CAPE FEAR RIVER STRIPED BASS SURVEY 2014

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Abstract.—A spawning stock assessment was conducted for Striped Bass *Morone saxatilis* on the Cape Fear River in 2014 as part of annual monitoring and an evaluation of stocking progeny of endemic broodfish initiated in 2010. A total of 167 individuals were collected representing nine year classes from four collection sites (Lock and Dams 1, 2, and 3 and Buckhorn Dam). Results indicate that overall relative abundance for 2014 (11.3 fish/h; SE = 2.9) was similar to 2013 (9.4 fish/h; SE = 2.9) while CPUE increased at Lock and Dam 1 over the last two years (2013: 26.3 fish/h; SE = 8.3, 2014: 25.8 fish/h; SE = 7.4). Males were comprised mainly of age-3 and age-4 year classes while females were comprised mainly of age-7 individuals. Male size structure ranged 206–703 mm while females ranged 442–794 mm. Genetic results from Commission surveys revealed that 2010-2013 cohorts were 100% hatchery origin (N = 95; size range = 164–621 mm) while 27 individuals of unknown origin were typically larger individuals (size range = 564–794 mm). North Carolina Division of Marine Fisheries creel survey results indicated that angler effort and catch of Striped Bass has increased, while overall angler effort has decreased since 2013. Passage upstream through the rock arch ramp and the locks and dams remain a significant bottleneck for Striped Bass in the Cape Fear River. Based on 2014 data, we recommend to maintain the harvest moratorium. Until fish passage is addressed at all locks and dams, consideration of recreational harvest may be appropriate for a population completely dependent on hatchery contributions. Harvest scenarios indicate that a minimum length limit of 661 mm would allow males ≤ age 6 and females ≤ age 5 to spawn before becoming vulnerable to harvest. Mortality estimates were lowest for 2013–2014 dating back to 2008. In the absence of commercial and recreational harvest, cryptic mortality rates likely exist and are poorly understood. We fully support continued cooperative efforts among stakeholders within the Cape Fear Partnership to better enhance the fish community and aquatic ecosystem of the Cape Fear watershed.

The North Carolina Wildlife Resources Commission (Commission) has conducted annual monitoring of the Striped Bass *Morone saxatilis* spawning stock on the Cape Fear River since 2006. Historically, the Cape Fear River supported important commercial and recreational fisheries for Striped Bass (Rulifson 1994; Winslow 1994). The Cape Fear River Striped Bass fishery has traditionally been small when compared to other North Carolina coastal river systems. The Cape Fear River is unique from other North Carolina rivers because three navigational lock and dams extend well into the coastal plain where Lock and Dam 1 is only 97 rkm from the mouth of the river. The lock and dams were constructed between 1913 and 1934 near Duart (Lock and Dam 3, rkm 186), Elizabethtown (Lock and Dam 2, rkm 149), and Riegelwood (Lock and Dam 1, rkm 97) and are owned and operated by the United States Army Corps of Engineers (USACOE). These structures have been shown to impede anadromous fish migrations, especially during periods of low flow (Raabe et al. 2014). Construction of these three structures fragmented and altered historic spawning grounds of Striped Bass and coupled with over fishing and water quality degradation, the population was greatly reduced. Since 1962, the Commission, and USACOE, prepares an annual cooperative agreement, known as the "locking schedule", to facilitate passage of anadromous fish to portions of their historical spawning grounds above the lock and dams during the spring migrations (Appendix A).

In the wake of the population decline, attempts have been made to conserve the stock. When many of North Carolina's coastal Striped Bass populations declined during the 1970's and 1980's (Hammers et al. 1996), the Commission and the North Carolina Marine Fisheries Commission in conjunction with the Atlantic States Marine Fisheries Commission (ASMFC), initiated efforts to restore these Striped Bass stocks (ASMFC 1989; Laney et al. 1994; Herndon et al. 2000). Initial efforts focused on restoring the Roanoke River-Albemarle Sound stock, and once considered recovered in the 1990's, focus turned towards other coastal river systems including the Cape Fear River. Since 2001, totals of 2,147,879 phase-I (TL = 25–75 mm) and 1,285,074 phase-II (TL = 100–150 mm) Striped Bass for a combined total of 3,432,953 have been stocked into the Cape Fear system (Table 1). Although past stockings up to 2009 have not been formally evaluated on the Cape Fear River, spawning stock surveys in the system indicate persistence at low levels of abundance rather than improvement in stock status.

Advances in genetic profiling have indicated that locally adapted, reproductively isolated populations of Striped Bass may exist in southern coastal rivers which may be better suited for use as brood fish for augmenting these populations. Bulak et al. (2004) conducted a study designed to determine the genetic distinctiveness of reproductively isolated Striped Bass populations in several South Carolina coastal rivers. These results along with findings from other stockings with different species suggest stockings with endemic broodfish are more successful than those produced from non-endemic broodfish (Bulak et al. 2004; Small et al. 2014). Along with using endemic broodfish, genetic markers can be used to track progeny back to parental broodfish to evaluate several management stocking scenarios. The advantages of utilizing genetic markers include the ability to evaluate stocking size (phase), stocking locations, and spawning stock composition (Darden et al. 2012). Therefore, in 2010 the Cape Fear River stocking program was modified to utilize endemic broodfish instead of traditional broodfish from the Roanoke River. A need therefore exists to determine the genetic composition of the Cape Fear River Striped Bass brood stock utilizing these techniques. Use of brood fish with progeny stocked back into their natal river should allow for cohorts better suited to building the

Cape Fear Striped Bass stock. Early findings have found that hatchery contributions to returning fish of 2010 and younger cohorts are at or near 100%.

In addition to a stocking source of endemic broodfish, habitat enhancement projects have been implemented to augment the Striped Bass population. The lock and dams do not allow fish passage during normal flows, so a locking schedule was implemented to allow migratory fish to ascend the river. A rock arch ramp was constructed in 2012 at Lock and Dam 1 to provide a series of rock steps and plunge pools with a shallow slope for fish to ascend while still impounding the upstream water for municipal use (Raabe et al. 2014). This modification is currently being evaluated to estimate passage efficiency of Striped Bass, American Shad *Alosa sapidissima*, and Flathead Catfish *Pylodictis olivaris* (surrogate for Atlantic Sturgeon *Acipenser oxyrinchus oxyrinchus*) by North Carolina State University. In 2014 rock substrate was deposited in the Lock and Dam 2 tailrace to improve spawning habitat for species that ascended the rock arch ramp but could not navigate through Lock and Dam 2. This habitat augmentation was evaluated during the spring of 2014 to quantify anadromous spawning by collecting eggs throughout the water column at fixed sites. Preliminary results have documented spawning by anadromous species at these locations although direct impacts of the augmentation are not known. The study is scheduled to be repeated in spring 2015 with the goal to determine the effects of the habitat enhancement on anadromous species.

Since 2011, North Carolina Division of Marine Fisheries (NCDMF) has conducted mark-recapture studies to annually estimate Striped Bass population abundance. Utilizing data from 2011–2013, the Cape Fear Striped Bass population for 2013 was estimated to be 15,209 individuals ≥ 250 mm (Collier et al. 2013). Although population estimates during this time frame have trended upward, this trend has not been reflected in Commission spawning stock assessments during the same time frame. This estimate is much lower than the carrying capacity goal of 100,000 individuals, which is based on past Striped Bass harvest records and biological insight for the Cape Fear River population (CFRBAP 2013). Currently, there is a harvest moratorium on Striped Bass in the Cape Fear River that has been in place since 2008 (NCDMF 2008; NCWRC 2008). An annual creel survey conducted by NCDMF was initiated in 2013 on the Cape Fear River to document angler effort and harvest rates for anadromous species.

The enhancement goals for the Striped Bass population in the Cape Fear River are to: 1) observe an increase in overall relative abundance as measured by catch per unit effort (CPUE), 2) increase the percentage of fish ≥ age-6, and 3) increase the number of cohorts represented. Specifically, an increase in CPUE from 7.9 fish/h (non-endemic mean) up to 24 fish/h (endemic mean), an increase from 14.3% to 43% of fish ≥ age-6, and an increase of 6 cohorts to ≥ 8 cohorts represented annually would be deemed successful (Table 2). Evaluation of success criteria will center on comparisons of population characteristics between non-endemic stocking years (2008–2012) and endemic stocking years (2015–2019). The specific objectives for this report were to assess the Striped Bass spawning population and specifically to describe: relative abundance (CPUE; fish/h), size structure, age structure, growth, and to determine hatchery contribution of Striped Bass collected during 2014 by the Commission and NCDMF. Additional objectives were to describe trends in Striped Bass mortality following implementation of the harvest moratorium and explore potential minimum length limits and how they would affect a population wholly supported by Commission hatchery efforts.

Methods

Field Collections.—Sampling took place at four sites: Buckhorn Dam (rkm 316) near Moncure, Lock and Dam 3 (rkm 186) near Duart, Lock and Dam 2 (rkm 149) near Elizabethtown and Lock and Dam 1 (rkm 97) near Riegelwood (Figure 1). Sampling began as water temperatures approached 14°C and was conducted simultaneously with other anadromous species surveys. A range of flows were targeted at each site to ensure safe, effective boat electrofishing. The criteria set for Lock and Dams 1, 2, and 3 were flows less than 20,000 cfs with no minimum flow. Flows of 900 cfs up to 5,000 cfs were deemed appropriate for the site downstream of Buckhorn Dam.

A boat-mounted electrofishing unit (Smith-Root 7.5 GPP) was used to capture fish during daylight hours. Directed sampling effort began as the water temperature approached 14°C, and ended when Striped Bass spawning appeared complete; optimum spawning temperatures range from 18–22°C for Striped Bass in the Cape Fear River. All four sites were sampled for 30 minutes. Actual electrofishing time (seconds) and water temperature (°C) was recorded for each sample station. Each fish was measured for total length (mm) and weighed (kg). Sex was determined for each captured fish by applying directional pressure to the abdomen toward the vent and observing the presence of milt or eggs. Striped Bass ≤ 400 mm lacking the presence of milt or eggs were recorded as "unknown", while fish ≥ 400 mm were considered females. Scales were removed from all fish on the left side between the lateral line and the dorsal fins. A small tissue sample was removed from the pelvic fin. Striped Bass were also tagged with individually numbered internal anchor and Passive Integrated Transponder (PIT) tags before being returned to the water as part of an ongoing study by NCDMF. Using the genetic markers obtained from sampling, the percent composition of hatchery fish to the spawning population, relative abundance, and cohort diversity was calculated.

Stock Assessment.—Several population metrics were evaluated for Striped Bass including relative abundance, size structure, age structure, and growth. Relative abundance was quantified by calculating CPUE, which was measured as the number of Striped Bass collected per hour of pedal time of electrofishing. Relative abundance was reported for sampling events when water temperature was at or above 14°C until spawning appeared complete and for the duration of optimal spawning temperatures (18–22°C). Size structure was evaluated using length-frequency histograms. Age structure was based on the percentage of fish in the sample that were within each age group. Scales were used to determine age; each structure was aged independently by two Commission staff. Age comparison followed by a concert read was used to reach 100% agreement. Any discrepancies that could not be resolved resulted in that scale being removed from the dataset. For fish from genetically marked cohorts, known ages were compared with scale ages and corrected accordingly. An age-length key was used to expand age information from the subsample of aged fish for all fish. Growth of Striped Bass was modeled for males, females, and both sexes combined using the von Bertalanffy growth curve:

$$Lt = L\infty\ (1 - e^{-k\,(t - t0)})$$

where L_t = length at time t, $L\infty$ = maximum length, k = growth coefficient, and t_0 = the theoretical age at which the fish would have zero length (Ricker 1975).

All prioritized genetic samples (fin clips) collected during the study were sent to the hatchery manager at the Watha State Fish Hatchery in Watha, North Carolina, for sample preparation and shipment to the Hollings Marine Laboratory, South Carolina Department of Natural Resources (SCDNR) for Parentage Based Tagging (PBT) analysis (O'Donnell et al. 2015). Sample preparation for shipment followed the protocols according to the NCWRC fin clip collections guidelines.

Along with Commission stock assessment samples, supplemental fin clips were collected through NCDMF independent sampling (January–March) and the Cape Fear River Watch Striped Bass Tournament (Striperfest) conducted in mid-January in the lower portion of the river near Wilmington, North Carolina. Previous years' analyses have shown that samples collected in the lower river are 100% hatchery origin and because of this, samples genotyped were prioritized by the following criteria: they either were collected in a tributary of the Cape Fear River (e.g. Northeast Cape Fear) or the fish were ≤ 250 mm. These criteria helped determine if genetically unique individuals not of hatchery origin are utilizing other tributaries while analysis of fish ≤ 250 mm determined if any natural reproduction is taking place in the river.

Broodfish were collected for spawning purposes to produce genetically marked offspring. For successful crossings and adequate progeny, a goal of three to four females ≥ 3.5 kg and 9–12 males ≥ 1 kg were targeted for broodfish. Broodfish collected at or upstream of Lock and Dam 2 for spawning were prioritized, as they have been most successful in past hatchery spawning attempts (J. Evans, Commission personal communication), although fish collected downstream of this location were also used. All parental Striped Bass broodfish utilized in production were assessed with genotyping. Fin clips were collected from all Striped Bass broodfish at the Watha hatchery and stored in pre-labeled vials. Fin clip procedures and sample preparation followed the protocols established by the NCWRC fin clip collections guidelines, and followed strict chain of custody procedures to ensure sample integrity and preservation.

Harvest Scenarios.—Impacts of harvest scenarios were explored utilizing length at age and growth curves to access vulnerability to harvest for 2014 data. Specific maturation timelines are unknown for the Cape Fear River so it was assumed that age-3 males and age-4 females will spawn for the first time. Growth rates and estimated lengths at age were utilized to compare minimum length limits of 458, 560, 661 mm, and a minimum length of 458 mm and a slot limit coupled with no harvest from 560-687 mm. Instantaneous mortality (Z) was calculated annually for 2008–2014 using the Chapman-Robson method (Robson and Chapman 1961) and modified based on recommendations of (Smith et al. 2012) utilizing catch curves of peak at age of recruitment plus one year. Total annual mortality estimates were converted from $A = 1 - e^{-Z}$. Although a harvest moratorium has been implemented since 2008, fishing mortality (F) was calculated by subtracting natural mortality from Z. The assumed natural mortality rate of M = 0.15 may be conservative so a higher rate (M = 0.30) was also calculated.

NCDMF Creel Survey.—A creel survey was conducted by NCDMF during the spring 2014 anadromous spawning run in the Cape Fear River. There were seven angler interception sites utilized for the survey. Sites were randomly selected with probabilities assigned to each site based on longitudinal location in the river and time period (Pollock et al. 1994). Probability values to survey a site were initially higher in the lower river and as water temperatures increased and the spawning season progressed, probabilities of sites farther upstream increased to account for fish migrating upstream. Each creel interview collected information

from anglers including: target species, fishing effort, catch, harvest, and release rates. In addition, anglers were requested to participate in a separate survey sent out by the Commission. This follow-up survey consisted of more in-depth questions about target species, fishing efforts, opinions on current regulations and overall satisfaction of the anadromous fishery in the Cape Fear River.

Results

Stock Assessment.—Striped Bass sampling was initiated on 9 April as water temperature approached 14°C and was terminated when spawning appeared complete and optimal spawning temperatures (18-22°C) were no longer observed (26 May). A total of 167 Striped Bass were collected during this time-frame; 31 females, 76 males, and 58 unknowns (Table 3). There were two within-season recaptures during this time frame as well. Four hybrid Striped Bass were also collected during 2014 sampling, three from Buckhorn Dam and one from Lock and Dam 3. Optimal spawning temperatures were observed during three weeks out of the eight weeks sampled in 2014. Mean CPUE for these three weeks (11.7 fish/h; SE = 2.9) was similar to the overall CPUE (11.3 fish/h; SE = 2.9) (Table 3). Overall CPUE at Lock and Dam 1 (25.8 fish/h; SE = 7.4) was highest among sites in 2014 (Figure 2). When compared to the CPUE during optimal spawning temperatures, abundance estimates were similar for each site with one notable exception where CPUE doubled at Lock and Dam 3 on 28 April 2014. Abundance estimates at Buckhorn Dam were similar to Lock and Dams 2 and 3 during the same time frame.

Striped Bass were collected at Lock and Dam 1 (most downstream site) as water temperatures exceeded 14°C by 7 April and persisted through the sampling period. By 24 April, Striped Bass were collected at all sample sites indicating upstream movement and distribution throughout the river. Striped Bass were consistently found in higher numbers at Lock and Dam 1 when compared to the other sites; however, in general, catch rates were more distributed throughout sites when water temperatures were at or near optimal spawning conditions (Figure 2). Sixty percent of the fish were collected upstream (N = 3 sample sites) of Lock and Dam 1. The Striped Bass male to female ratio was 2.5:1 for 2014 (Table 3).

Striped Bass relative abundance increased in 2013 and 2014 at Lock and Dam 1 when compared to previous years dating back to 2008 (Figure 2) while relative abundance has remained variable but lower at Lock and Dams 2 and 3. Relative abundance of age-3 fish and fish ≥ age-6 have remained under 3 fish/h dating back to 2008 with the exception of 2010 for Striped Bass ≥ age-6 where CPUE increased to 7 fish/h (Figure 3).

Striped Bass size structure varied for males, females, and unknowns (Figure 4). There were 58 Striped Bass where sex could not be determined; of these 45 were ≤ 300 mm. Male length distribution peaked between 550–600 mm, while female length distribution peaked between 600–650 mm and 700–750 mm (Figure 4).

Scale aging and genetics determined nine year classes of Striped Bass were represented (Table 4). Eight percent of the aged individuals were ≥ age-6. For females, the 2010 (age-4) year class contributed 35% of the sample, followed by the 2007 (age-7) year class comprising 19% (Table 4). Mean lengths of females ranged from 442 mm (age-2) up to 794 (age-8). The majority of males were from the 2011 (age-3) and 2010 (age-4) year classes, which comprised 65% of all confirmed males. Mean lengths of males ranged from 206 mm (age-1) to 700 mm (age-8).

Striped Bass length varied considerably for each age class with some potential outliers present from age-1 up to age-5 (Figure 5). Striped Bass growth rates differed by gender where von Bertalanffy growth model estimated growth to asymptote for males around 725 mm and growth rate was k = 0.36 compared to female growth with an $L\infty$ = 847 mm and a slower growth rate of k = 0.26 (Figure 6). The combined growth curve for both sexes resulted in parameter estimates of $L\infty$ = 838 mm, and k = 0.34 (Figure 6).

Parentage Based Tagging analysis revealed high contributions of hatchery origin fish. Of 149 samples analyzed from the survey collections; 95 were hatchery origin from 2010–2013 cohorts (Figure 7). These fish ranged in size from 164 mm to 621 mm. Of the hatchery origin fish, 39 were stocked at Castle Street in Wilmington and another 56 were stocked in multiple locations (phase-I stockings in Piedmont reservoirs and phase-II stockings at Castle Street). Twenty seven Striped Bass that ranged 564–794 mm could not be genetically matched back to any genotyped broodfish and were considered unknown origin. Twenty-seven Striped Bass from Roanoke broodfish were collected from 2010–2012 cohorts with 22 representing the 2012 year class. Eleven of twelve Striped Bass collected at Buckhorn Dam were from Roanoke broodfish, followed by 7, 4, and 5 collected at Lock and Dams 3, 2, and 1, respectively. To date, Commission samples from the 2010–2013 cohorts are 100% hatchery-origin (Figure 8). Collections from NCDMF in the lower Cape Fear River revealed similar patterns where 90 of the 138 samples were hatchery origin from 2010–2013 cohorts. These Striped Bass ranged in size 165–620 mm. Sixty-five of these were stocked at Castle Street, followed by 24 from multiple stocking locations and 1 fish from the 2012 cohort was stocked as a phase-I at the Castle Hayne Landing in the Northeast Cape Fear River. Of the remaining fin clips, 37 could not be typed back to the genetically marked broodfish and were considered unknown origin. These fish ranged in size 570–789 mm; with the exception of one fish that was 311 mm. The remaining 11 fish were progeny of Roanoke broodfish that were stocked in Jordan Lake, all from the 2012 cohort.

There was not a strong correlation between CPUE (fish/h) and river flow (Figure 9), although catch rates general decreased at the highest observed flows. Catch rates were most productive for Lock and Dam 1 at flows < 10,000 cfs. For the other three sites, flows < 5,000 cfs were productive. CPUE generally increased as water temperatures increased (Figure 10).

Broodfish Collections.—On 28 April, three females were collected at Lock and Dams 1 and 3 that ranged in length from 638–730 mm and had pre-spawn weights from 3.3 to 5.3 kg. Ten males were collected at Lock and Dams 1, 2, and 3 and ranged in length 430–700 mm. Pre-spawn weights were not collected for the males. A total of 4,972,000 Striped Bass fry were produced from three families, and surviving fry were stocked into available ponds at Watha State Fish Hatchery to maintain chain of custody of genetically unique broodfish families (Evans 2014). A total of 211,726 genetically unique phase-I Striped Bass were stocked on 27 and 30 June 2014 at Lillington (rkm 302). During the week of 2–5 December 2014, 141,752 genetically unique phase-II Striped Bass were stocked at Castle Street (rkm 40) in Wilmington.

Harvest Scenarios.—Minimum length limits have been plotted with von Bertalanffy growth curves for Striped Bass. Males took longer to reach the 661 mm minimum length limit and were age 6 at this size compared to females that reached the same length by age 5. The percentage of Striped Bass vulnerable to harvest decreased with an increase in a minimum size limit with the exception of a slot limit (Table 5). All Striped Bass were most vulnerable with the inclusion of a 458 mm length limit with 58% of the 2014 sample being of legal harvest size. The 661 mm

minimum length limit for males resulted in 12% being vulnerable to harvest, along with 35% of females, and 13% for the total sample. Catch curves for 2013–2014 revealed peak at age of full recruitment to sampling gear for each year (Figure 11). Instantaneous mortality estimates (*Z*) peaked in 2012 (*Z* = 1.58) but dropped to its lowest levels in 2013 (*Z* = 0.44) and 2014 (Z = 0.47) (Figure 12). Total annual mortality followed a similar trend with 2013 (*A* = 36%) and 2014 (*A* = 37%) having the lowest estimates since 2008 (Figure 13). Sources of "unknown" mortality was *F* = 0.21 and *F* = 0.22 for 2013 and 2014 (Figure 14).

Creel survey.—The NCDMF creel survey indicated that overall fishing effort and hours fished were substantially less than what was observed in 2013. Hours fished were 99,826 in 2013 and dropped to 28,622 hours in 2014. However, there was an increase in number of trips, hours fished, and discards reported in 2014 for anglers targeting Striped Bass (Table 6). In 2014 there was an estimated 418 trips and 2,164 hours spent targeting Striped Bass in the Cape Fear River. Catch and release discards were estimated to be 1,551 Striped Bass.

Follow-up Commission surveys were sent to 54 people, and 24 surveys were completed and returned. Most of the anglers that responded fished between Lock and Dams 1 and 3. Anglers fished almost equally from the bank or a boat. They supported the harvest moratorium until the population is deemed recovered and are in favor of habitat enhancement projects. Eighty-six percent of anglers surveyed were either very satisfied or satisfied with their fishing trip on the Cape Fear River.

Discussion

Population characteristics of the 2014 Striped Bass spawning stock in the Cape Fear River were similar to what was observed in 2013. Site comparisons to 2013 revealed similar estimates of CPUE at Lock and Dam 1 and slightly higher CPUE estimates at Lock and Dams 2 and 3 in 2014. Increased catch rates at specific sites may be attributed to optimal spawning temperatures along a temporal and spatial scale of the four sampling sites. More Striped Bass were collected upstream of Lock and Dam 1 in 2014 (60%) than in 2013 (27%). Both years had similar flow regimes and were either at or above normal flows throughout the spring. The addition of a new site did influence the percentage of fish collected upstream as well. The Buckhorn Dam site comprised 19% of the upstream catch in 2014, and increased catch rates observed during optimal spawning temperatures could explain some of the discrepancy. Age composition was dominated by age-3 and age-4 males and age-7 and age-4 females. Nine year classes (age 1–9) present in 2014 were higher than the pre-endemic mean (2008–2012) of 6 year classes and similar to the 10 observed in 2013. The percentage of fish ≥ age-6 in 2014 (32%) was similar to 2013 (33%) and was higher than the pre-endemic stocking mean of (14%). Estimated growth rates of Striped Bass indicated that both males and females grew rapidly from age 1 to age 2 and around 100 mm per year from age 2 to age 4. Growth slowed considerably after age 4, and females attained larger sizes, maxing out around 847 mm. While the current harvest moratorium is still in effect for the Cape Fear River, understanding how density dependence, hatchery versus wild origin, and how various other factors influence growth rates are vital components of future management strategies.

Commission surveys and North Carolina State University research have shown that Striped Bass are not able to ascend the rock arch ramp in sufficient numbers when compared to other

species (Raabe et al. 2014). Relative abundance of Striped Bass at Lock and Dam 1 has increased in the last 2 years while other sites have remained low (< 6.5 fish/h). Modifications to the rock arch ramp may make conditions more suitable for Striped Bass passage. Currently, the ramp is a series of steps, dropping in elevation from the dam to the pool below. One proposed change would be to construct one or several small channels down the ramp. This may alter the hydrology of the ramp enough for Striped Bass to ascend successfully.

Along with further modifications to the rock arch ramp and the other lock and dams, the addition of the Buckhorn Dam sampling site will be informative in understanding the composition of the Striped Bass population in the terminal, upstream reach on the Cape Fear River. The 2014 results revealed that only one Striped Bass navigated through the locks and dams upstream to Buckhorn Dam and the remainder emigrated from Jordan Lake downstream to our sites. With this in mind, production of a genetically unique family of Cape Fear origin Striped Bass is vital to be stocked in Jordan Lake to evaluate any effects of emigration as well as potential for returning adults to the spawning stock. An additional site at Smiley Falls (rkm 280) will be added in 2015. This reach of river is considered the historical spawning grounds for Striped Bass, although access is limited and dependent on adequate flows. This site was sampled a few times in 2014 but could not be added to the weekly sampling schedule because of equipment failures and flow requirements that do not allow for access with our current sampling vessels. Currently, sampling Smiley Falls involves launching at the Commission boating access area in Lillington and floating approximately 54 rkm downstream to the Riverside Bait and Tackle boat ramp (Person Street Bridge) in Fayetteville. Improvements to the canoe launch at the Cape Fear River Trail Park in Erwin could improve access and decrease the float trip to approximately 11 rkm. More attention will be paid to this site and others between Lock and Dam 3 and Buckhorn Dam in future surveys.

Striped Bass originally stocked in Jordan Lake for recreational harvest were present at all sampling sites in 2014 with the 2012 cohort being most abundant. Hybrid Striped Bass were also present in 2014 samples. Downstream migration of hybrid Striped Bass from Jordan Lake was well documented in Commission and NCDMF surveys and led to the termination of stocking hybrid Striped Bass in Jordan Lake in 2002 (Patrick and Moser 2001). These current captures enforce the need of utilizing endemic broodfish on a watershed level because of migration of populations from upstream reservoirs. Striped Bass and hybrid Striped Bass are currently stocked in Oak Hollow Reservoir in the Deep River and Lake Townsend in the Haw River. Annual monitoring utilizing PBT to document reservoir populations is necessary to better understand what factors (e.g. seasonal flows, stocking rates) influence downstream migration.

Since 2010, all endemic phase-II Striped Bass have been stocked at Castle Street in Wilmington. The suitability of this location for Striped Bass to fully imprint on the Cape Fear River is unknown and is based on where a 100–150 mm Striped Bass spawned naturally would likely be in the river. Imprinting is vital to avoid straying, and for a population to ascend the river in adequate numbers to reproduce successfully. There has been one confirmed Cape Fear hatchery origin Striped Bass collected in the Pamlico Sound that demonstrates some straying and more opportunities to document this will be available as other coastal North Carolina rivers are utilizing PBT to determine hatchery contributions to spawning stocks. To test this approach, one option is to stock phase-II Striped Bass farther upstream at Lock and Dam 1 and Lock and Dam 2. This may provide the stocked phase-II Striped Bass sufficient chemical and

environmental cues to return, ascend the rock arch ramp and lock and dams, and spawn in more robust numbers to have an effect at the population level. If logistically feasible, phase-II Striped Bass may be developed from two genetically unique families and stocked separately at Lock and Dams 1 and 2. A goal of two unique groups comprised of 50,000 phase-II Striped Bass will be utilized for stocking in 2015. Striped Bass will not be stocked at Castle Street during this time period.

Parentage Based Tagging revealed that there was no detectable natural reproduction occurring in the Cape Fear River. One 311 mm Striped Bass from NCDMF collections was considered unknown but without more samples of non-hatchery origin fish younger than the 2010 cohort (beginning of PBT in Cape Fear River) it is difficult to expand on this one individual fish, although natural recruitment cannot be ruled out. Genetic analysis also demonstrated spatially how far upstream Striped Bass are migrating. Of the 12 Striped Bass collected at Buckhorn Dam, 11 of these migrated downstream from Jordan Lake and only one migrated from the lower river. Smith and Hightower (2012) did document some tagged Striped Bass migrating upstream of Lock and Dam 3 and one relocated 1-rkm downstream of Buckhorn Dam. More surveys are needed in this upper reach to determine if aggregations of Striped Bass migrating upstream exist.

Harvest scenarios based on length at age and growth rates were explored for a population assuming 1) no natural recruitment, and 2) sustained entirely by hatchery efforts. Utilizing 2014 Commission stock assessment data, a minimum length limit of 661 mm was shown to be a target size limit to allow larger females sufficient opportunity to spawn before being harvested. Broodfish collection, tank spawning, fingerling production, and stocking are a sizable undertaking utilizing Sport Fish Restoration funds. Although management efforts will continue to promote a self-sustaining population by addressing life history bottlenecks and pursuing the enhancement of fish passage, larval, juvenile, and adult habitats, forage availability, and water quality issues, the enhancement of angling opportunities needs to be addressed as well. If current conditions persist then stocked cohorts will eventually die off with only catch and release opportunities available to the public. A conservative length and creel limit may be appropriate to strike a suitable balance between an entirely hatchery-produced population, angling opportunities, logistical costs, and the management and conservation of a diminished population.

Mortality rates were estimated throughout the harvest moratorium to determine impacts of an unexploited population. Annual mortality estimates dropped below 40% in 2013 and 2014 for the first time since 2008. These results may be the effects of a change in the Commission's stocking program where the annual stocking of phase-II fish are expanding the age structure in the system in the presence of a harvest moratorium. Stocking prior to 2010 consisted of Roanoke broodfish progeny and typically phase-I fish. Our annual estimate of mortality (M = 0.44; 95% CI = 0.33%, 0.55%) was higher than what was estimated by NCDMF surveys where M = 0.24 for 2013 (Collier et al. 2013). Differences in sample design or stock structure may account for this. Fishing mortality was calculated even with the harvest moratorium and resulted in varying degrees of unknown, or cryptic, mortality, such as delayed mortality in the recreational or commercial sectors. Nelson (1998) estimated that catch and release resulted in 6.4% mortality in the Roanoke River Striped Bass fishery. The Cape Fear River has commercial fisheries including mullet *Mugil* spp., flounder *Paralichthys* spp., and shad fisheries that may

contribute to discard mortality. Past commercial harvest rates were low when compared to other systems in North Carolina with mean commercial landings (586.8 kg; SE = 115.2) from 1990-2008 (NCDMF 2014) and was mainly a by-catch fishery during the commercial drift gill net shad fishery in the Cape Fear River. Striped Bass encountered during Commission surveys downstream of Lock and Dam 1 have had what appears to be gill net scars around the head potentially from the commercial shad fishery (personal observations). Efforts to determine specific impacts of the shad gill net fishery on Striped Bass in the Cape Fear River are needed to better manage both species.

Along with a better understanding of commercial and recreational bycatch mortality rates, there are several Striped Bass information gaps that have been identified which could provide for more appropriate management decisions for the Cape Fear River population. A more comprehensive assessment of harvest scenarios (daily and seasonal creel limits) is warranted for the Cape Fear River. Sample sizes of stock assessments are low but continue to increase each year. Actual spawning success quantified by egg collections may be a more viable technique to document spawning location, timing, and success. A maturation study is needed to help manage and protect females with the greatest spawning potential. Empirical, age-specific mortality estimates also need to be understood instead of a general overall natural mortality rate. Other information gaps in the Cape Fear River include documenting the size and age structure of resident Striped Bass utilizing habitats upstream of Lock and Dam 1. There is also little information of the early life history of Striped Bass in the Cape Fear River and impacts that water quality within the river have on fertilized eggs, larvae, and young-of-year. Assumed spawning habitat needs to be quantified and assessed at each tailrace (available spawning habitat if upstream migration is unsuccessful) to determine if fertilized eggs can even survive.

Annual endemic phase-II stockings appeared to have higher survival and return rates than previous phase-I Roanoke stockings. The 2014 year also introduces another factor to evaluate in that over 200,000 phase-I Striped Bass were stocked in the upper river along with over 140,000 phase-II fish in the lower river. These two stockings are genetically unique and the opportunity to evaluate each stocking event will be available as fish return in the future.

Overall fishing effort decreased substantially in 2014 when compared to 2013 estimates. Monthly comparisons of Striped Bass effort are only applicable to the month of May because access to Lock and Dam 1 was limited in 2013. Construction necessitated closure of the boat ramp in March and April so there was no access at this location. Lock and Dam 1 is the primary fishing location for anglers pursuing Striped Bass during springtime migratory runs, and although angler efforts were likely diverted elsewhere, Striped Bass effort was reduced. When comparing the month of May; the number of trips were similar, hours fished were almost double in 2014, while discards (fish caught and released) were higher in 2013. The higher rates of discards in May could be the result of reduced fishing pressure during the previous two months. Angler effort targeting Striped Bass was higher (effort = 2,164 angler hours) in 2014 than in the 2003–2004 Commission creel survey (pre-harvest moratorium) where anglers expended 1,037 angler hours from March through May 2004. Estimated catch from March through May 2014 (N = 1,551) was higher than the same time frame in 2004 (N = 476). From the estimated 476 caught in 2004, 58 were harvested (37%) of the total yearly estimated harvest (Ashley and Rachels 2005). Striped Bass angling effort comprised 8% of the total effort for March through May while the 2004 estimates were 2% of the total effort during the same

time frame. While methodologies of both creel surveys differed, it is interesting to see estimates of pre-harvest moratorium and contemporary angling efforts for general comparisons. Creel surveys will continue to be beneficial in the Cape Fear River to monitor angler effort and discards of Striped Bass to compliment Commission sampling. Gross trends in overall abundance of Striped Bass are assumed to be documented with both methods. While creel data on Striped Bass does not include any information regarding size of fish caught, it is valuable in understanding angler response to management efforts for a diminished population.

Comparing this year's results to 2013 and to the long-term objectives for evaluating stocking utilizing endemic broodfish in the Cape Fear River, several things are noteworthy. CPUE has increased considerably at Lock and Dam 1 in 2013 and 2014. Endemic stocking was initiated in 2010 and those fish have started to return in the last two years. CPUE at Lock and Dam 1 is around 25 fish/h which is meeting one of the study's goals of a three-fold increase in CPUE from pre-endemic stocking estimates. It is uncertain if the increase in relative abundance is from more fish returning or less fish being able to ascend the rock arch rapids. The long-term study objective is for the overall CPUE to increase, but these increases upstream have not been observed within the same time period. Fish passage is likely the most significant bottleneck for Cape Fear Striped Bass, and until passage at each Lock and Dam is addressed, the population will likely remain dependent on hatchery contributions. During this period of limited fish passage for Striped Bass, limited recreational harvest may be justified until sufficient progress on fish passage construction has occurred. The evaluation of the rock arch ramp will continue through the spawning season of 2015. Management efforts will continue to focus on fish passage success or lack thereof for Striped Bass and other migratory species. Several information gaps have been addressed, and further collaboration on additional efforts with partner agencies, universities, and basin partnerships will continue to enhance the fish community throughout the Cape Fear River.

Management Recommendations

1. Maintain harvest moratorium for Striped Bass in the Cape Fear River during 2015.
2. Continue to utilize endemic broodfish for stocking efforts and stock 100,000 phase-II Striped Bass into the Cape Fear River. To determine effects of stocking location on returning cohorts, two genetically unique families will be recommended for stocking at Lock and Dams 1 and 2 for 2015.
3. Maintain genetically unique families of Striped Bass to be stocked in upstream reservoirs of Cape Fear origin, with emphasis on B.E. Jordan Reservoir stockings.
4. Based on 2014 data, a minimum length limit of 661 mm may be appropriate although exploration of daily creel limits and timeframe of open harvest season is warranted during the harvest moratorium evaluation period.
5. Document spawning locations and quantify reproductive success through egg collections. Assess minimum environmental requirements (water velocity, salinity, etc.) at both spawning locations and downstream habitats for egg and larval survival.
6. Determine effects of water quality on fertilized eggs, larval survival, and recruitment of young-of-year Striped Bass.
7. Develop a maturation and fecundity study of Cape Fear River Striped Bass in 2016.

8. Continue to improve fish passage at Lock and Dams 1, 2, and 3 through modifications to the rock arch ramp and locking schedule.
9. Quantify habitat with side-scan sonar to determine spawning habitats throughout the river.

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We thank Tim Ellis and Kyle Hussey for their efforts in field collections. Jeff Evans, Landon Beaver, Matthew Turpin, and Barry Midgette at Watha State Fish Hatchery spawned, produced and stocked all Striped Bass progeny. Hollings Marine Laboratory of South Carolina Department of Natural Resources analyzed all genetic material. USACOE conducted all locking throughout the year. We thank Kevin Dockendorf, Jeremy McCargo, and Chad Thomas for edits on previous drafts of this document.

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TABLE 1.—Total numbers of phase-I (25–75 mm TL) and phase-II (100–150 mm TL) Striped Bass stocked into the Cape Fear River system, 2001–2014. Note the hatchery staff observed high mortality of the 2004 year class post stocking and this year class likely failed.

Year	Broodfish Origin	Phase-I	Phase-II
2001	Roanoke	184,232	
2002	Roanoke	100,000	
2003	Roanoke	256,648	
2004	Roanoke	100,000	172,055
2005	Roanoke	109,000	
2006	Roanoke	164,575	102,283
2007	Roanoke	160,066	
2008	Roanoke	585,686	92,580
2009	Roanoke	218,562	112,674
2010	Cape Fear		210,105
2011	Cape Fear		130,665
2012	Cape Fear	57,384	127,078
2013	Cape Fear		195,882
2014	Cape Fear	211,726	141,752
Total		2,147,879	1,285,074
Combined Total			3,432,953

TABLE 2.—Long-term goals evaluating the impact of stocking utilizing endemic broodfish. Stocking utilizing broodfish from the Roanoke River (non-endemic) was conducted prior to 2010 while broodfish endemic to the Cape Fear River has been utilized since 2010. Evaluation periods are pre-endemic (2008-2012) and post-endemic (Goal; 2015-2019).

Mean (SE) or Frequency	Pre-endemic (2008-2012)	Goal (2015-2019)
CPUE (fish/h)	7.9 (± 0.8)	24
Percent of fish ≥ age-6	14.3	43
Cohorts represented	6 (± 0.7)	≥ 8

TABLE 3.—Weekly CPUE (fish/h) (SE) for Striped Bass for 2013 (A) and 2014 (B). Dates with and asterisk represents sampling events during optimal spawning temperatures (18-22°C). The value (na) represents no data was available.

(A)

Week	Effort (h)	Catch	M:F Ratio	Weekly CPUE (SE)	Lock and Dam 1		Lock and Dam 2		Lock and Dam 3		Buckhorn Dam		Number of Sites	Mean Water Temp (°C)	Mean Flow (cfs)
					Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE			
4/8/2013	1.5	0	na	na	0	0	0	0	0	0	na	na	3	14.4	7,065
4/15/2013*	1.5	14	10:1	9.3(9.3)	14	28	0	0	0	0	na	na	3	19.6	4,015
4/22/2013*	1.5	18	1.6:1	12(8)	14	24	2	4	2	4	na	na	3	18.8	3,385
4/29/2013	1.0	2	1:0	2(0)	na	na	1	2	1	2	na	na	2	17.1	9,810
5/6/2013	1.5	31	4:1	20.7(15.8)	26	52	1	2	4	8	na	na	3	17.5	4,985
5/13/2013*	1.5	25	1.1:1	16.7(13.7)	22	44	2	4	1	2	na	na	3	20.3	4,275
5/20/2013	1.5	8	2:1	5.3(0.7)	3	6	2	4	3	6	na	na	3	23.3	1,725
Total or Mean (SE)	10	98	2.3:1	9.4(2.9)	79	26.3(8.3)	8	2.7(0.7)	11	3.1(1.1)	na	na			5,037
Optimum Temp Mean CPUE				12.7(2.1)		33.3(5.3)		2.7(1.3)		2(1.2)	na	na			

(B)

4/7/2014	2.0	8	na	4(13.9)	7	14	0	0	0	0	1	0	4	16	6,947
4/14/2014	2.0	28	3:1	13.9(12)	25	50	3	6	0	0	0	0	4	16	8,767
4/21/2014	2.0	13	3:1	6.5(2.6)	7	14	2	4	1	2	3	6	4	15	10,519
4/28/2014*	1.9	24	3.3:1	12.6(4.2)	9	18	1	2	9	20	5	10	4	19	6,546
5/5/2014*	2.0	36	1.5:1	18(9.8)	23	46	4	8	8	16	1	2	4	20	3,724
5/12/2014	1.9	8	2:1	4.1(1.6)	2	4	4	8	0	0	2	5	4	25	3,257
5/19/2014*	2.0	9	8:0	4.5(1.7)	3	6	0	0	2	4	0	0	4	21	13,030
5/26/2014	1.5	40	2.5:1	26.5(14.6)	28	56	7	14	5	10	na	na	3	25	3,260
Total or Mean (SE)	15.3	166	2.5:1	11.3(2.9)	104	25.8(7.4)	21	5.3(1.7)	25	6.5(2.8)	12	3.5(1.4)			7,006
Optimum Temp Mean CPUE				11.7(4.4)		23.3(11.8)		3.3(2.4)		13.4(4.9)		4.0(23.1)			

TABLE 4.—Age composition of female and male Striped Bass for 2014 in the Cape Fear River. Female Striped Bass CPUE was ≤ 0.5 fish/h for all age classes while male Striped Bass CPUE was ≤ 1.1 fish/h for all age classes.

Females

Year Class	Age	N aged	Estimated N	Percent Composition	Total	Mean	SE	Min	Max
2013	1	0	0	0	0	0	0	0	0
2012	2	5	0	16	5	442	9	422	459
2011	3	3	0	10	3	479	36	403	528
2010	4	9	2	35	11	592	11	504	638
2009	5	2	0	6	2	650	13	637	664
2008	6	2	0	6	2	737	0	739	745
2007	7	4	2	19	6	745	5	728	757
2006	8	1	0	3	1	794	0	794	794
2005	9	1	0	3	1	720	0	720	720
Total		27	4	100	31				

Males

Year Class	Age	N aged	Estimated N	Percent Composition	Total	Mean	SE	Min	Max
2013	1	1	0	1	1	206	0	206	206
2012	2	11	0	14	11	471	19	372	571
2011	3	24	1	33	25	534	8	428	598
2010	4	23	1	32	24	554	11	483	703
2009	5	10	1	14	11	646	14	557	700
2008	6	3	0	4	3	637	14	620	670
2007	7	0	0	0	0	0	0	0	0
2006	8	1	0	1	1	700	0	700	700
Total		73	3	100	76				

TABLE 5.—Percent of Striped Bass vulnerable to harvest at different minimum length class scenarios. Each gender column is the percentage of that gender while the Total column includes males, females, and unknown gender. The fourth harvest scenario is a slot limit protecting fish from harvest that are < 458 mm and between 560-687 mm. English units are in parenthesis by length limits.

	Percent Vulnerable to Harvest		
Total Length in mm	Male	Female	Total
≥ 458 (18 in)	91%	84%	58%
≥ 560 (22 in)	43%	71%	33%
≥ 661 (26 in)	12%	35%	13%
≥ 458 (18 in); 560-687 (22-27 in)	54%	45%	33%
N	76	31	167

TABLE 6.—NCDMF creel survey on the Cape Fear River from March to May in 2013 and 2014. All effort is fishing trips and hours fished for all anglers interviewed while Striped Bass effort reports anglers targeting Striped Bass. Note that since there is a harvest moratorium there is no size or daily creel limits and all Striped Bass caught must be released. Construction at Lock and Dam 1 in March and April of 2013 prevented access at this site and an alternate boat ramp was used for anglers and creel clerks. This alteration likely influenced overall and Striped Bass effort as Lock and Dam 1 is the primary location Striped Bass fishing occurs.

Year	All Effort		Striped Bass Effort		
Month	Trips	Hours	Trips	Hours	Discards
2013					
March	8,958	33,293	0	0	0
April	9,102	40,116	92	399	81
May	3,272	26,417	165	470	274
Season	21,333	99,826	257	870	355
2014					
March	1,058	4,744	138	582	0
April	3,954	18,397	138	833	1,412
May	1,919	5,481	161	748	139
Season	6,931	28,622	438	2,164	1,551

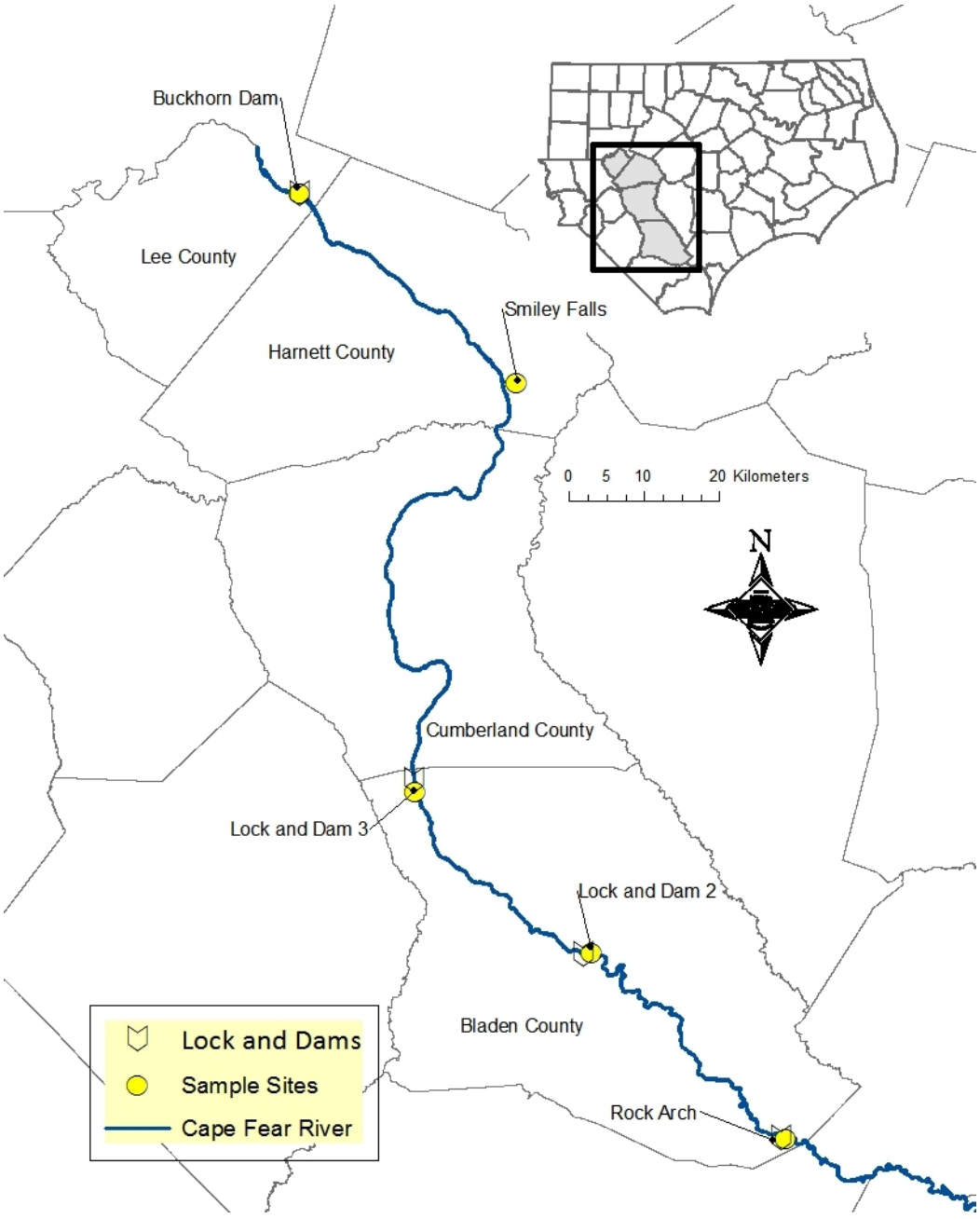

FIGURE 1.—Map of Striped Bass sampling sites, Lock and Dams 1, 2, and 3 on the Cape Fear River. The rock arch ramp was constructed at Lock and Dam 1.

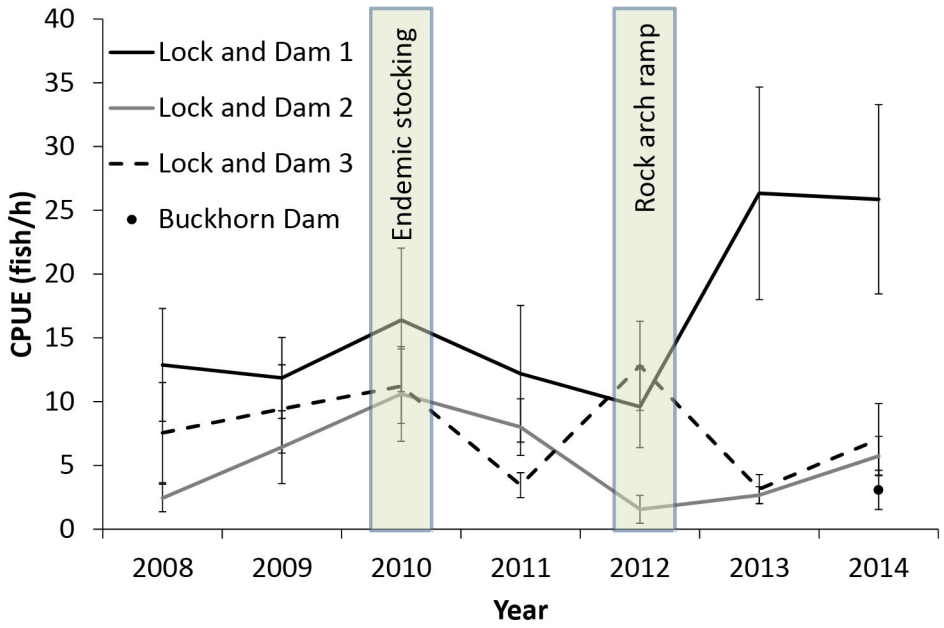

FIGURE 2.—Relative abundance (CPUE; fish/h) for each Cape Fear River sample site from 2008 until 2014. Stocking with progeny from endemic broodfish was initiated in 2010. In 2012, the rock arch ramp was completed at Lock and Dam 1 and locking at the location was suspended to evaluate fish passage. Buckhorn Dam site was added in 2014.

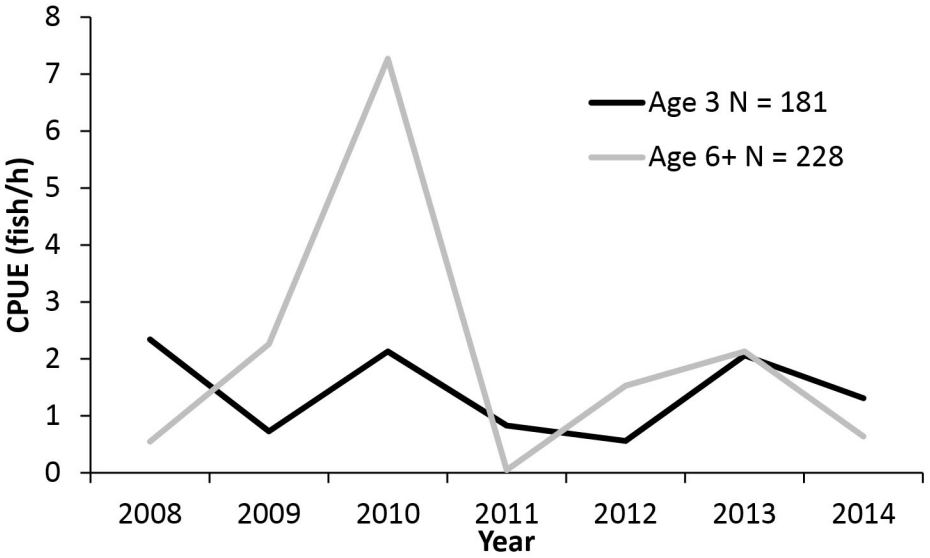

FIGURE 3.—Relative abundance of age-3 and 6+ Striped Bass in sample years 2008-2014.

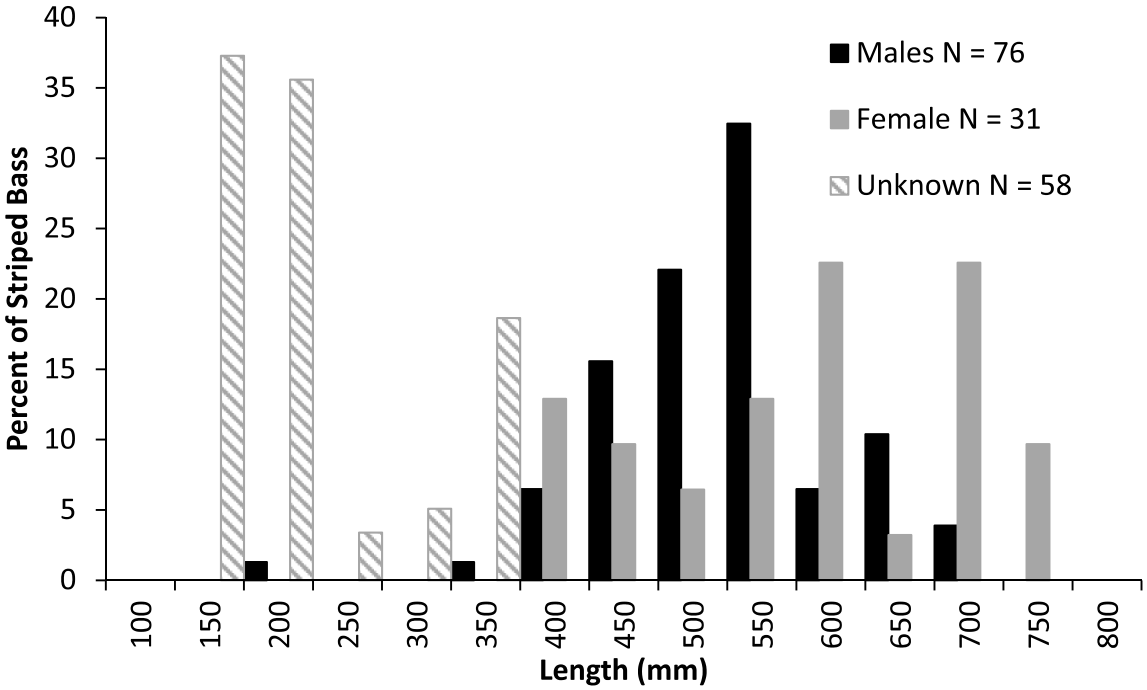

FIGURE 4.—Length frequency histogram for male, female, and unknown (sex undetermined) Striped Bass collected in 2014. Within-season recaptures (N = 2) were excluded. Each category is summed to 100%.

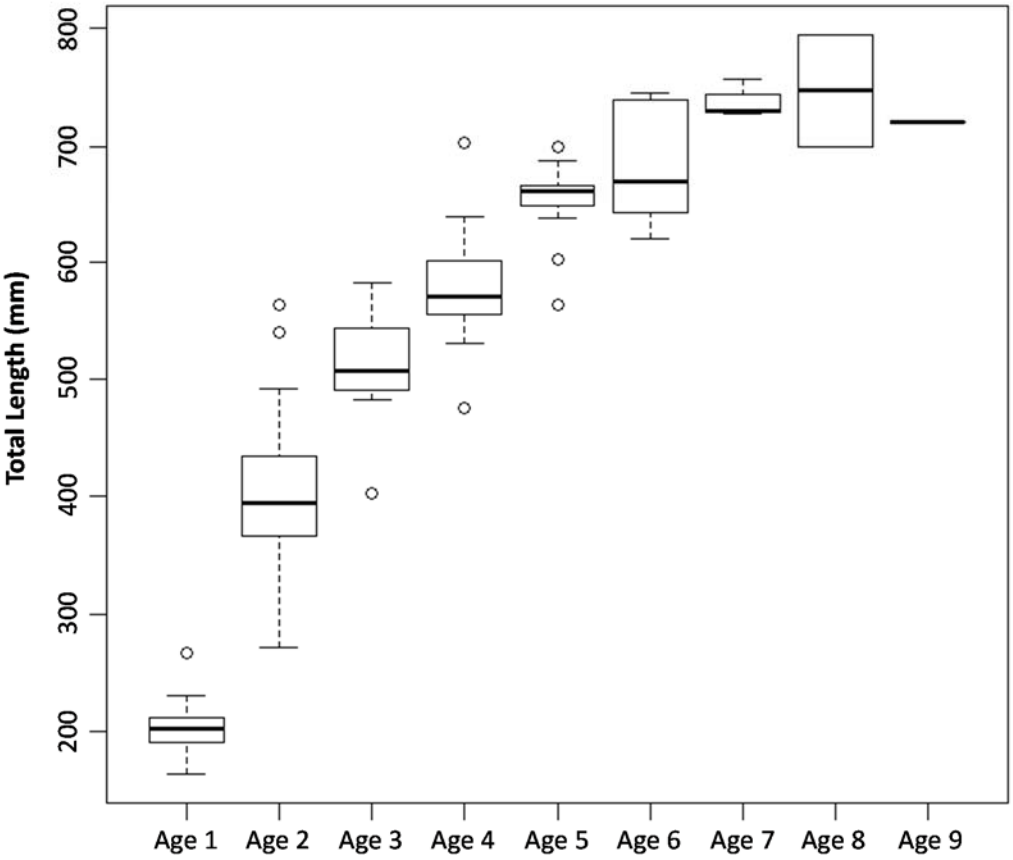

FIGURE 5.—Box and Whisker chart of 9 year classes of Striped Bass collected in the Cape Fear River in 2014. The values portrayed are the box showing the median in bold, and first and third quartiles, and the whiskers represent min and max values. Outliers are shown as circles.

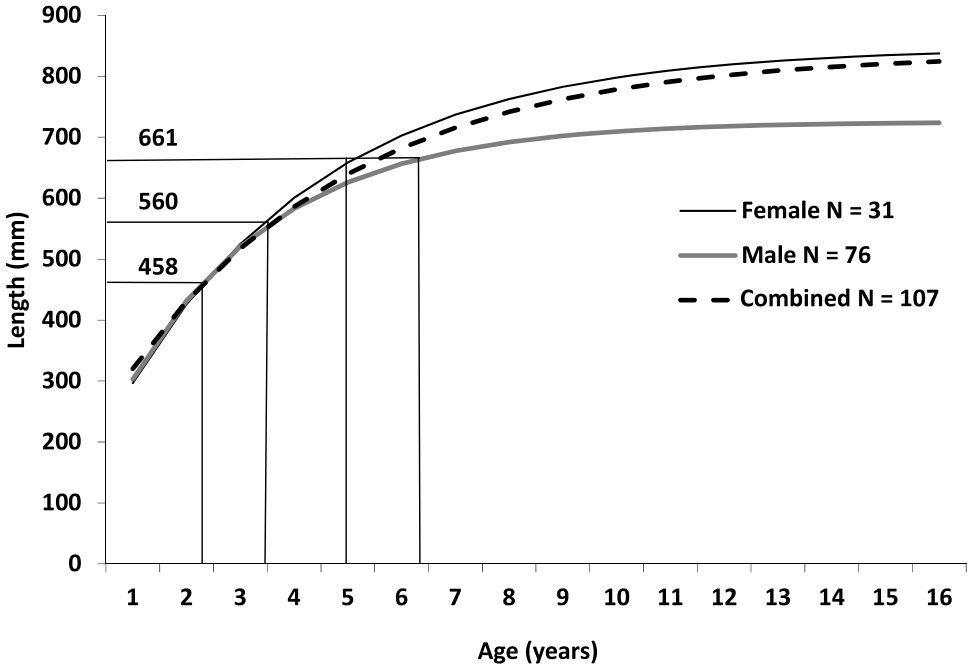

FIGURE 6.—Striped Bass von Bertalanffy growth models predicted for 2014 in the Cape Fear River. Parameter estimates are: Female: $L\infty = 847.46$, $k = 0.26$, and $t^0 = -0.61$, Male: $L\infty = 725.60$, $k = 0.36$, and $t^0 = -0.49$, Combined: $L\infty = 838.30$, $k = 0.34$, and $t^0 = -1.00$.

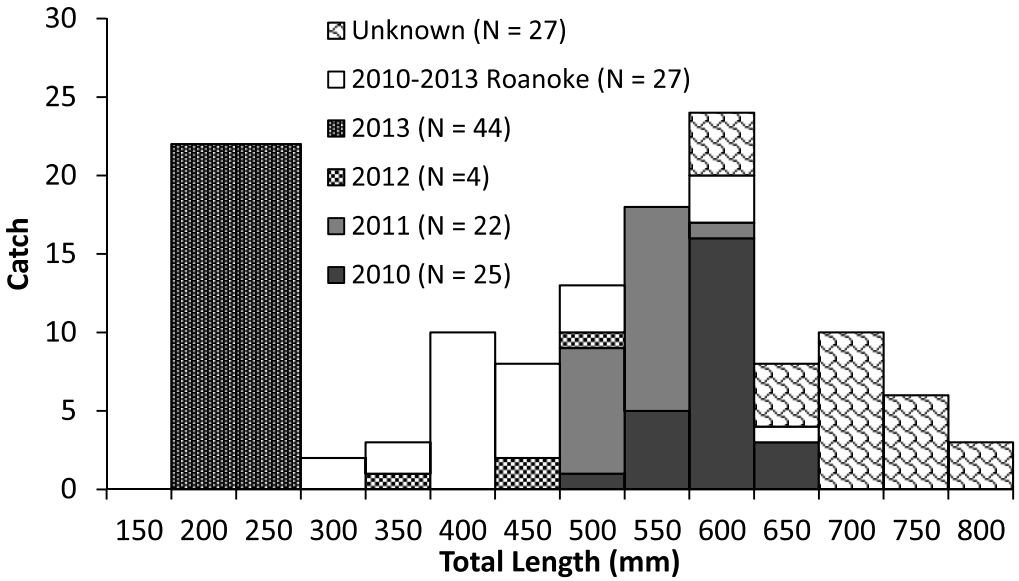

FIGURE 7.—Hatchery and unknown origin size classes from 2014 Commission spawning stock surveys.

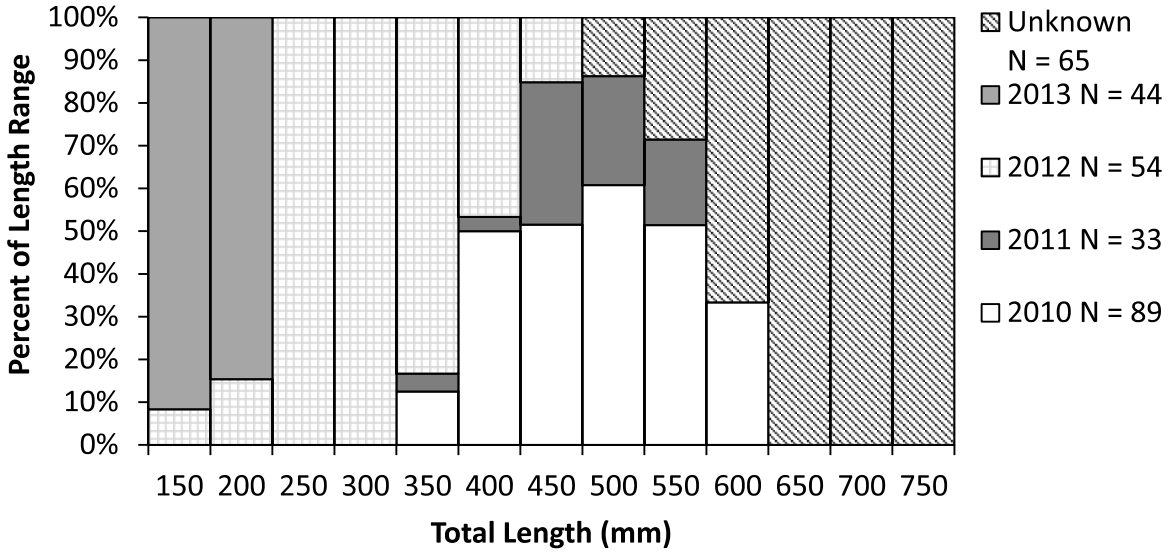

FIGURE 8.—Composition of hatchery and unknown origin Striped Bass derived from genetic genotyping from 2012-2014 Commission collections. Stocking utilizing endemic broodfish was initiated in 2010.

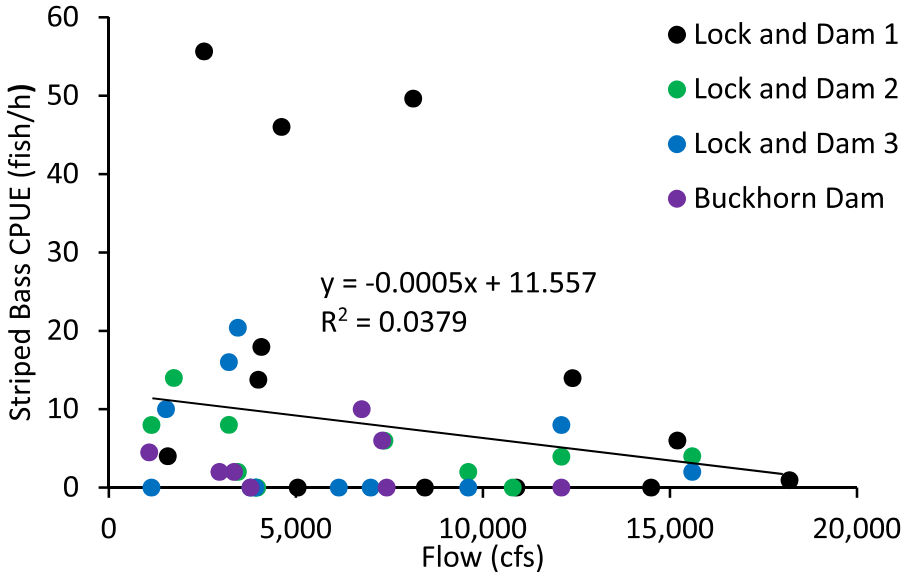

FIGURE 9.—Daily CPUE (fish/h) for each sampling site plotted against river flow.

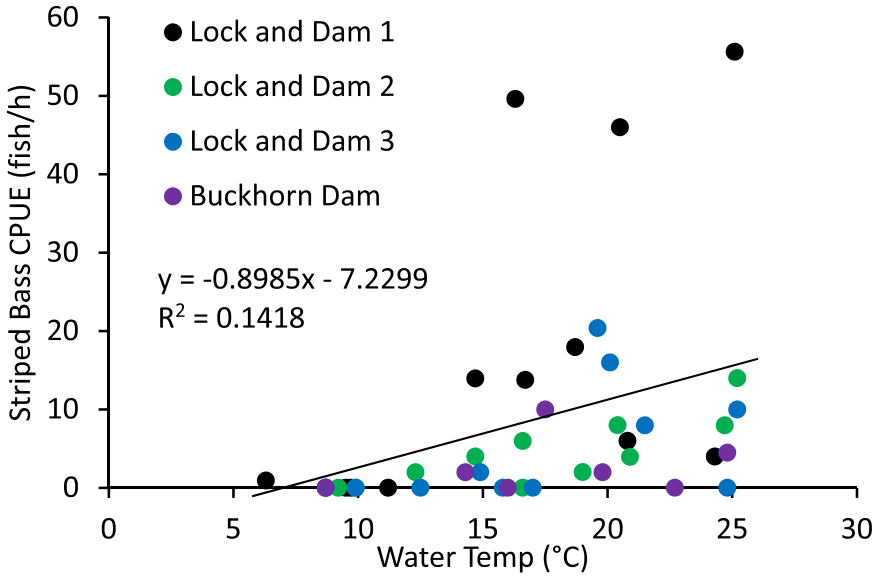

FIGURE 10.—Daily CPUE (fish/h) for each sampling site plotted against observed water temperature.

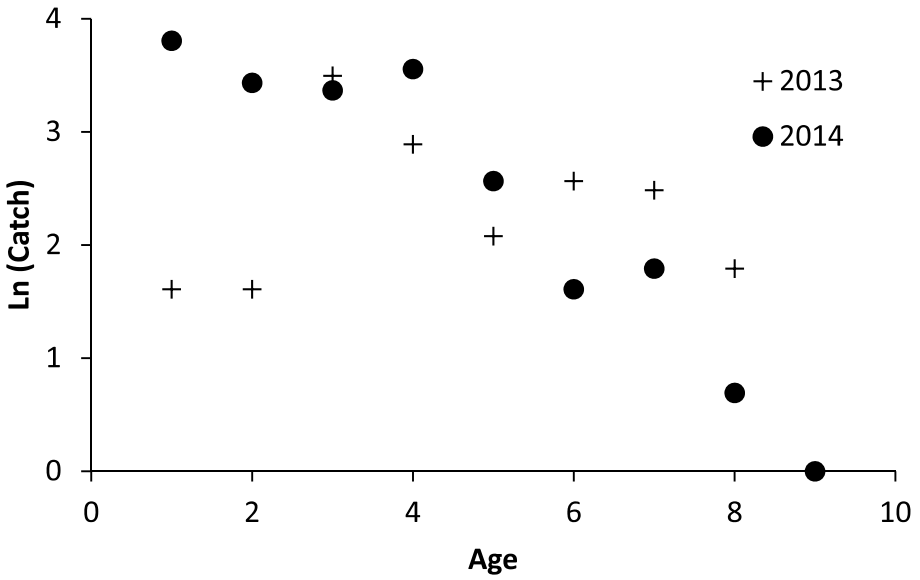

FIGURE 11.—Catch curves for 2013-2014 Striped Bass collected during spawning stock surveys. Instantaneous mortality (*Z*) for 2013 and 2014 was *Z* = 0.44 and *Z* = 0.47.

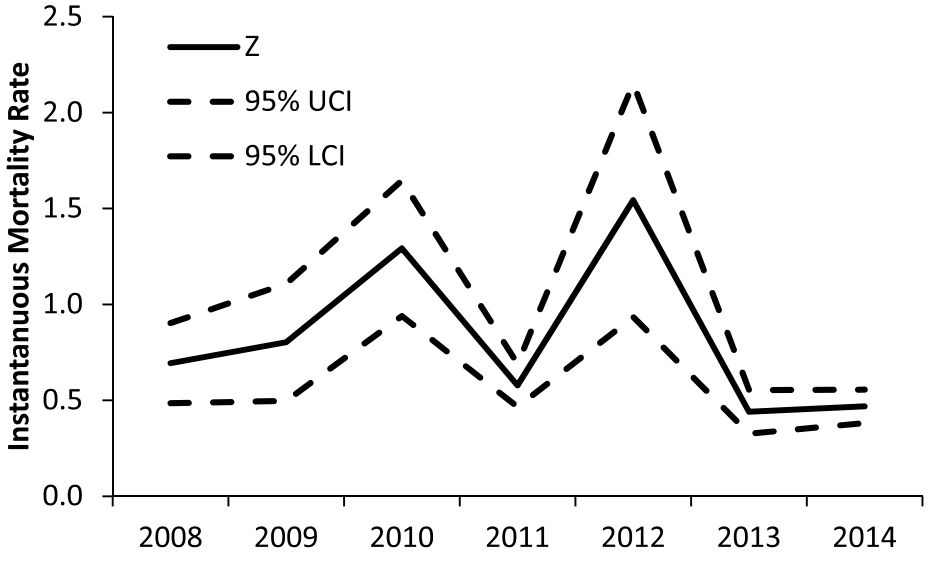

FIGURE 12.—Instantaneous mortality rates with 95% confidence intervals for Striped Bass collected during Commission spawning surveys from 2008-2014.

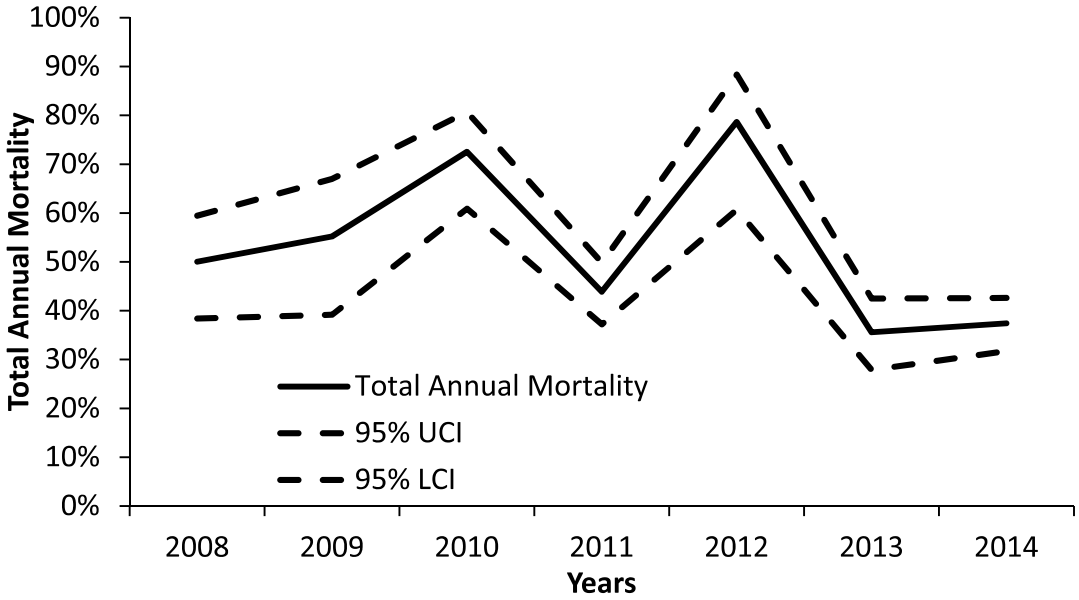

FIGURE 13.—Total annual mortality with 95% confidence intervals for Striped Bass collected during Commission spawning surveys from 2008-2014.

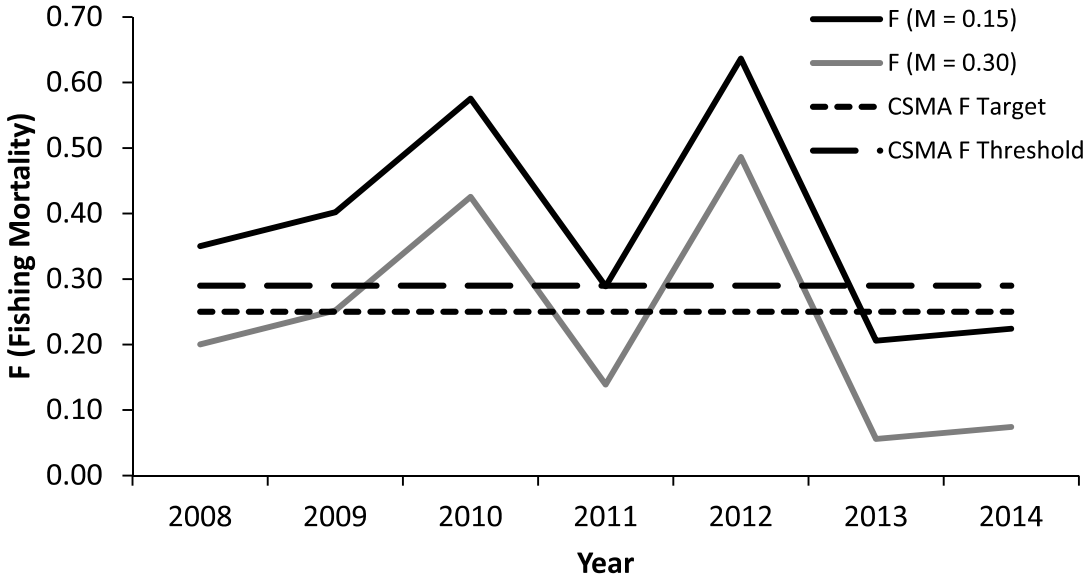

FIGURE 14.—Fishing mortality for Striped Bass at assumed natural mortality rates of M = 0.15 and M = 0.30 in the Cape Fear River 2008-2014. CSMA target F and F threshold adopted from the Albemarle Sound Stock are included as general bench marks. Since there has been a harvest moratorium since 2008, F is representing recreational and commercial catch and release mortality, as well as unknown causes of mortality.

APPENDIX A.—2014 Locking schedule for the Cape Fear River.

Due to the evaluation of fish passage at the rock arch rapids at Lock and Dam 1 being conducted by North Carolina State University there will be no locking at Lock and Dam 1.

Phase-I Lock Schedule:

Lock and Dam 2: January 1, 2014 through March 15, 2014
Lock and Dam 3: January 1, 2014 through March 22, 2014
Procedures: Phase-I operations will include one lockage per week according to the following schedule:

- 1400 to 1430 hours – close lower gates; open both upper gates to release fish upstream;
- 1530 and 1600 hours – close upper gates; open inside lower gate to attract fish into the lock chamber (leave gate open until 1400 the following day).

Phase-II Lock Schedule:
Lock and Dam 2: March 18, 2014 through May 17, 2014
Lock and Dam 3: March 25, 2014 through May 24, 2014
Procedures: Phase-II operations will involve three complete lockages daily, Monday through Friday according to the following schedule:

- 0700 to 0730 hours – close lower gate, open both upper gates to release fish upstream;
- 0830 to 0900 hours – close upper gates, open inside lower gate to attract fish into the lock chamber;
- 1200 to 1230 hours – close lower gate, open both upper gates release fish upstream;
- 1330 to 1400 hours – close upper gates, open inside lower gate to attract fish into the lock chamber;
- 1700 to 1730 hours – close lower gate, open both upper gates to release fish upstream;
- 1830 to 1900 hours – close upper gates, open inside lower gate to attract fish into the lock chamber (leave gate open until 0700 the following day).

Phase-I Lock Schedule Continued:
Lock and Dam 2: May 20, 2014 to Dec. 31, 2014
Lock and Dam 3: May 27, 2014 to Dec. 31, 2014
Procedures: Phase-I operations will commence again for a second period following the Phase-I weekly schedule identified earlier.