status of Guadalupe bass: implications for conservation and management. Transactions of the American Fisheries Society 142 (3) 681–689.

Bonar, S.A., S. Contreras-Balderas, and A.L. Iles. 2009. An introduction to standardized sampling. Pages 1–11 *in* S.A. Bonar, W.A. Hubert, and D.W. Willis, editors. Standard methods for sampling North American freshwater fishes. American Fisheries Society, Bethesda, Maryland.

Buynak, G.L., L.E. Kornman, A. Surmont, and B. Mitchell. 1989. Longitudinal differences in electrofishing catch rates and angler catches of black bass in Cave Run Lake, Kentucky. North American Journal of Fisheries Management 9:226–230.

Claussen, J.E. 2015. Largemouth bass *Micropterus salmoides* (Lacepede, 1802). Pages 27–34 *in* M.D. Tringali, J.M. Long, T.W. Birdsong, and M.S. Allen, editors. Black bass diversity: multidisciplinary science for conservation. American Fisheries Society, Symposium 82, Bethesda, Maryland.

Courtenay, W.R. 2007. Introduced species: what do you have and how do you know? Transactions of the American Fisheries Society 136:1160–1164.

Crooks, J.A. and M.E. Soulè. 1999. Lag times in population explosions of invasive species: cause and implications. Pages 103–125 *in* O.T. Sandlund, P.J. Schei, and A. Viken, editors. Invasive Species and Biodiversity Management, Kluwer Academic Publishers, New York, New York.

Cucherousset, J. and J.D. Olden. 2011. Ecological impacts of non-native freshwater fishes. Fisheries 36:215–230.

Godbout, J.D., D.D. Aday, J.A. Rice, M.R. Bangs, and J.M. Quattro. 2009. Morphological models for identifying largemouth bass, spotted bass, and spotted bass hybrids. North American Journal of Fisheries Management 29:1425–1437.

Greene, J. C. and M. J. Maceina. 2000. Influence of trophic state on spotted bass and largemouth bass spawning time and age-0 population characteristics in Alabama reservoirs. North American Journal of Fisheries Management 20:100–108.

Henson, J.C. 1991. Quantitative description and development of a species-specific growth form for Largemouth Bass, with application to the relative weight index. Master's Thesis. Texas A&M University, College Station.

Long, J.M. and W.L. Fisher. 2005. Distribution and abundance of black bass in Skiatook Lake, Oklahoma, after introduction of smallmouth bass and a liberalized harvest regulation on spotted bass. North American Journal of Fisheries Management 25:49–56.

Maceina, M. J. and D. R. Bayne. 2001. Changes in the black bass community and fishery with oligotrophication in West Point Reservoir, Georgia. North American Journal of Fisheries Management 21:745–755.

McCullagh, P. and J. A. Nelder. 1989. Generalized Linear Models, 2nd ed. Chapman & Hall/CRC Press, New York, New York.

Miranda, L.E. and E. D. Dibble. 2002. An ecological foundation for black bass management. Pages 433–453 *in* D.P. Philipp and M.S. Ridgeway, editors. Black bass: ecology, conservation, and management. American Fisheries Society, Symposium 31, Bethesda, Maryland.

——— and J. Boxrucker. 2009. Warmwater fish in large standing waters. Pages 29–42 *in* S.A. Bonar, W.A. Hubert, and D.W. Willis, editors. Standard methods for sampling North American freshwater fishes. American Fisheries Society, Bethesda, Maryland.

Moyer, G.R., A.S. Williams, M.L. Jolley, B.J. Ragland, and T.N. Churchill. 2014. Genetic confirmation and assessment of an unauthorized fish introduction in Parksville Reservoir, Tennessee. Journal of the Southeastern Association of Fish and Wildlife Agencies 1:64–69.

Moyle, P.B., H.W. Li, and B.A. Barton. 1986. The Frankenstein effect: impact of introduced fishes on native fishes in North America. Pages 415–426 *in* R.H. Stroud, editor. Fish Culture in Fisheries Management. American Fisheries Society, Bethesda, Maryland.

Pierce, P.C. and M.J. Van Den Ayvle. 1997. Hybridization between introduced spotted bass and smallmouth bass in reservoirs. Transactions of the American fisheries Society 126:939–94.

Rider, S.J. and M.J. Maceina. 2015. Alabama bass *Micropterus henshalli* (Hubbs and Bailey 1940). Pages 83–91 *in* M.D. Tringali, J.M. Long, T.W. Birdsong, and M.S. Allen, editors. Black bass diversity: multidisciplinary science for conservation. American Fisheries Society, Symposium 82, Bethesda, Maryland.

Sammons, S.M. and P.W. Bettoli. 1999. Spatial and temporal variation in electrofishing catch rates of three species of black bass (*Micropterus* spp.) from Normandy Reservoir, Tennessee. North American Journal of Fisheries Management 19:454–461.

SAS 2012. SAS System for linear models, ver 9.4. SAS Institute, Cary, North Carolina.

Shaw, S.L. 2015. Black bass diversity and conservation: an overview. Pages 3–8 *in* M.D. Tringali, J.M. Long, T.W. Birdsong, and M.S. Allen, editors. Black bass diversity: multidisciplinary science for conservation. American Fisheries Society, Symposium 82, Bethesda, Maryland.

Siler, J.R., W.J. Foris, and M.C. McInerny. 1986. Spatial heterogeneity in fish parameters within a reservoir. Pages 122–136 *in* G.E. Hall and M.J. Van Den Avyle, editors. Reservoir Fish Management: Strategies for the 80's. Reservoir Committee, Southern Division American Fisheries Society, Bethesda, Maryland.

Skrondal, A. and S. Rabe-Hesketh. 2004. Generalized Latent Variable Modeling: Multilevel, longitudinal, and structural equation models. Chapman & Hall/CRC Press, New York, New York.

Stormer, D.G. and M.J. Maceina. 2008. Relative abundance, distribution, and population metrics of shoal bass in Alabama. Journal of Freshwater Ecology 23: 651–661.

Wiens, J.R., C.S. Guy, and M.L. Brown. 1996. A revised standard weight (W_s) equation for spotted bass. North American Journal of Fisheries Management 16:958–959.