Assessment of Striped Bass Spawning Stock in Roanoke River, North Carolina

Kent L. Nelson, *North Carolina Wildlife Resources Commission, 512 N. Salisbury Street, Raleigh, NC 27604-1188*

James W. Kornegay, *North Carolina Wildlife Resources Commission, 512 N. Salisbury Street, Raleigh, NC 27604-1188*

Abstract: A total of 4,920 striped bass (*Morone saxatilis*) were collected from Roanoke River near Weldon, North Carolina, by electrofishing during the spring of 1991 and 1992. Study objectives were to determine sex ratio and age composition of the Albemarle Sound/Roanoke River striped bass spawning stock. Differences in catch per unit effort (CPUE) between years, among year classes, and between sexes were analyzed. Male striped bass represented 83% and 87% of the sample over the 2 years. Nearly all male (99%) and female (91%) striped bass captured were Ages 2 through 4. Ninety-six percent of the fish in 1991 and 89% in 1992 were from the 1988 and 1989 year classes. A greater proportion of striped bass, both male and female, migrated to the spawning grounds at Age 3 than at Age 2 and females did not migrate in equal proportions as males until at least Age 4. Analysis of variance (ANOVA) of log-transformed CPUE data between 1991 and 1992 indicated that catch rates were significantly lower in 1992 for the 1982 through 1988 year classes. Mean CPUE for these year classes decreased by 54% (range: 23%–79%) in 1992. The scarcity of older age classes on the spawning grounds suggests that fishing has affected survival. If the CPUE decline observed between 1991 and 1992 reflected annual mortality, then the mortality rate exceeded that targeted for restored, healthy striped bass populations. We recommend that fishing rates or other sources of mortality be reduced to sustain the recovery of the Albemarle Sound/Roanoke River population.

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From 1976 to 1988, the Albemarle Sound/Roanoke River striped bass population experienced poor reproductive success as evidenced by low abundance of young-of-year and failure to establish a dominant year class (Henry and Taylor 1991). Factors believed to be responsible included unfavorable water flow regimes in Roanoke River during spawning, poor water quality, and overfishing (N.C. Striped Bass Study Manage. Board 1991). Low reproductive success and recruitment were reflected in poor catches of striped bass by sport and commercial fishermen (Hassler et al. 1981, Mullis and Guier 1982).

During 1988 and 1989, juvenile abundance indices (JAI) were the highest estimated since 1976 (Henry and Taylor 1991). In 1990, fishermen began reporting large numbers of small (350–400 mm) striped bass in Albemarle Sound and tributaries. The CPUE of striped bass by sport fishermen in Roanoke River increased during the spring of 1990 and 1991, primarily as a result of these 2 abundant year classes.

The Albemarle Sound/Roanoke River striped bass population is regulated by the North Carolina Wildlife Resources Commission and North Carolina Division of Marine Fisheries. The population is considered to be rebuilding and is managed as a transitional fishery with harvest restrictions in accordance with Atlantic States Marine Fisheries Commission (ASMFC) guidelines (ASMFC 1989). A harvest quota, based on an 80% reduction of total harvest from 1972–1979, was implemented in 1991 and allocated between the recreational and commercial fisheries. Annual spawning stock assessments in major striped bass spawning areas, including Roanoke River, are integral to an effective striped bass management program (ASMFC 1989). Spawning stock characteristics are used as indicators of population status. Populations subject to high fishing rates (F) typically exhibit truncated age distributions and the proportion of older fish in the spawning stock suggests whether fishing rates are affecting the survival of mature striped bass. In order to evaluate spawning stock status for the Albemarle Sound/Roanoke River striped bass population, unbiased fishery-independent estimates of age and sex composition were needed.

Electrofishing is commonly used for evaluating fish population structure and abundance but is subject to several potential biases. Biases include differences in vulnerability as a function of species, size, habitat characteristics, equipment, operating conditions or environmental factors (season, water temperature and clarity, day vs. night sampling, and conductivity) (Reynolds 1983). Sampling adult fish of a single species will minimize size selectivity biases, while environmental biases can be reduced by standardized sampling methods. Study objectives were to determine age and sex composition of striped bass on the Roanoke River spawning grounds and analyze year, year class, and sex effects on CPUE.

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Methods

Striped bass were collected weekly between mid-April and early June 1991 and 1992 from Roanoke River near Weldon, North Carolina. One or 2 boatmounted electrofishing units (Smith-Root 7.5 GPP) were used during daylight hours to capture fish. Sampling began when water temperatures approached 18° C, just prior to the optimum temperature range (18°–22° C) for striped bass spawning in the Roanoke River (Rulifson and Manooch 1990). Sampling was conducted primarily in the vicinity of Roanoke Rapids (river mile (RM) 137) and Weldon (RM 130), the historical spawning area for Roanoke River striped bass (Hassler et al. 1981). Various habitats in the main river channel and secondary channels were sampled, depending on accessibility. To minimize size selection during sampling, all striped bass were picked up as they were encountered. To determine CPUE for striped bass, actual electrofishing time was recorded for each sampling area. Electrofishing CPUE was calculated as number of fish captured per hour. Water temperature (C) was recorded each sample day.

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. During 1991, if milt or eggs were not released after several attempts, a 3-mm diameter capillary tube was inserted into the vent and tissue removed by suction to determine sex. Less than 1% of catheterized fish were found to be males and subsequently, in 1992, all fish not releasing milt were assumed to be female. Each fish was measured for total length in millimeters. Scales were removed from the left side of the fish between the lateral line and the dorsal fins.

Scales were examined at 33X magnification on a microfiche reader. Ages were determined from a subsample of striped bass, with a minimum of 46 fish aged per 25-mm size group for each sex. Size groups of males subsampled were between 350 and 499 mm in 1991 and between 350 and 524 mm in 1992. Females between 425 and 524 mm in length were subsampled in 1992. Proportions of each age group in each 25-mm size group were computed and then expanded to the total number of fish within each size group. Mean length at capture was calculated from lengths of aged fish for each age group.

Three-way ANOVA, including interactions, was used to test for significant ($P < 0.05$) differences in CPUE between years, among all year classes captured (1982–1990), and between sexes (SAS Inst. 1989). Data were subsequently reanalyzed for only the 1982–1988 year classes. Two-way ANOVA with interactions was done for each year class to further examine differences between years and sexes. Data were non-normally distributed and a natural log ($\log_e x + 1$) transformation was used to normalize the distribution and stabilize the variance.

Results and Discussion

A total of 2,001 and 2,919 striped bass were collected from Roanoke River during 1991 and 1992, respectively. Mean CPUE was 104.2 and 126.4 fish per hour during the 2 years. Sampling encompassed the period before, during, and after peak striped bass spawning activity in both years with water temperatures ranging from 15°–26° C in 1991 and from 16°–22° C in 1992. A concurrent striped bass egg study indicated that peak spawning activity occurred between 8–15 May

Table 1. Percent age distribution of striped bass by sex and date captured by electrofishing from Roanoke River, spring 1991.

		Date (1991)								
Age	Sex	15 Apr	22 Apr	1 May	9 May	14–15 May	21 May	28 May	4 Jun	10 Jun
2	M	69.9	70.3	72.5	69.2	78.4	83.3	88.7	90.7	87.6
	F			40.0	6.8	19.1	13.5	35.3	37.7	60.4
3	M	27.4	28.4	27.3	28.8	14.9	15.5	11.3	8.9	7.5
	F		100.0	40.0	79.5	59.6	71.2	47.1	54.7	34.0
4	M	2.7	1.3	0.1	1.3	2.4	0.6		0.4	3.9
	F				6.8	6.7	3.8	14.7		5.7
5	M				0.3	2.4	0.3			1.0
	F			20.0	2.3	3.4	1.9			
6	M				0.3	1.0				
	F					1.1	5.8		1.9	
7	M					0.5	0.3			
	F				4.5	3.4	3.8		3.8	
8	M					0.5				
	F					4.5		2.9		
9	M									
	F					2.2			1.9	
Total sample sizes (N)										
	M	78	73	158	318	208	331	130	263	102
	F	0	4	5	44	89	52	34	53	53
	%M	100	94.8	96.3	87.8	70.0	86.4	79.3	83.2	65.8
	%F	0	5.2	3.7	12.2	30.0	13.6	20.7	16.8	34.2
Cumulative										
	%M	100	97.4	97.2	92.2	85.5	85.7	85.0	84.7	83.3
	%F	0	2.6	2.8	7.8	14.5	14.3	15.0	15.3	16.7

1991 and 15–25 May 1992 (R. A. Rulifson, East Carolina Univ., pers. commun.).

Male striped bass comprised 83% and 87% of the sample during the 2 years (Tables 1, 2). This disparity resulted from greater numbers of Age 2 and 3 males captured than females, which suggests that females do not migrate to the spawning grounds in equal proportion to males until at least Age 4. This is likely an effect of differential maturation. Roanoke River striped bass males mature at 2- to 3-years-old, whereas all females are not mature until Age 6 (Olsen and Rulifson 1992).

Differential migration of striped bass as a function of age and sex is supported by spring gill net sampling in western Albemarle Sound during the spawning season. Striped bass stage in the western Albemarle Sound near the mouth of the Roanoke River prior to the spawning migration and are concentrated in this area and the lower Roanoke River from March–June (L. Henry, N.C. Div. Mar. Fish., pers. commun.). During March and April 1991 and 1992, 74% to 83% of the fish captured in western Albemarle Sound were male (Henry 1993). The proportion of females increased during May 1991 and 1992 to 71% and 88%, suggesting that many males had moved into the Roanoke River. During May 1991, concurrent with the peak of the spawning season, fish remaining in the western Albemarle

Table 2. Percent age distribution of striped bass by sex and date captured by electrofishing from Roanoke River, spring 1992.

		Date (1992)								
Age	Sex	21 Apr	28 Apr	5 May	11 May	18 May	26 May	2 Jun	8 Jun	15 Jun
2	M	8.0	6.6	5.8	11.4	10.9	11.4	13.1	9.4	11.1
	F					1.5	4.8		1.7	1.7
3	M	84.2	86.0	87.8	79..9	80.2	78.1	69.4	80.6	84.3
	F	33.9	47.8	45.2	64.7	55.0	75.0	67.1	79.1	74.2
4	M	7.5	7.4	5.3	8.0	8.2	9.2	16.2	8.3	4.6
	F	53.0	52.2	45.2	5.9	30.5	17.9	23.3	16.6	15.8
5	M	0.4		1.0	0.7		0.4	0.5	0.2	
	F	8.7		7.7	11.8	6.8		5.8	0.1	8.3
6	M						<0.1	0.3	0.8	
	F	4.3				1.2				
7	M					0.4	0.2	0.5		
	F				5.9	2.9				
8	M					0.4	0.2		0.8	
	F			1.9	5.9	2.1			1.2	
9	M						0.4			
	F				5.9		2.4			
10	M									
	F							3.8	1.2	
Total sample sizes (N)										
	M	321	269	299	151	281	484	392	265	74
	F	23	23	52	17	80	42	52	82	12
	%M	93.3	92.1	85.2	89.9	78.0	92.2	87.8	76.7	86.0
	%F	6.7	7.9	14.8	10.1	22.0	7.8	12.2	23.3	14.0
Cumulative										
	%M	93.3	92.8	90.1	90.0	87.1	88.4	88.4	86.9	86.9
	%F	6.7	7.2	9.9	10.0	12.9	11.6	11.6	13.1	13.1

Sound were primarily Age 2 and 3, with a greater proportion being immature females (Henry et al. 1992).

Males also migrate to the spawning grounds earlier in the spring than females, which was evident in the distribution of fish by sex and date (Tables 1, 2). The relative proportion of females increased monthly during 1991 and 1992 with females comprising 2.6%, 16.4%, and 22.5% of the April, May, and June 1991 samples, respectively, and 7.2%, 13.6%, and 16.6% during these months, respectively, in 1992. Differences in sex composition were observed between sample locations within sample dates. The most notable example occurred between 21 May and 10 June 1991, when females comprised 43.0% (range: 28.7%–56.5%) of the fish collected at the upstream site (Roanoke Rapids). During these 4 sample dates, females comprised only 6.9% (range: 3.9%–16.3%) of the downstream samples at Weldon. Sampling on other dates did not show disparities in sex composition of this magnitude.

Flow rates appear to have a major influence on the distribution of striped bass on the spawning grounds. At high flows striped bass reportedly spawn upstream in the vicinity of Roanoke Rapids, while during lower flows, spawning is concentrated in the vicinity and downstream of Weldon. CPUE declined from 565 fish per hour on 5 May to 6 fish per hour on 11 May 1992 at Roanoke Rapids concurrent with declining discharge rates. This downstream movement of striped bass from Roanoke Rapids likely contributed to the increasing catch rate in the Weldon area from 116 to 275 fish per hour during this period.

Most of the male and female striped bass collected during both years were from the 1988 and 1989 year classes (Tables 3, 4). These year classes accounted for 98.0% of the males and 85.9% of the females in 1991 and 89.3% (males) and 89.9% (females) in 1992. No Age 1 striped bass were captured on the spawning grounds during either year. Abundance of these year classes is reflected in electrofishing CPUE (Table 5). Highest catch rates during both years were for 1989 year class males. Increased CPUE during 1992 for 1989 and 1990 year class males and females is consistent with a greater proportion of striped bass migrating to the spawning grounds at Age 3 than at Age 2. A greater rate of migration by males at Age 2 and 3 is indicated by relative differences in the CPUE of the 1989 and 1990 year classes between sexes at Age 2 and 3 and the larger increase in CPUE of 1989 year class females relative to males in 1992. Decreasing catch rates were observed for all other year classes with the exceptions of 1983 and 1984 year class males; however, few fish (<10) were present in any age class before 1987.

Three-way ANOVA of log-transformed CPUE data examining year, year class (1982–1990), and sex differences showed all interactions to be significant. Visual inspection of the means showed increased catch rates in 1992 of the 1989 and

Table 3. Age composition and length at capture of a subsample of striped bass collected by electrofishing from Roanoke River in 1991.

Year class	Age	*N* aged	Estimated *N* (% Composition)	Total length (mm) Mean	Min.	Max.
Males						
1989	2	173	1317.8 (79.3)	384	315	431
1988	3	176	309.7 (18.6)	465	409	507
1987	4	18	18.8 (1.1)	517	492	573
1986	5	7	7.5 (0.4)	542	505	576
1985	6	4	4.2 (0.3)	587	559	603
1984	7	2	2.0 (0.1)	666	626	707
1983	8	1	1.0 (0.1)	648		
Females						
1989	2	93	93 (27.8)	399	351	445
1988	3	194	194 (58.1)	493	427	538
1987	4	19	19 (5.7)	537	510	573
1986	5	6	6 (1.8)	602	549	658
1985	6	5	5 (1.5)	671	644	709
1984	7	9	9 (2.7)	716	660	746
1983	8	5	5 (1.5)	789	747	845
1982	9	3	3 (0.9)	816	791	831

Table 4. Age composition and length at capture of a subsample of striped bass collected by electrofishing from Roanoke River in 1992.

Year class	Age	N aged	Estimated N (% Composition)	Total length (mm)		
				Mean	Min.	Max.
Males						
1990	2	103	247.5 (9.8)	383	338	434
1989	3	193	2037.4 (80.3)	445	392	507
1988	4	101	228.4 (9.0)	510	463	569
1987	5	8	8.7 (0.3)	560	531	597
1986	6	4	4.2 (0.2)	660	615	710
1985	7	3	3.8 (0.1)	637	630	643
1984	8	4	4.0 (0.2)	700	676	725
1983	9	2	2.0 (0.1)	778	766	789
Females						
1990	2	4	5.7 (1.5)	414	368	435
1989	3	142	236.8 (61.8)	473	421	527
1988	4	89	107.4 (28.0)	524	486	595
1987	5	18	18.1 (1.8)	588	545	645
1986	6	1	1.0 (0.3)	637		
1985	7	2	2.0 (0.5)	712	694	729
1984	8	5	5.3 (1.4)	766	748	784
1983	9	3	3.7 (1.0)	795	782	805
1982	10	3	3.0 (0.8)	832	810	847

1990 year classes. To further clarify year and sex effects, 2-way ANOVA with interactions was done for each year class separately, with significant differences indicated for the 1984, 1989, and 1990 year classes. For the 1984 year class, significant differences were found between sexes ($P = 0.04$), with non-significant differences between years ($P = 0.80$), and sex by year interaction ($P = 0.32$). Within years, mean CPUE for females was greater than for males for other year classes prior to 1986; however, these differences were not significant. The 1989 year class showed significant CPUE differences between sexes (males > females; $P = 0.0001$) and year (1992 > 1991; $P = 0.01$) with non-significant interaction effects ($P = 0.16$). Significance of both main effects supports the premise that greater numbers of striped bass migrate at Age 3 than at Age 2, and that a greater proportion of males migrate at Age 2 and 3 than females. For the 1990 year class, year, sex, and interaction effects were significantly different ($P = 0.0001$). The absence of 1990 year class fish at Age 1 in 1990 is reflected in the significance of the sex by year interaction. The absence of Age 1 fish during both years further indicates the influence of age on the migration pattern of striped bass. CPUE between 1988 year class males and females between years were marginally different ($P = 0.0640$).

Data suggested that, by year class, striped bass are not present on the spawning grounds relative to their abundance in the population until at least Age 4. We concluded, therefore, that between year effects of fishing and other mortality factors would be better indicated by examining CPUE of year classes at least Age 4.

Table 5. Mean catch per unit effort (CPUE = *N* fish/hour), standard deviation (SD), and percent change between years for male and female striped bass from Roanoke River electrofishing surveys, 10 surveys in 1991 and 9 surveys in 1992.

Year class	Sex	Year 1991 CPUE	1991 SD	1992 CPUE	1992 SD	Percent change between years
1990	Male			11.44	5.27	+100
	Female			0.20	0.30	+100
1989	Male	82.91	77.62	101.53	53.08	+22
	Female	4.66	4.94	11.22	8.75	+141
1988	Male	24.06	36.50	10.03	4.55	-58
	Female	14.62	18.21	6.13	6.61	-48
1987	Male	1.64	1.81	0.43	0.74	-74
	Female	1.48	1.96	1.14	1.38	-23
1986	Male	0.39	0.64	0.17	0.26	-56
	Female	0.65	0.19	0.04	0.13	-94
1985	Male	0.21	0.47	0.14	0.25	-33
	Female	0.31	0.63	0.16	0.31	-48
1984	Male	0.06	0.13	0.17	0.27	+183
	Female	0.65	0.94	0.37	0.56	-43
1983	Male	0.03	0.09	0.07	0.20	+133
	Female	0.64	1.78	0.24	0.43	-62
1982	Male					
	Female	0.25	0.59	0.07	0.14	-72

CPUE differences were re-analyzed for only the 1982–1988 years. Three-way ANOVA indicated significant differences in CPUE between years ($P = 0.0088$), among year classes ($P = 0.0001$), and for sex by year class interaction ($P =$

Table 6. Three-way analysis of variance for natural log transformed catch-per-unit-effort data for striped bass between 1991 and 1992, among year classes 1982–1988, and between sexes, Roanoke River, North Carolina (overall $F = 21.56$, $P = 0.0001$, $r^2 = 0.7098$; Type III sum of squares[a]).

Source	df	F	Pr . F
Sex	1	0.01	0.9116
Year	1	6.97	0.0088
Sex × year	1	0.20	0.6576
Year class	6	90.14	0.0001
Sex × year × class	6	2.90	0.0096
Year class × year	6	1.11	0.3550
Sex × year class × year	6	0.49	0.8188

[a] Model-order independent

0.0096) (Table 6). Mean CPUE for the 1982 through 1988 year classes decreased by 54% (range: 23%–79%) between 1991 and 1992. The significant interaction effect may relate to the general pattern of higher mean CPUE for females than males at older ages and lower CPUE of females at younger ages. While the year and year class effects were significant in this analysis, 2-way ANOVA indicated that year effects were not significant when each of the 1982 through 1988 year classes were examined separately. Considering the low numbers of fish in the 1987 and earlier year classes, these results are expected.

Fishing mortality rates for the Albemarle Sound-Roanoke River population have been estimated to be approximately 1.0 in recent years (J. Hightower, U.S. Fish and Wildl. Serv., pers. commun.), a rate well in excess of that recommended for striped bass stocks. Target fishing rates are 0.25 for striped bass populations during the recovery phase and 0.50 for fully restored, healthy populations, based on modeling conducted by ASMFC (1989). At F of 0.25 and 0.50, total mortality would be approximately 36% and 50% of legal fish per year. At F of 1.0, assuming a natural mortality rate of 0.2, total mortality would be about 70% per year. As an estimator of annual mortality, the 54% decline in CPUE between 1991 and 1992 for the 1982–1988 year classes found in this study, was somewhat less than model results. The CPUE decline may have been somewhat underestimated by including the 1988 year class. Marginal differences ($P = 0.0640$) in CPUE of 1988 year class males and females suggested that some females do not migrate until age 4. If so, a greater rate of migration in 1992 of 1988 year class females at age 4 would result in underestimating the decline in CPUE. While the 54% CPUE decline for age 4 and older striped bass observed between 1991 and 1992 reflects a mortality rate less than expected at F of 1.0, it does, nonetheless, exceed that targeted for a population during the recovery period.

In summary, we found differential migration of striped bass to the spawning grounds in relation to sex and age. Because of the increased migration rate of males from Age 2 to 3, and apparent increased migration rate of females until at least Age 4, between year effects of fishing and other mortality factors are better examined through comparisons of CPUE of year classes at least 4 years old. The scarcity of older age classes on the spawning grounds suggests that fishing rates have noticeably affected survival. A significant, 54% decline in CPUE between 1991 and 1992 for Age 4 and older striped bass further suggests that mortality rate is excessive. We recommend that fishing rates or other sources of mortality be reduced to sustain the recovery of the Albemarle Sound-Roanoke River population.

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