CHARACTERISTICS OF THE 2015 ROANOKE RIVER STRIPED BASS SPAWNING POPULATION

Federal Aid in Sport Fish Restoration
Project F-108
Report Type: Survey

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Raleigh

2016

Keywords: Striped Bass, Roanoke River, electrofishing, spawning stock assessment, coastal region.

This project was funded under the Federal Aid in Sport Fish Restoration Program utilizing state fishing license money and federal grant funds derived from federal excise taxes on fishing tackle and other fishing related expenditures. Funds from the Sport Fish Restoration Program are used for fisheries management and research, aquatic education, and boating access facilities. The program is administered cooperatively by the N.C. Wildlife Resources Commission and the U.S. Fish and Wildlife Service.

Abstract. — An electrofishing survey for spawning Striped Bass *Morone saxatilis* was conducted near Weldon, NC, in the spring of 2015. Weekly surveys collected a total of 1,867 Striped Bass. Males represented 86.9% of the total catch, while females represented 13.1%. Overall relative abundance of Striped Bass was 169.4 fish/h. Peak relative abundance of 307.8 fish/h occurred on May 4, 2015. The low CPUE in 2015 continued a decreasing trend in relative abundance that has been seen since 2006. Age analysis indicated that the 2015 population was composed mainly of age-3 (2012 year class; 42.7%) and age-4 (2011 year class; 44.3%) fish. Relative abundance of older fish (> age-9) was 1.46 fish/h and remained below the long-term average of 4.7 fish/h. In 2015, 41.2% of all males and 71.9% of all females were available for potential harvest, but only 0.74% of all males and 7.8% of all females were available for harvest above the protective slot limit (662 mm). Annual mortality estimates for the 1992 to 2009 cohorts ranged from 0.30 (1995) to 0.67 (2002). An increasing trend in cohort mortality was observed, with more recent year classes (2001–2009) having mortality rates above 0.50. High mortality rates experienced by recent cohorts are likely the cause in reduction in relative abundance of fish older than age 9.

The Albemarle-Roanoke (A/R) stock of Striped Bass *Morone saxatilis* is jointly managed by the North Carolina Wildlife Resources Commission (NCWRC) and the North Carolina Division of Marine Fisheries (NCDMF). The NCWRC is responsible for Striped Bass management in the Roanoke River Management Area (RRMA), while NCDMF manages Striped Bass in the Albemarle Sound Management Area (ASMA). As a requirement of the interstate fisheries management plan for Striped Bass (ASMFC 1981) and its associated amendment (ASMFC 2003) and addendum (ASMFC 2014), data from both agencies are combined to produce North Carolina's annual Striped Bass stock status report to the Atlantic States Marine Fisheries Commission (ASMFC). These data are combined with long-term population trends to calculate benchmark values for fishing mortality (F) and spawning stock biomass (SSB). In cooperation with the ASMFC Striped Bass Technical Committee and Management Board, approved benchmark values are incorporated into the North Carolina Estuarine Striped Bass Fisheries Management Plan for the A/R Striped Bass stock (NCDENR 2013). Total allowable landings (TAL) along with regulations to control harvest (length, harvest season, and creel limits) may be adjusted to comply with the approved benchmark values.

The NCWRC conducts two annual surveys for Striped Bass on the Roanoke River; a creel survey to evaluate the recreational harvest throughout the RRMA, and the spawning stock assessment of the segment of the population migrating to the spawning grounds near Weldon, NC. Unlike previous years, these two surveys will be contained in two separate documents. The results of the annual creel survey were summarized by Dockendorf et al. (2016), while this report documents and summarizes the results from the annual NCWRC electrofishing survey. The objective of this survey was to characterize the spawning portion of the A/R stock in the RRMA by estimating relative abundance, age-structure, and size-structure. Cohort mortality for the Roanoke River Striped Bass population was also estimated in this report.

Methods

Spawning Stock Assessment.—Striped Bass were sampled weekly from April 13 to May 18, 2015. Sampling started once water temperatures reached 15°C and continued until Striped Bass spawning was complete, which usually occurs when water temperatures surpassed the optimal spawning temperature (22°C). A boat mounted electrofishing unit (Smith-Root 7.5 GPP, one netter) was used to collect Striped Bass from their historic spawning grounds near Weldon, NC (Figure 1). Sampling stations were located on main and secondary river channel habitats (strata). A total of three strata were sampled each day, and strata selection was dependent on flow conditions. Flows of approximately 7,000 ft^3/s (cfs) or less restricted access to strata above the rapids near the Weldon boating access area (Figure 1). Two sites were selected within each stratum for a total of six sampling sites per day.

At each station, all Striped Bass were netted and placed into an oxygenated holding tank until they could be transported to a nearby workup boat. All Striped Bass were measured for total length (TL, mm), and sex was determined by assessing the presence of eggs or milt when pressure was applied to the fish's abdomen. Weight (kg) and scales (dorsal area) were obtained from a subsample of up to five fish in each 25-mm size group per sex per sampling date. In addition, scales and weights were collected for every fish greater than 700 mm. Scales were removed from the left side of the fish between the lateral line and dorsal fin and stored in

numbered envelopes. All fish were tagged with a NCDMF internal anchor tag following NCDMF Striped Bass tagging protocols (Winslow 2010). If a fish was recaptured from a previous year, scales were taken from the right side of the fish and tag number was recorded. Tags that were deemed illegible were cut at the base of the tag, and a new tag was inserted. In-season recaptures were recorded but excluded from analyses. The tagging project is administered by NCDMF, and as such, no project objectives or results will be shared within this report (See Winslow 2010; Callihan et al. 2014). Striped Bass scales were pressed and aged following standard protocol (NCWRC and NCDMF 2011). Scales were aged using an EyeCom 3000 microfiche reader at 24X and 36X magnification. The primary reader aged up to 15 individuals per 25-mm length group per sex, and a subsample (20% of aged scales) was aged by a secondary reader for age verification. Discrepancies between the primary and secondary ages of the subsample were reconciled in concert by the two readers.

Relative abundance of Striped Bass was indexed by catch-per unit-effort (CPUE) and was expressed as the number of fish captured per hour of electrofishing (fish/h). Overall CPUE (total fish collected/hours of electrofishing effort) for all sample sites as well as daily CPUE were calculated. Additionally, a 3-week mean of CPUE (peak CPUE ± 1 week) was calculated and compared to previous years. Mean daily water temperature (°C) was calculated from temperature values collected at each sampling site. Mean daily discharge (cfs) was recorded from the U.S. Geological Survey gaging station (02080500) at Roanoke Rapids, NC. An age-length key created from scale age data was applied to any unaged fish to complete age distributions for male and female Striped Bass. Mean lengths at age were calculated for males and females of the entire 2015 sample using methods described by Bettoli and Miranda (2001).

Cohort Mortality.—Annual mortality (*A*) was estimated for each Striped Bass cohort from 1992 to 2009 using the Chapman-Robson mortality estimator and variance inflation factor as described by Smith et al. (2012). Using this method, age of full recruitment is the age of maximum catch plus 1 year (peak plus method), and at least three years of data are needed following the age of full recruitment. Thus, 2010–2014 cohorts were excluded from the analysis. Scale age data collected during the NCWRC annual electrofishing surveys from 1993 to 2015 was used for the cohort mortality analysis. Relative abundance (CPUE; fish/h) for each age of a cohort was used instead of the conventional catch-at-age data to account for any biases due to changes in sampling effort over the time period.

Broodfish Collection.—Collections of Striped Bass brood fish utilized for stocking programs in both North Carolina and Virginia were conducted concurrently during the 2015 spawning stock survey on April 20, April 27, and May 5, 2015. Broodfish collected from spawning survey sample sites were included in all analyses. However, broodfish collected outside of normal survey protocols were excluded from analyses.

Results

Spawning Stock Assessment.—Electrofishing in the spring of 2015 yielded a total of 1,868 Striped Bass in 11.02 hours of sampling. Males made up 86.9% of the sample (N=1,626), while females accounted for 13.1% (N=242). Overall relative abundance of Striped Bass was 169.5 fish/h (1,868 fish/11.02 h). The peak in daily pooled CPUE was 307.8 fish/h and occurred on May 4, 2015, when average water temperature was approximately 17.0°C (Table 1). Mean peak

CPUE ± 1 week was 248.4 fish/h (SE=32.3). Water temperatures remained within the spawning range throughout the entire sampling period. Flows in the Roanoke River were fairly stable for the first four weeks of the survey period but dropped significantly during the last two weeks (Table 1). Low flow conditions (2,959 cfs) during the May 18 sampling date restricted sampling to sites below the rapids in proximity of the Weldon boating access area.

A total of 294 Striped Bass were aged by the primary reader, and a subsample of 76 Striped Bass were aged by a secondary reader. Exact agreement between the two readers was 78%, while initial agreement ± 1 year was 93%. Age discrepancies were rectified in concert, and 100% agreement was achieved for the subsample. Final ages from the subsample (double reads) were similar to the full sample (single reads; Figure 2), indicating adequate precision of the primary reader's ages. Analysis of the 2015 age data indicated 11 year classes of Striped Bass were present during the spawning stock assessment. The age distribution ranged between 1 and 14 years (Figure 3). The 2011 cohort (age 4) made up the majority (44.3%) of the fish collected in 2015 and was the main contributor to the overall relative abundance with a CPUE of 77 fish/h (Table 2). The 2012 cohort (age 3) was the other major contributor to the catch (42.7%) and overall abundance (72.2 fish/h). The remaining ages (1 and 5–14) made up only 12.9 % of the entire 2015 catch.

Female Striped Bass collected in 2015 were represented by 10 year classes (ages 3–10, 12, and 14), while males were represented by 9 year classes (ages 1 and 3–10). The female catch was dominated by the age-4 cohort (2011 year class), which represented 48.1% of all females (Table 3). Age-3 (2012 year class) and age-5 (2010 year class) females comprised 18.1% and 16.5% of the female age distribution, respectively. Fish older than age 6 represented 17.3% of the female Striped Bass catch. Male Striped Bass were mainly represented by the 2011 (age-4) and 2012 (age-3) year classes, which accounted for 45.5% and 45.1% of the male catch, respectively. Striped Bass older than age 5 represented 9.4% of the total male catch (Table 3). Relative abundance of Striped Bass $\geq$ age 9 increased slightly from 2014 but was well below the long-term average of 4.7 fish/h and was much lower than peak values seen between 2002 and 2008 (Figure 4).

In 2015, male and female Striped Bass exhibited variable growth rates. Annual growth rates for females < age 8 ranged 34–92 mm, while male growth rates ranged 45–63 mm. Mean length at age was higher for females than males, and differences in size between males and females were greater for larger fish (Table 3). Mean length at age for year classes examined since 1991 has shown minor annual variation in growth rates between year classes. As seen in 2014 (McCargo and Dockendorf 2015), total lengths of the 2010 (age-5) and 2011 (age-4) year classes continued to be below the long-term average (Tables 4 and 5). Mean weights (calculated for a subsample of fish in 2015) for males and females were similar for Striped Bass ages 2–8, but older females (≥ age 9) were heavier than the males from the same year class (Table 6).

In 2015, the length distribution for males was unimodal, while the female length distribution was bimodal. The peak in the male length distribution was between 400 mm and 499 mm (Figure 5). Based on length-at-age analysis, the peak in male distribution was composed of mainly the 2011 (age-4) and 2012 (age-3) year classes. The number of males of harvestable size was low in 2015 with 28.1% between 450 and 550 mm and only 0.7% available above the protective slot. Males larger than 625 mm TL were scarce in 2015. The primary peak

in female distribution was from 450 mm to 549 mm (Figure 5). These fish were likely from the 2010 (age-5) and 2011 (age-4) year classes. The second peak in female length distribution occurred from 575 mm to 649 mm and were likely age-5 and age-6 (2009 and 2010 year classes). A total of 71.9% of females collected in the electrofishing surveys were available for harvest in 2015, with 64% of the females available below the protective slot. Females above the slot limit accounted for 7.8% of the total female catch. Striped Bass within the protective slot limit accounted for 4% of the male and 15% of the female catch, yet 5% of the total Striped Bass catch during the 2015 sampling season were within the protective slot limit.

Cohort Mortality.—Annual mortality estimates and 90% confidence intervals were calculated for the 1992–2009 cohorts. Age of full recruitment ranged from age 3 to age 5, with age 4 being the fully recruited age in 83% of the cohorts (Table 7). The number of ages used for each cohort varied from three to twelve, with the more recent cohorts having fewer age classes available for inclusion in the analyses (Table 7). Mortality ranged from 0.30 (1995 cohort) to 0.67 (2002 cohort). The 1992 to 2000 cohort mortalities were low and ranged from 0.30 to 0.39. However, the 2001 to 2009 cohorts have experienced higher mortality rates ranging from 0.47 to 0.67, with all but one year class experiencing mortalities of 0.50 or greater (Table 7).

Broodfish Collection.—Collection of female broodfish continued to be difficult in 2015 as significant time was spent searching for female broodfish of ideal weight (4.0–10 kg). A total of 10 females (608–1,092 mm; 3.27 kg – 18.1 kg) and 21 males (412–508 mm) were transported to the NCWRC Watha State Fish Hatchery for spawning purposes to meet statewide Striped Bass and Hybrid Striped Bass production goals (Evans 2015). A total of four females (679–895 mm) and 12 males (409–511 mm) were transported to the Virginia Department of Game and Inland Fisheries hatchery in King and Queen County. All but seven females and 20 males were captured outside normal sampling protocols. Total weight of the broodfish removed from the Roanoke River was 137.9 kg (females = 101.7 kg and males = 36.2 kg) or 304.0 lb. Thirty male Striped Bass (31.5 kg) were also removed for a collaborative research project within our agency.

Discussion

The decreasing trend in relative abundance of Roanoke River Striped Bass that has been evident since 2006 continued in 2015 (Figure 6). A slight increase in relative abundance was observed in 2014 (McCargo and Dockendorf 2015), but relative abundance in 2015 was lower than the 2014 value and was similar to values observed in 2011–2013. Because the Roanoke River Striped Bass spawning stock has been largely composed of males (86.9 % in 2015), long term trends in male CPUE closely mimic overall CPUE trends (Figure 6). Female CPUE increased from 14.1 fish/h in 2014 (McCargo and Dockendorf 2015) to 21.9 fish/h in 2015. Despite the slight increase in female CPUE observed in 2015, the decreasing trend seen over the past six years continued, and female CPUE was well below the long-term average of 36.9 fish/h. The spawning stock in 2015 was comprised mainly (87%) of age-3 (2012 YC) and age-4 (2011 YC) fish. The relative abundance of Striped Bass > age 9 has decreased in the past several years and is similar to pre-2000 values. Reductions in relative abundance of Striped Bass on the Roanoke River spawning grounds is most likely caused by low abundance of fish older than age 4 in the population.

Two distinct trends in annual mortality were observed for the year classes examined in the cohort mortality analysis. Mortalities of the 1992–2000 year classes were consistently low, with estimates near 0.35, while mortalities for the 2001–2009 year classes were higher and more variable, ranging 0.47–0.67 (Figure 7). The cohorts with lower mortalities were present in the fishery when the stock was rebuilding, harvest quotas were lower, and regulations were more restrictive; thus, cohorts from the 1990s were provided more protection and experienced lower mortality rates. Those cohorts also provided years of age structure expansion within the Roanoke River population because a substantial portion of each cohort was able to survive to older ages. Most of the fish from the 1990s cohorts, however, have now aged out of the population and no longer contribute to the Roanoke River spawning stock. The cohorts with the higher mortalities have experienced higher fishing pressure due in part to designation of the population in 1997 as "recovered", and subsequent increases in harvest quotas and less restrictive regulations. The high mortalities experienced by these cohorts have likely been the cause of the decreasing trend in relative abundance as well as the contraction of the age structure documented in the last several years of spawning stock assessments (McCargo and Dockendorf 2013, 2014, 2015). Cohort mortality analyses may be improved by the use of otolith ages because of known inaccuracies and bias associated with the use of scale ages compared to otolith ages (Welch et al. 1993; Secor et al. 1995). Nevertheless, we feel confident that recent Roanoke River Striped Bass cohorts have experienced high levels of annual mortality compared to earlier years, when the stock was rebuilding and harvest was lower. The contribution of important variables that regulate cohort mortality and abundance on the spawning grounds such as commercial harvest, bycatch of Striped Bass in commercial fisheries, and reproductive success were not examined within this report.

In 2014, the benchmark stock assessment for A/R Striped Bass indicated that a TAL of 550,000 lb was unsustainable (Mroch and Godwin 2014). To address the stock assessment results and declining trends in survey abundance and landings (NCDENR 2013), changes were made to the TAL and biological reference points (F_{Target} and $F_{Threshold}$). Starting on January 1, 2015, a lower TAL of 275,000 lb was split between the ASMA commercial fishery (137,500 lb) and the recreational fishery in both the ASMA and RRMA (68,750 lb each). Biological reference points associated with the lower TAL will be produced during the next benchmark stock assessment. The reductions in the TAL were established with the attempt to achieve spawning stock biomass estimates similar to those calculated in 1997, while allowing for 25% expansion above those numbers. Despite the decreasing trends of female and older fish, recent NCDMF sampling results from seine and trawl surveys in Albemarle Sound reported some of the highest juvenile abundance index values on record in 2014 (NCDMF 2015) and 2015 (C. Godwin, NCDMF, personal communication). These two potentially large year classes coupled with a reduction of the TAL in 2015 have the potential to increase relative abundance of the Roanoke River spawning population in the near future and improve population recruitment and age expansion. However, juvenile abundance is often not correlated with year class strength at age 3 or age 4 on the spawning grounds because of the variable mortality that likely occurs between the young of year and adult life stages. Mortality of these strong cohorts as well as other cohorts remaining in the population should be assessed annually to determine if the harvest reduction leads to an increase in abundance of the Roanoke River spawning population.

Management Recommendations

1. Maintain the current harvest season for Striped Bass in the RRMA from 1 March–30 April, despite the reduction in the Total Allowable Landings. Monitor and document the Striped Bass population under current TAL levels of 68,750 lb.
2. Maintain the current size and creel regulations for Striped Bass in the RRMA. However, conduct a thorough analysis of the slot limit effects on population size structure given the continued absence of fish within the protective slot limit. Collaborate with NCDMF to explore and model the effects of minimum length limit changes on spawning stock biomass in the Roanoke River and Albemarle Sound.
3. Continue coordination efforts with U.S. Army Corps of Engineers and other Roanoke River stakeholders to provide flow conditions that will be favorable for successful Striped Bass year class production in 2016.
4. Continue to provide opportunities for Roanoke River broodfish collections to Watha State Fish Hatchery to meet the division's production goals, yet provide flexibility for hatchery staff to consider alternative broodfish sources.
5. Subsample Striped Bass less than 400 mm to examine sex by dissection in 2016.

Acknowledgments

We thank Kevin Dockendorf and Chad Thomas for reviewing and commenting on this report. We would also like to thank Kyle Rachels for his assistance and comments regarding mortality estimates and the associated methods. We would also like to thank Charlton Godwin and NCDMF staff for assistance in tagging and data collection during the spawning stock survey.

References

ASMFC (Atlantic States Marine Fisheries Commission). 1981. Interstate fisheries management plan for the Striped Bass. National Marine Fisheries Service (NMFS) cooperative agreement NA-80-FA-00017.

_____. 2003. Supplement to the ASMFC Striped Bass Fisheries Management Plan – Addendum Fisheries Management Report No. 41. ASMFC, Washington, DC.

_____. 2014. Addendum IV to Amendment 6 to the Atlantic Striped Bass Interstate Fishery Management Plan. Atlantic States Marine Fisheries Commission, Arlington, Virginia.

Bettoli, P.W., and L.E. Miranda. 2001. Cautionary note about estimating mean length at age with subsampled data. North American Journal of Fisheries Management 21:425-428.

Callihan, J.L., C.H. Godwin, and J.A. Buckel. 2014. Effect of demography on spatial distribution: movement patterns of the Albemarle Sound-Roanoke River stock of Striped Bass (*Morone saxatilis*) in relation to their recovery. Fisheries Bulletin 211:131-143.

Dockendorf, K.J., K.J. Linehan, and J.M. Hadley. 2016. Roanoke River Striped Bass Creel Survey, 2015. North Carolina Wildlife Resources Commission, Federal Aid in Sport Fish Restoration, Final Report, Raleigh.

Evans, J.F. 2015. Striped and Bodie Bass fry production report, 2015. North Carolina Wildlife Resources Commission, Federal Aid in Sport Fish Restoration, Final Report, Raleigh.

Mroch, R., and C.H. Godwin. 2014. Stock Status of Albemarle Sound-Roanoke River Striped Bass. North Carolina Division of Marine Fisheries, Morehead City.

McCargo, J.W., and K.J. Dockendorf. 2013. A Review of Striped Bass Fisheries and Monitoring Programs in the Roanoke River, North Carolina-2012. North Carolina Wildlife Resources Commission, Federal Aid in Sport Fish Restoration, Final Report, Raleigh.

_____. 2014. A Review of Striped Bass Fisheries and Monitoring Programs in the Roanoke River, North Carolina-2013. North Carolina Wildlife Resources Commission, Federal Aid in Sport Fish Restoration, Final Report, Raleigh.

_____. 2015. A Review of Striped Bass Fisheries and Monitoring Programs in the Roanoke River, North Carolina-2014. North Carolina Wildlife Resources Commission, Federal Aid in Sport Fish Restoration, Final Report, Raleigh.

NCDENR (North Carolina Department of Environment and Natural Resources). 2013. Amendment 1 to the North Carolina Estuarine Striped Bass Fishery Management Plan. North Carolina Division of Marine Fisheries and North Carolina Wildlife Resources Commission, Morehead City.

NCDMF (North Carolina Division of Marine Fisheries). 2015. Review of Striped Bass fisheries and monitoring programs in North Carolina—2014. Report to the ASMFC Striped Bass Technical Committee, North Carolina Division of Marine Fisheries, Elizabeth City, North Carolina.

NCWRC (North Carolina Wildlife Resources Commission) and NCDMF (North Carolina Division of Marine Fisheries). 2011. Estuarine Striped Bass in North Carolina: Scale ageing methods, version 4.0. North Carolina Wildlife Resources Commission, Federal Aid in Sport Fish Restoration, Final Report, Raleigh.

Secor, D.H., T.M. Trice, and H.T. Hornick. 1995. Validation of otolith-based ageing and a comparison of otolith and scale-based ageing in mark-recaptured Chesapeake Bay Striped Bass, *Morone saxatilis*. Fishery Bulletin 93:186-190.

Smith, M.W., A.Y. Then, C. Wor, G. Ralph, K.H. Pollock, and J.M. Hoenig. 2012. Recommendations for catch-curve analysis. North American Journal of Fisheries Management 32:956–967.

Welch, T.J., M.J. van den Avyle, R.K. Betsill, and E.M. Driebe. 1993. Precision and relative accuracy of Striped Bass age estimates from otoliths, scales, and anal fin rays and spines. North American Journal of Fisheries Management 13:616-620.

Winslow, S.E. 2010. North Carolina Striped Bass tagging and return summary, January 1980-September 2010. North Carolina Division of Marine Fisheries, Final Report, Morehead City.

TABLE 1.—Daily pooled CPUE (daily catch/daily effort) of Striped Bass collected by electrofishing on the Roanoke River spawning grounds during 2015. Mean daily discharge was reported from the US Geological Survey gaging station at Roanoke Rapids, NC.

Date	Effort (h)	Catch	Pooled CPUE	Discharge (cfs)	Water temperature (°C)
4/13/2015	2.1	28	13.0	8,335	15.0
4/20/2015	1.9	356	189.5	11,112	16.9
4/27/2015	1.8	434	240.8	11,831	15.4
5/4/2015	1.5	470	307.8	8,787	17.0
5/12/2015	1.9	379	196.5	5,032	20.3
5/18/2015	1.7	200	115.2	2,959	22.6
Total	11.0	1868			

TABLE 2.—Striped Bass age distributions (percent composition) and relative abundance (CPUE; fish/h) of 9 male year classes and 10 female year classes collected by electrofishing on the Roanoke River spawning grounds, 2015.

		Percent composition			CPUE (fish/h)		
Year Class	Age	Male	Female	Overall	Male	Female	Overall
2014	1	0.1		0.1	0.1		0.1
2013	2						
2012	3	39.5	2.4	41.9	66.9	4.0	70.9
2011	4	39.2	6.3	45.5	66.4	10.6	77.0
2010	5	4.6	2.1	6.8	7.8	3.6	11.4
2009	6	2.1	0.5	2.6	3.5	0.9	4.5
2008	7	0.9	1.0	1.9	1.5	1.7	3.3
2007	8	0.2	0.2	0.4	0.3	0.4	0.6
2006	9	0.2	0.2	0.4	0.4	0.3	0.6
2005	10	0.2	0.1	0.3	0.3	0.2	0.5
2004	11						
2003	12		0.1	0.1		0.2	0.2
2002	13						
2001	14		0.1	0.1		0.2	0.2
Totals		86.9	13.1	100	147.2	22.0	169.5

TABLE 3.—Age composition and mean total length (mm) of 9 year classes of male Striped Bass and 10 year classes of female Striped Bass collected by electrofishing on the Roanoke River spawning grounds, 2015.

Males

Year Class	Age	Number aged	Number estimated	Number total	Percent composition	Total Length (mm) Mean	SD	Min.	Max.
2014	1	1	0	1	0.1	245	0	245	245
2013	2								
2012	3	54	683	737	45.4	434	29	365	541
2011	4	47	685	732	45.1	464	31	378	717
2010	5	26	60	86	5.3	528	33	493	623
2009	6	22	17	39	2.4	578	44	535	718
2008	7	13	4	17	1.1	630	28	575	686
2007	8	3	0	3	0.2	770	104	682	893
2006	9	4	0	4	0.3	775	92	702	909
2005	10	3	0	3	0.2	912	125	798	1,034
Total		173	1,449	1,622	100				

Females

Year Class	Age	Number aged	Number estimated	Number total	Percent composition	Total Length (mm) Mean	SD	Min.	Max.
2012	3	21	23	44	18.1	454	31	399	510
2011	4	44	73	117	48.1	497	31	417	593
2010	5	21	19	40	16.5	534	38	463	606
2009	6	9	1	10	4.1	607	51	549	688
2008	7	15	4	19	7.8	670	80	611	906
2007	8	2	2	4	1.6	787	100	740	930
2006	9	3	0	3	1.2	929	58	872	968
2005	10	2	0	2	0.8	1,012	35	997	1,045
2004	11								
2003	12	2	0	2	0.8	1,137	35	1,106	1,156
2002	13								
2001	14	2	0	2	0.8	1,112	71	1,060	1,168
Total		121	122	243	100				

TABLE 4.—Mean total length (mm) at age for male Striped Bass year classes collected in Roanoke River from 1991–2015. Only those year classes with four or more individuals aged are included.

Year Class	Age 1	2	3	4	5	6	7	8	9	10	11	12
1988			465	510	545	573	581					
1989		384	445	495	523	553	586	623				
1990		383	452	494	525	560	597	647				
1991		397	450	483	539	569	613	646				
1992		397	450	474	543	579	610	682	755	805	901	
1993		373	428	511	535	573	617	661	737	800		
1994		311	462	488	537	569	608	647	740	806	867	
1995		383	435	496	534	564	616	656	758	833	845	
1996		382	441	495	530	563	611	649	711	808	826	927
1997		369	450	489	527	569	596	644	744	799	839	
1998		387	438	486	531	553	601	670	746	807		957
1999	316	389	450	490	524	565	618	666	760	815	876	
2000		352	439	491	529	567	616	640	727		812	
2001	291	369	441	489	536	573	609	646	715	812		
2002	304	379	445	491	523	569	598	648	702			
2003		386	438	485	525	570	615	687				
2004		352	428	479	531	570	612	752				
2005	286	365	436	492	532	531	593					
2006	278	362	445	492	519	577	649		775			
2007	307	377	446	492	533	587	616					
2008	306	373	453	498	522	567	630					
2009	310	417	464	500	533	578						
2010		319	399	466	528							
2011		332	413	464								
2012		375	434									
2013												
2014												
Mean	300	371	442	490	531	567	609	660	739	809	852	942
Min.	278	311	399	464	519	531	581	623	702	799	812	927
Max.	316	417	465	511	545	587	649	752	775	833	901	957

TABLE 5.—Mean total length (mm) at age for female Striped Bass year classes collected in Roanoke River from 1991–2015. Only those year classes with four or more individuals aged are included.

Year Class	Age 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1988			493	524	578	592	621		749								
1989		399	473	518	549	580	626	665					1,033				
1990		414	472	513	545	596	626	671	773								
1991		376	478	503	553	597	631	693		856	936	975	1,005				
1992		447	466	511	572	595	638	729	778	883	933	979					
1993		375	441	536	551	602	664	705	789	883	938	990	1,059	1,024	1,112		
1994			469	507	563	616	636	696	798	882	937	1,012	1,039	1,043	1,098	1,133	
1995		381	462	513	573	584	629	697	798	890	950	995	1,040	1,051	1,132		1,092
1996		423	476	531	541	586	644	704	780	875	945	979	1,037	1,058	1,041	1,137	
1997		429	472	512	546	583	636	685	785	870	927	996	1,027	1,070	1,105		
1998		439	462	511	546	583	635	700	776	876	936	1,000	1,045	1,098			
1999			474	511	550	595	640	697	794	866	932	970	1,075				
2000		370	466	515	552	590	639	694	790	855	955	1,030					
2001			464	514	557	595	636	669	788	868	1,002	993					
2002			466	515	549	580	623	691		951	981						
2003			472	507	552	586	642	677	833								
2004		351	453	515	555	596	614	784									
2005		403	457	509	552	584	685	794									
2006		384	461	513	543	607	676	737									
2007	314	405	462	525	595	619	633										
2008		383	466	525	555	606	670										
2009		399	480	517	549	607											
2010		325	408	500	534												
2011		327	441	497													
2012		362	454														
2013																	
2014																	
Mean	314	389	464	514	555	595	640	705	787	880	948	993	1,040	1,057	1,098	1,135	1,092
Min.		325	408	497	534	580	614	665	749	855	927	970	1,005	1,024	1,041	1,133	
Max.		447	493	536	595	619	685	794	833	951	1,002	1,030	1,075	1,098	1,132	1,137	

TABLE 6.—Mean, minimum, and maximum weight (kg) at age of a subsample of male and female Striped Bass collected from the Roanoke River by electrofishing, 2015.

Males

Year Class	Age	Number aged	Weight			
			Mean	SD	Min.	Max.
2014	1	1	0.1		0.1	0.1
2013	2					
2012	3	54	0.7	0.3	0.2	1.9
2011	4	47	1.4	0.8	0.5	4.9
2010	5	26	2.1	0.7	1.2	4.0
2009	6	22	2.4	0.7	1.6	3.9
2008	7	13	3.0	0.4	2.2	3.6
2007	8	3	5.6	2.2	3.7	8.0
2006	9	4	6.2	3.2	4.4	11.0
2005	10	3	9.6	3.5	6.7	13.5

Females

Year Class	Age	Number aged	Weight			
			Mean	SD	Min.	Max.
2012	3	21	0.8	0.3	0.4	1.5
2011	4	44	1.3	0.4	0.2	2.3
2010	5	21	1.9	0.5	1.1	2.7
2009	6	9	2.7	0.8	1.4	3.8
2008	7	15	3.9	1.5	2.6	8.0
2007	8	2	5.7		5.7	5.7
2006	9	3	10.3	3.9	7.5	13.0
2005	10	2	13.5	2.1	12.0	15.0
2004	11					
2003	12	2	19.6	4.9	16.1	23.0
2002	13					
2001	14	2	19.3	1.8	18.0	20.5

TABLE 7.—Cohort mortality estimates from 1992 to 2009. Age of full recruitment (peak plus) and variance inflation factor (ĉ) are described by Smith et al. 2012.

Cohort	Age of full recruitment	Number of ages used	Annual mortality (*A*)	Lower 90% CI	Upper 90% CI	Variance inflation factor (ĉ)
1992	Age 5	12	0.30	0.22	0.38	1.00
1993	Age 4	13	0.32	0.26	0.37	1.04
1994	Age 4	13	0.35	0.29	0.40	1.45
1995	Age 4	14	0.30	0.25	0.34	1.01
1996	Age 4	13	0.35	0.30	0.41	1.46
1997	Age 5	12	0.36	0.29	0.42	1.00
1998	Age 4	12	0.40	0.34	0.45	1.00
1999	Age 5	10	0.37	0.29	0.44	1.00
2000	Age 4	10	0.39	0.29	0.48	2.68
2001	Age 4	11	0.56	0.51	0.61	1.00
2002	Age 4	9	0.67	0.61	0.73	2.13
2003	Age 4	9	0.64	0.55	0.72	1.48
2004	Age 4	7	0.47	0.39	0.55	1.00
2005	Age 4	7	0.52	0.44	0.59	1.57
2006	Age 3	7	0.65	0.61	0.69	1.00
2007	Age 4	5	0.59	0.49	0.68	1.00
2008	Age 4	4	0.66	0.57	0.73	1.00
2009	Age 4	3	0.66	0.47	0.78	1.45

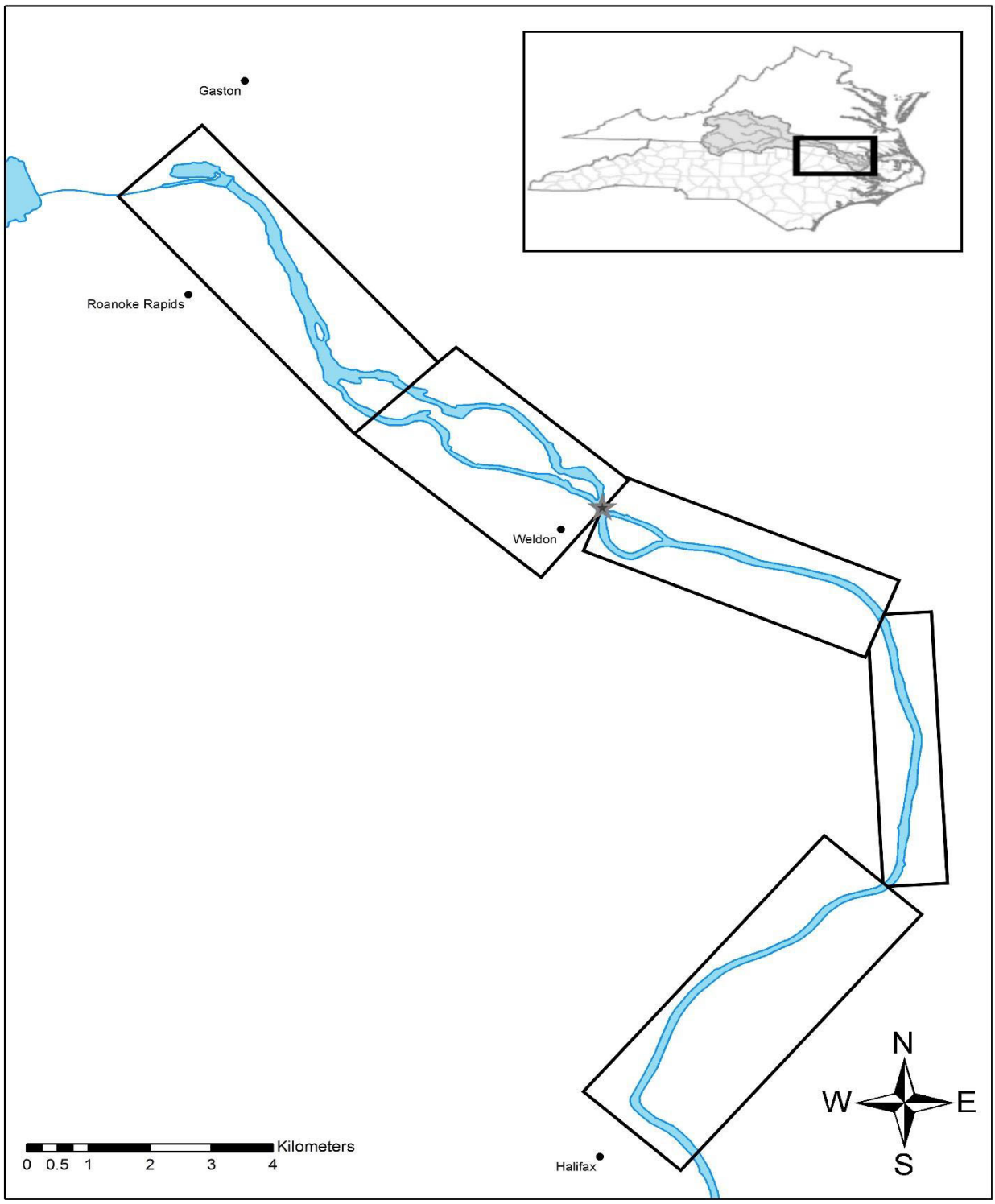

FIGURE 1.—Striped Bass spawning grounds on the Roanoke River, near the vicinity of Weldon, NC. Black boxes represent relative locations of river strata. The gray star indicates location of rapids near the Weldon boating access area; flows less than 7,000 cfs restrict access to the strata above this location.

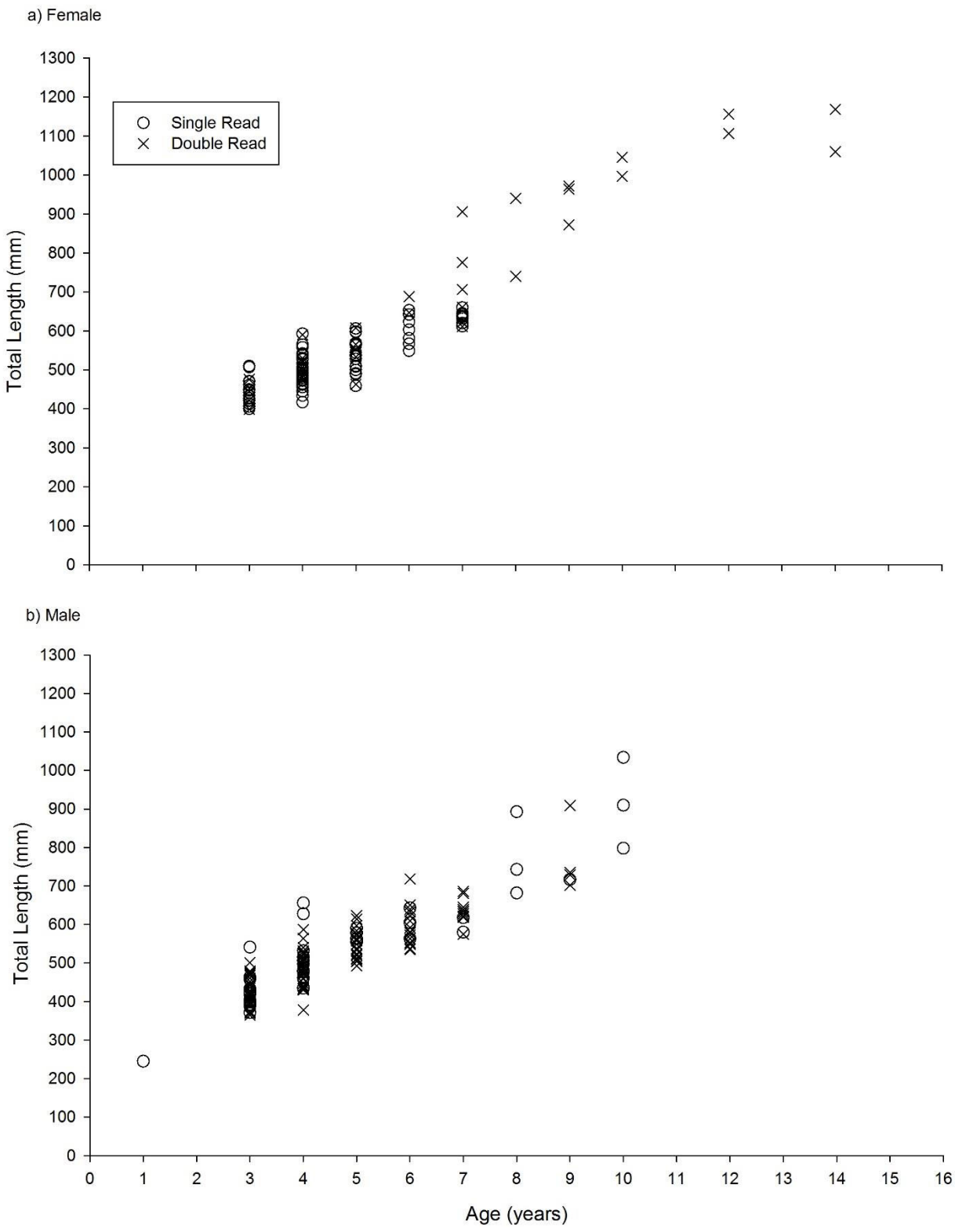

FIGURE 2.—Comparison of single and double-read scale ages for female (a) and male (b) Striped Bass collected from the Roanoke River during spring 2015.

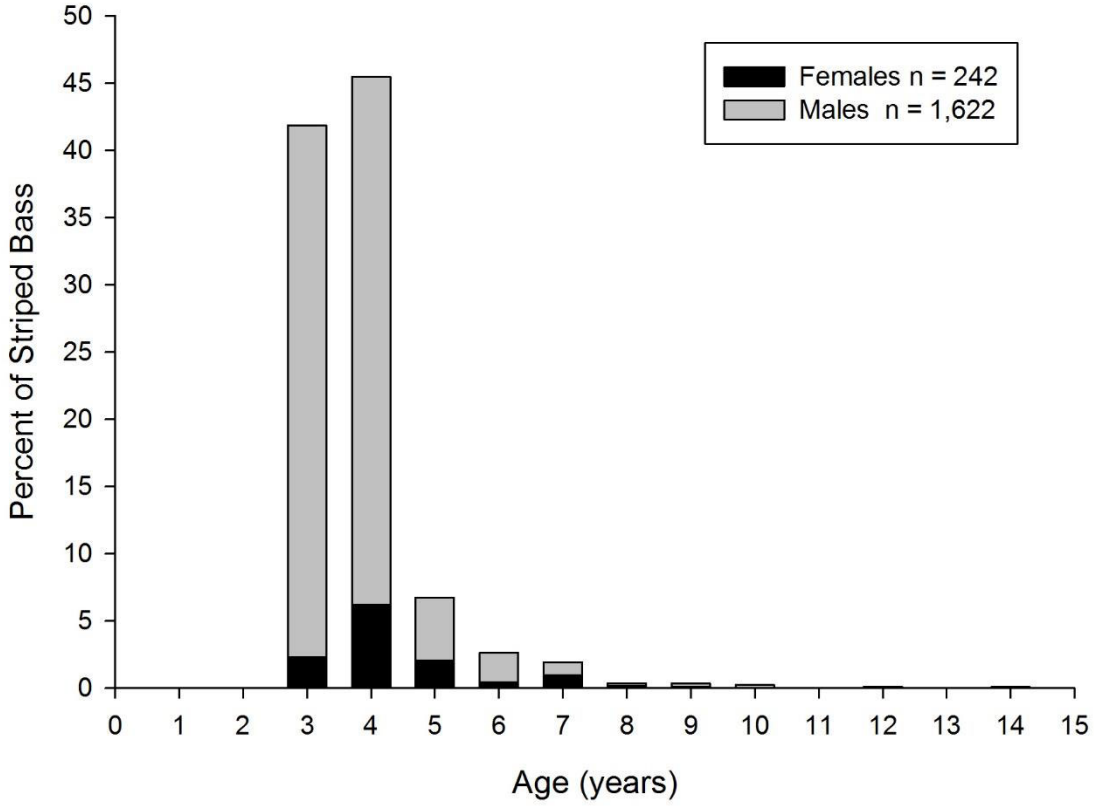

FIGURE 3.—Age distribution for Striped Bass collected from the Roanoke River, spring 2015.

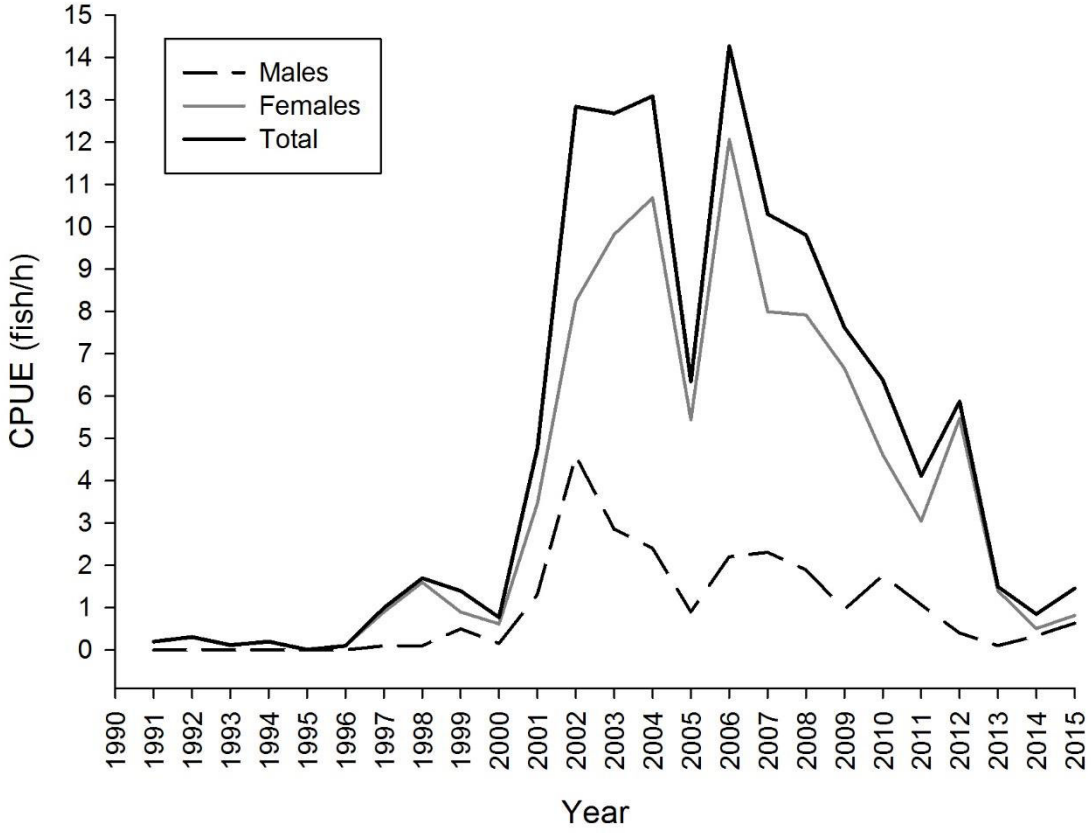

FIGURE 4.—Relative abundance (CPUE; fish/h) of Roanoke River Striped Bass ≥ age 9 collected by electrofishing during spawning stock surveys at Weldon, NC; 1991–2015.

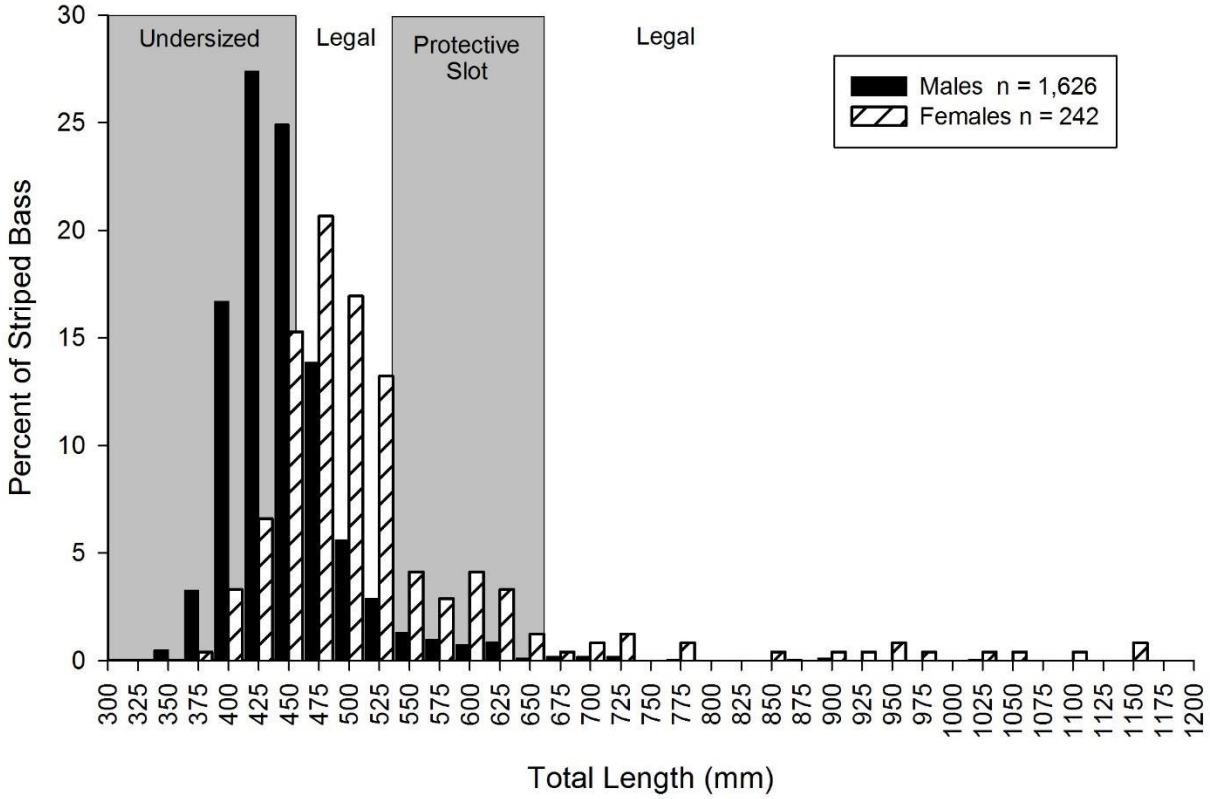

FIGURE 5.—Length frequency histograms for Striped Bass collected from the Roanoke River, spring 2015. Male and female plots each sum separately to 100. Shaded areas indicate sizes protected from legal harvest (< 457 mm and 559–686 mm).

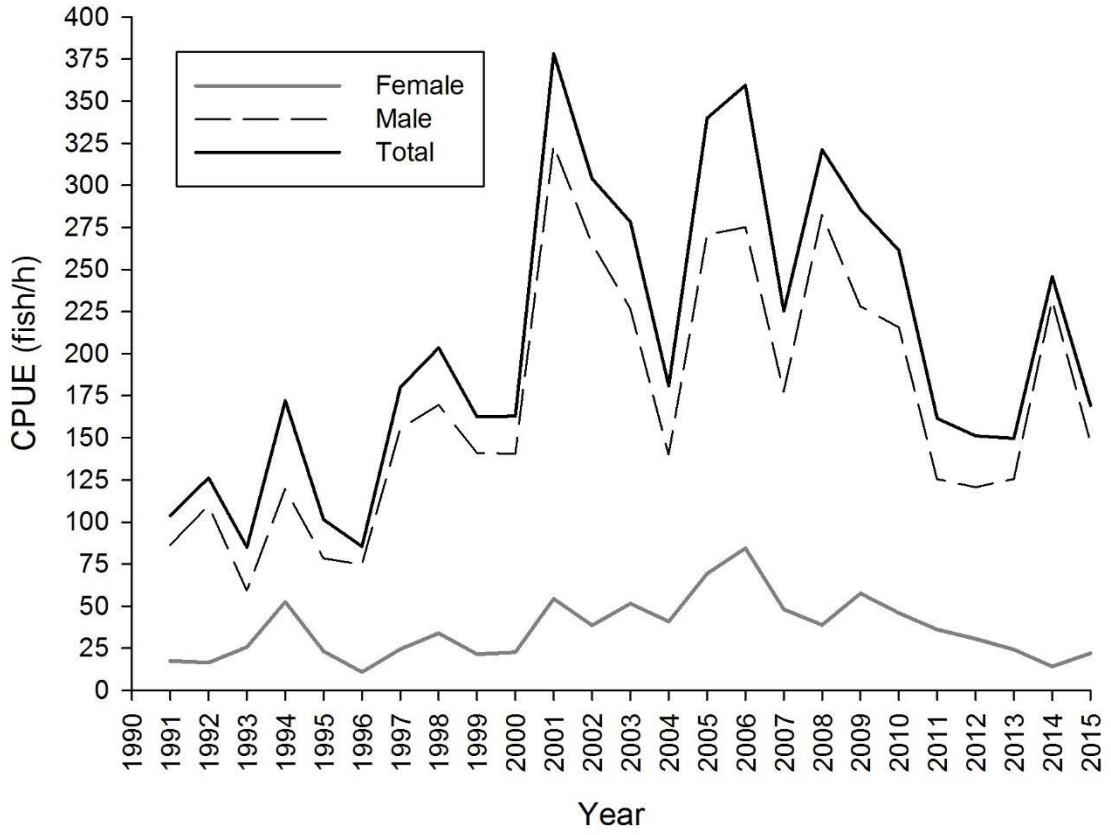

FIGURE 6.—Relative abundance of female and male Striped Bass from the Roanoke River, North Carolina from 1990 to 2015.

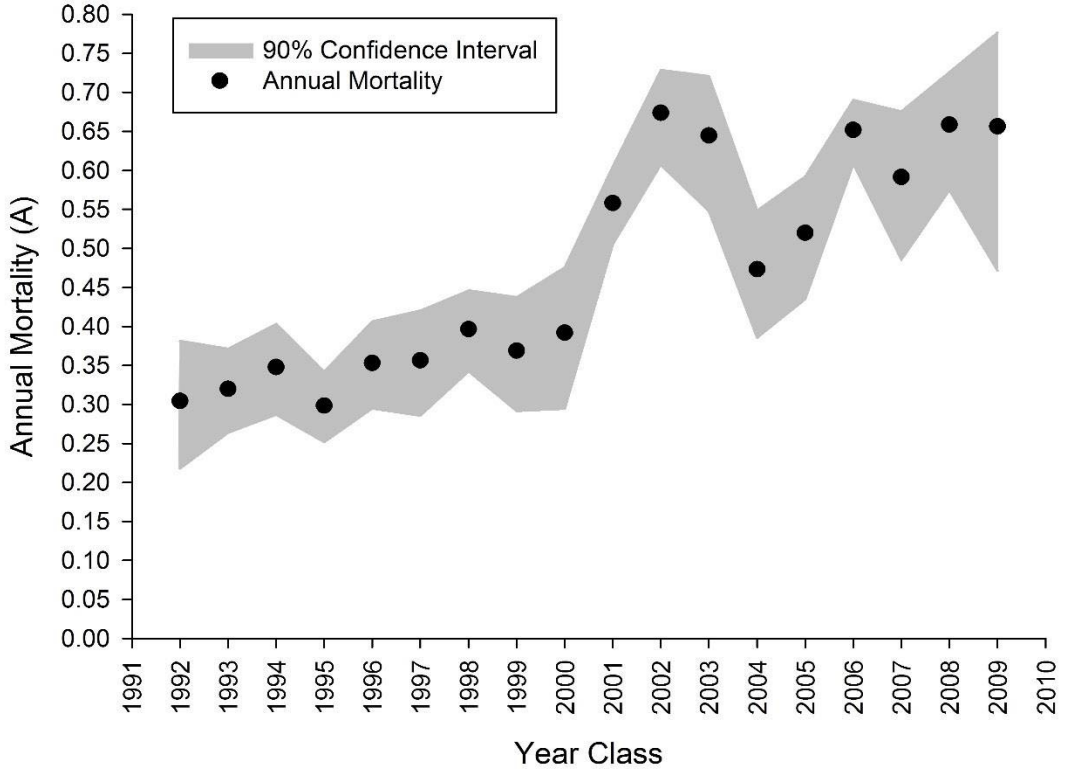

FIGURE 7.—Cohort mortality analysis results for 1992–2009 year classes of Roanoke River Striped Bass.