

Cape Fear River Anadromous Fish Stock Assessment, 2019



Federal Aid in Sport Fish Restoration
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Abstract. Spawning stocks of anadromous American Shad *Alosa sapidissima* and Striped Bass *Morone saxatilis* are monitored annually by the North Carolina Wildlife Resources Commission. During 2019 boat-electrofishing surveys, 251 Striped Bass and 345 American Shad were captured, with a mean CPUE (SE) of 17.9 (3.7) fish/h for Striped Bass and 35.6 (9.4) fish/h for American Shad. American Shad ranged from 2 to 7 years old, while Striped Bass ranged from 1 to 9 years old. The American Shad population abundance was relatively stable in the Cape Fear River, but the Striped Bass population abundance was limited due to a variety of issues, such as impeded access to spawning grounds and high mortality. Striped Bass are stocked every year in the Cape Fear River and have also been stocked in upriver reservoirs, with stocked fish representing 90% of Striped Bass individuals. Current management efforts have allowed for a relatively stable population of American Shad. However, the inability of Striped Bass to access spawning habitats has resulted in a population that is not self-sustaining despite a long-term harvest moratorium. Management goals and actions should be developed that optimize angler utility and resource conservation.

The Cape Fear River once supported large populations of anadromous species, but factors such as dams impeding access to spawning habitats and overfishing have depleted populations of American Shad and Striped Bass (Stevenson 1897; Cobb 1906; Smith 1907; Nichols and Louder 1970). A harvest moratorium, enacted in 2008, is currently in effect for Striped Bass. Striped Bass have been stocked into the Cape Fear River annually since 1998 and have also been stocked in upriver reservoirs (Rachels and Morgeson 2018). The goals for Striped Bass management in estuarine waters of North Carolina, according to Amendment 1 of the North Carolina Estuarine Striped Bass Fishery Management Plan, are to “achieve sustainable harvest through science based decision-making processes that conserve adequate spawning stock, provide and maintain a broad age structure, and protect the integrity of critical habitats,” and the Cape Fear River Striped Bass population is currently not meeting these goals (NCDMF 2013).

Although the American Shad population in the Cape Fear River is depleted compared to historic levels, it has been relatively stable for the past two decades (ASMFC 2020; NCDMF and NCWRC 2020). Compared to Striped Bass, American Shad have maintained a relatively high passage rate (60-83%) through and/or over the three Lock and Dams on the Cape Fear River, allowing some individuals to reach adequate spawning habitat (Raabe et al. 2019). American Shad from the Cape Fear River south to Florida have a shorter life history than American Shad in more northern parts of the United States, with most individuals in the Cape Fear River dying after their first spawning run (semelparous; ASMFC 2020).

Each year, since 2001 for American Shad and 2003 for Striped Bass, the North Carolina Wildlife Resources Commission conducts sampling to monitor populations of anadromous spawning stocks in the Cape Fear River. The objectives of continued monitoring are to measure relative abundance and demographic characteristics of Striped Bass and American Shad utilizing the main stem Cape Fear River, obtain Striped Bass fin clips for parentage-based tagging (PBT) analysis, collect American Shad otoliths to determine age, and to evaluate compliance of American Shad fisheries with the North Carolina American Shad Sustainable Fishery Plan (NCDMF and NCWRC 2020). This report summarizes the results of 2019 sampling and suggests future directions for American Shad and Striped Bass monitoring and management in the Cape Fear River.

Methods

Study site. Six sites, including the three Lock & Dams on the Cape Fear River and Buckhorn Dam, were sampled during the season (Figure 1; Table 1). ArcMap (version 10.7) was used to create a map of the study sites based on site coordinates and data from NC OneMap, North Carolina Department of Transportation, North Carolina Center for Geographic Information and Analysis, and Esri.

Field collection. Sampling occurred during 24 sampling events across 13 dates from March through May of 2019 (Table 1). American Shad and Striped Bass were collected using boat-mounted electrofishing (Smith-Root 7.5 GPP; 120 PPS; 6 A; 1000V) and one dip netter. A YSI Pro2300 or YSI 85 meter was used to measure water temperature (°C), conductivity (µS/cm), dissolved oxygen (mg/L), % saturation, and salinity (ppt). Captured fish were identified to species, measured for total length (TL; mm) and weight (g), and sexed using directional pressure on the abdomen of the fish toward the vent to observe either milt (male) or eggs

(female). Unknown sex was assigned for Striped Bass ≤ 400 mm TL that did not express eggs or milt. Striped Bass larger than 400-mm TL that did not express milt were recorded as female.

American Shad aging. Otoliths were collected from up to five fish per 10-mm size-class for both male and female American Shad. Collected otoliths were cleaned, immersed in water against a dark background, and read using a stereomicroscope with reflected light. Two readers independently read and recorded annuli and resolved differences using a concert read to establish 100% agreement.

Striped Bass aging. Partial pelvic fin clips were collected from each collected Striped Bass and preserved in 95% ethyl alcohol for parentage-based tagging (PBT) analysis. Fin clips were genotyped at the Hollings Marine Laboratory in Charleston, South Carolina. Scales were collected from Striped Bass greater than 300-mm TL.

Data analyses. All data were archived in the NCWRC BIODE database. Mean weekly catch per unit effort (CPUE; fish/h), calculated using BIODE, was used to evaluate relative abundance. Analyses were performed using R 4.0.3 (R Core Team 2020) and RStudio (version 1.2.5033; RStudio Team 2020). Sex-specific length frequency histograms were used to evaluate size structure (Ogle 2015; Wickham 2016). Length-at-age was assessed using sex-specific box plots (Wickham 2016). Multinomial regression models were used to create sex-specific age-length keys for American Shad and Striped Bass using data on fish collected and aged in 2019 (Venables and Ripley 2002; Gerritsen et al. 2006; Ogle 2015; Ogle et al. 2020; Wickham et al. 2020). Individual ages were assigned to unaged fish using the sex-specific age-length keys (Isermann and Knight 2005; Ogle 2015).

Results

American Shad. Sampling yielded 345 American Shad (214 males and 131 females; Table 2). Mean weekly CPUE (SE) was 43.3 (9.9) fish/h (Table 2), and CPUE peaked during week 15 (Figure 2, Figure 3). American Shad females, on average, were larger (488 mm mean TL) than males (423 mm mean TL; Table 2, Figure 4). American Shad ranged in age from 2 to 7 years old, and the highest proportion (35%) were age 5 (Figure 5). The difference in size between female and male American Shad appeared to increase with age (Figure 6). The two age-6 males that were captured and aged using otoliths were relatively small (428 mm TL and 446 mm TL), leading to potential error with fitting the length-at-age curve to unaged males; however, analysis indicates very few males captured were older than age 5 (Figure 6).

Striped Bass. Striped Bass were captured at all six of the Cape Fear River sampling sites. Sampling yielded 251 Striped Bass (106 males, 29 females, and 116 unknown; Table 2). Mean weekly CPUE (SE) for Striped Bass was 17.9 (4.4) fish/h (Table 2), and CPUE peaked during week 16 (Figure 7, Figure 8). On average, female Striped Bass were larger (605 mm mean TL) than male Striped Bass (383 mm mean TL; Table 2, Figure 9). Striped Bass ranged in age from 1 to 9 years old, with age-1 Striped Bass making up 55% of those captured (Table 3, Figure 10). CPUE was highest at CFR98 (48.4 fish/h), and 92% of fish captures occurred at or downstream of Lock & Dam 3 (Table 4). Age and capture location was not assessed for 11 Striped Bass due to broodstock collections/lack of length data, and stocking size and location was not assessed for 28 Striped Bass due to broodstock collections and random data incongruities. For age-1 Striped Bass, 46% were captured at Lock & Dam 1 and 42% were captured at CFR98 (Table 4). The

difference in size between female and male Striped Bass appeared to increase slightly with age (Figure 11).

Parentage-based tagging analysis was conducted on 241 fin-clip samples. Two fish were confirmed as Hybrid Striped Bass *M. chrysops* x *M. saxatilis*. Of the remaining samples, 216 were hatchery-origin, resulting in a stocking contribution of at least 90% (Figure 12). Overall contribution of Striped Bass stocked in B. Everett Jordan Reservoir to individuals captured in the Cape Fear River was 76%, with 72% of age-1 Striped Bass originating from stocking in B. Everett Jordan Reservoir (Table 5). Two unknown-origin fish were from the largest size-class and may be older than the 2010 year-class, which precedes the ability of PBT to assign origin. The remaining 21 unknown-origin fish were likely less than age 10, suggesting some natural recruitment or immigration has occurred. Natural recruitment is more likely for the 18 unknown-origin fish less than 275-mm TL (Figure 12), corresponding to the 2018 (age-1) year-class.

Discussion

The American Shad population in the Cape Fear River has been relatively steady for the past two decades based on electrofishing catch per unit effort data, though there is insufficient data for the ASMFC to classify the population as stable (ASMFC 2020; NCDMF and NCWRC 2020). The age range of American Shad captured in the Cape Fear River in 2019 (2 to 7 years old) was similar to other rivers in North Carolina, and commercial harvest data indicated that American Shad mortality is relatively low (29.5%), both positive signs for the American Shad population in the Cape Fear River (White and McCargo 2020). Based on 2019 commercial harvest and independent gill net samples, American Shad mortality was lower in the Cape Fear River (29.5%) than in other areas of North Carolina (33.8% in the Albemarle Sound, 35.8% in the Pamlico River, and 34.3% in the Neuse River; White and McCargo 2020). However, the semelparous nature, and, therefore, the high natural mortality, of the Cape Fear River American Shad stock may make it more susceptible to declines caused by commercial and recreational fishing or poor year-classes. Modeling to determine the status of the Cape Fear River American Shad stock must consider their semelparous nature, as demonstrated by the 2020 American Shad Benchmark Stock Assessment and Peer Review Report (ASMFC 2020).

The Striped Bass population in the Cape Fear River is dependent upon stocking and fails to meet the goals specified in Amendment 1 of the Estuarine Striped Bass Management Plan (NCDMF 2013). In 2017, the hatchery contribution was 88% and the reservoir contribution was 25%, with 37% of individuals being age-3 or younger (Rachels and Morgeson 2018). In 2019, the hatchery contribution was 90% and the reservoir contribution was 76%, with the majority (90%) of Striped Bass captured in the Cape Fear River in 2019 being age-3 or younger. We were unable to calculate accurate mortality rates due to relatively few captures of age-3 and older Striped Bass, but this indicates that Striped Bass struggle to reach maturity in the Cape Fear River, even with the harvest moratorium that has been in place since 2008. However, sampling occurred less than a year after Hurricane Florence struck North Carolina, causing widespread flooding, low dissolved oxygen levels, and large fish kills in eastern North Carolina. The observed fish kills affected a variety of species, truncated the age distribution of Striped Bass and other fish species, and contributed to high mortality rates. Threats to the Cape Fear River

Striped Bass population are also present at the individual level, including threats from chemical contamination from per- and polyfluoroalkyl substances (PFAS) that affects immune system and liver function (Guillette et al. 2020).

The three lock & dams and their impact on fish passage is the greatest obstacle to anadromous fish recovery in the Cape Fear River. Construction of the “rock arch rapids” and locking through Lock & Dams 2 and 3 allowed for an adjusted maximum passage efficiency of 60–83% for American Shad (Raabe et al. 2019). However, adjusted maximum passage efficiency for Striped Bass was only 21–53% (Raabe et al. 2019). Actual passage efficiency has been minimal at Lock & Dams 2 and 3 during recent years as the lock structures were damaged from Hurricane Florence in 2018, limiting volitional passage to high streamflow events. In 2019, 67.5% of Striped Bass were captured at or below Lock & Dam 1, and many of the Striped Bass caught above Lock & Dam 1 emigrated from B. Everett Jordan Reservoir. Funding is in place to conduct renovations to the “rock arch rapids” to address issues that may be limiting Striped Bass passage efficiency at Lock & Dam 1, but until issues at Lock & Dams 2 and 3 are resolved, the Striped Bass population in the Cape Fear River will be unable to access spawning habitat and is therefore unlikely to recover. Lack of access to the spawning grounds at Smiley Falls and high mortality has created a Striped Bass population dependent on stocking efforts that may support a put-grow-take fishery (Rachels and Morgeson 2018). American Shad spawning migrations are also restricted by the lack of locking at Lock & Dams 2 and 3. Impacts may become evident when the 2019 and later year-classes conduct spawning migrations in 2022.

Improving anadromous fish passage at Lock & Dams 2 and 3 should be the highest priority to improve natural recruitment of Striped Bass and to ensure the continued sustainability of American Shad. Until improved passage is realized, Striped Bass management actions should be developed to provide the greatest utility to anglers. Management actions may include allowing harvest of Striped Bass in the Cape Fear River, stocking Striped Bass in alternative locations (stocking in B. Everett Jordan reservoir ended in 2020), stocking different sizes of Striped Bass, or varying numbers stocked until access to spawning habitat is improved and a self-sustaining population is viable. Additional investigation is needed to determine the impacts of limited passage on American Shad.

Management Recommendations

1. Establish regulations to initiate a put-grow-take Striped Bass fishery in the Cape Fear River.
2. Collaborate with partners to provide passage for anadromous fish at Lock & Dams 2 and 3.
3. Establish internal funding capacity to support construction or repair of anadromous fish passage infrastructure.
4. Conduct hydroacoustic survey to elucidate impacts of derelict lock structures on American Shad spawning migrations.
5. Optimize Striped Bass stocking program. Consider use of alternative sizes, numbers, and stocking locations.
6. Collaborate with the North Carolina Department of Health and Human Services to evaluate application of fish consumption advisories in the Cape Fear River.
7. Devise data collection procedures that would allow for classification of the status of the American Shad stock in the Cape Fear River.

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TABLE 1. Survey site data for Cape Fear River Anadromous Fish Stock Assessment sampling events in 2019. Discharge data were collected from USGS gage numbers 02105769 (located at Lock & Dam 1), 02105500 (located at William O. Huske Lock & Dam), and 02102500 (located on the Cape Fear River in Lillington, NC). For site name and boating access area, LD1 = Lock & Dam 1, LD2 = Lock & Dam 2, LD3 = Lock & Dam 3 (also known as William O Huske Lock & Dam), RL = Riverside Landing, BD = Buckhorn Dam, and BL = Buckhorn Landing. For target species, AS = American Shad and SB = Striped Bass. American Shad captured at Buckhorn Dam were not included in the analysis.

Date	Site name	Latitude	Longitude	Boating Access Area	Target Species	Water Temperature (°C)	Discharge (CFS)
Mar 11	LD1	34.4047000	-78.2928000	LD1	AS, SB	10.1	16,700
Mar 21	LD1	34.4047000	-78.2928000	LD1	AS, SB	11.8	14,500
Mar 21	LD3	34.8352000	-78.8226000	LD3	AS, SB	11.3	10,500
Mar 28	LD1	34.4047000	-78.2928000	LD1	AS, SB	12.9	11,900
Mar 28	LD3	34.8352000	-78.8226000	LD3	AS, SB	12.5	12,400
Apr 4	LD1	34.4047000	-78.2928000	LD1	AS, SB	13.8	7,180
Apr 4	LD3	34.8352000	-78.8226000	LD3	AS, SB	12.7	6,450
Apr 9	LD1	34.4047000	-78.2928000	LD1	AS, SB	16.0	10,700
Apr 9	LD3	34.8352000	-78.8226000	LD3	AS, SB	16.9	11,300
Apr 15	CFR98	34.4040000	-78.2799000	LD1	SB	18.7	19,500
Apr 15	LD1	34.4047000	-78.2928000	LD1	AS, SB	18.7	19,500
Apr 22	CFR98	34.4040000	-78.2799000	LD1	SB	18.7	13,000
Apr 22	LD1	34.4047000	-78.2928000	LD1	AS, SB	18.7	13,000
Apr 22	LD3	34.8352000	-78.8226000	LD3	AS, SB	18.1	11,000
Apr 23	LD1	34.4047000	-78.2928000	LD1	SB	17.9	12,400
Apr 23	LD3	34.8352000	-78.8226000	LD3	SB	17.9	12,300
Apr 26	LD2	34.6271000	-78.5770000	LD2	SB	19.9	11,600
Apr 29	CFR262	35.5522003	-77.1016006	RL	SB	19.2	10,700
Apr 29	LD3	34.8352000	-78.8226000	LD3	AS, SB	19.3	12,200
Apr 30	CFR98	34.4040000	-78.2799000	LD1	SB	19.7	12,500
Apr 30	LD1	34.4047000	-78.2928000	LD1	AS, SB	19.7	12,500
May 6	LD1	34.4047000	-78.2928000	LD1	AS, SB	21.8	10,200
May 6	LD3	34.8352000	-78.8226000	LD3	AS, SB	22.3	10,700
May 8	BD	35.5393100	-78.9902800	BL	AS*, SB	21.3	4,620

TABLE 2. Summary statistics for the 2019 Cape Fear River anadromous fish stock assessment. Statistics for American Shad include catches from only the three Lock & Dam sites. Note: Male = M, Female = F, Unknown = U, and Total Length = TL.

Species	Effort (h)	Catch M	Catch F	Catch U	M:F Ratio	Mean CPUE (SE)	Mean Male TL	Mean Female TL	Max TL
Striped Bass	12.2	106	29	116	3.7:1	17.9 (4.4)	383	605	796
American Shad	9.4	214	131	-	1.6:1	43.3 (9.9)	423	488	554

TABLE 3. Age, sex, and origin of Striped Bass captured during 2019 sampling.

Age	Year-Class	Number Male	Number Female	Number Unknown	Total	Hatchery Origin (%)	Unknown Origin (%)
1	2018	33	0	105	138	81	19
2	2017	46	5	10	61	92	8
3	2016	13	4	0	17	69	31
4	2015	2	3	0	5	100	0
5	2014	1	3	0	4	80	20
6	2013	1	4	0	5	83	17
7	2012	3	2	0	5	100	0
8	2011	1	0	0	1	100	0
9	2010	0	4	0	4	50	50

TABLE 4. Mean weekly CPUE, effort, and age of Striped Bass captured at each sampling location in 2019. Several (n = 11) of the Striped Bass were not included because we were unable to assign an age.

Capture Location	Mean Weekly CPUE	Total Effort (h)	Age									Total
			1	2	3	4	5	6	7	8	9	
Buckhorn	33.9	0.5		5	7		2		2		1	17
CFR262	2.4	0.4	1									1
LD 3	12.8	4.3	15	30	6	1	1	2	1	1	2	59
LD 2	2.0	0.5						1				1
LD 1	15.1	4.6	64	14	3	2		1	1			85
CFR98	48.4	2.0	58	12	1	2	1	1	1		1	77
Total	19.1	12.3	138	61	17	5	4	5	5	1	4	240

TABLE 5. Year-class, stocking size, stocking location, and contribution of fish stocked in B. Everett Jordan Reservoir to Striped Bass captured in the Cape Fear River in 2019. Of the 251 Striped Bass captured in 2019, 2 were confirmed to be Hybrid Striped Bass, and an assessment of stocking size and location combined with age was unfeasible for 40 individuals.

Age	Year-Class	Stocking size and location			Total	Reservoir contribution
		Reservoir phase I	CFR phase I	CFR phase II		
1	2018	80		31	111	72%
2	2017	55		2	57	96%
3	2016	12		1	13	92%
4	2015	4		3	7	57%
5	2014	3		1	4	75%
6	2013	1		6	7	14%
7	2012	3		3	6	50%
8	2011			1	1	0%
9	2010				3	0%
	Totals	158		48	209	76%

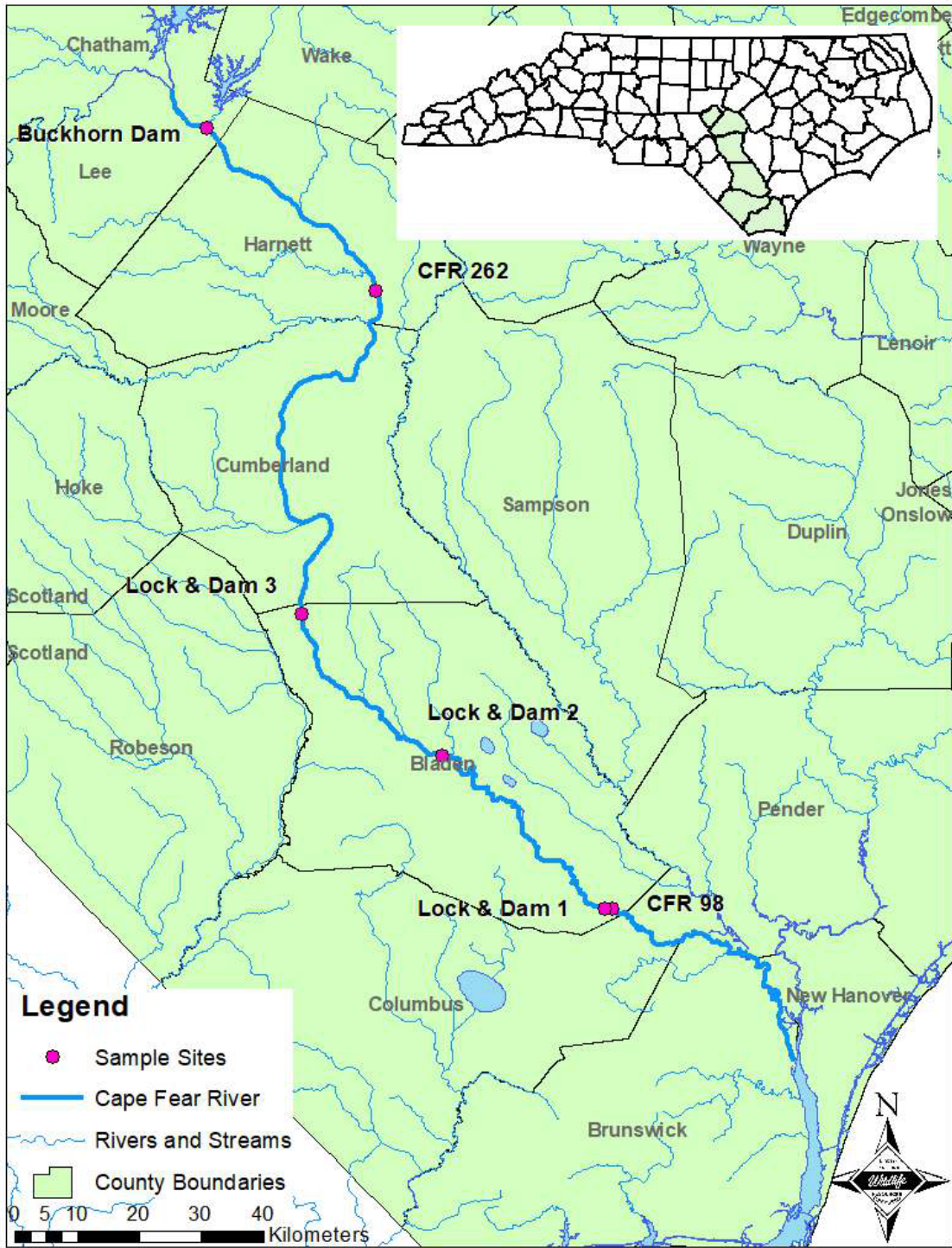


FIGURE 1. American Shad and Striped Bass sampling locations on the Cape Fear River for 2019.

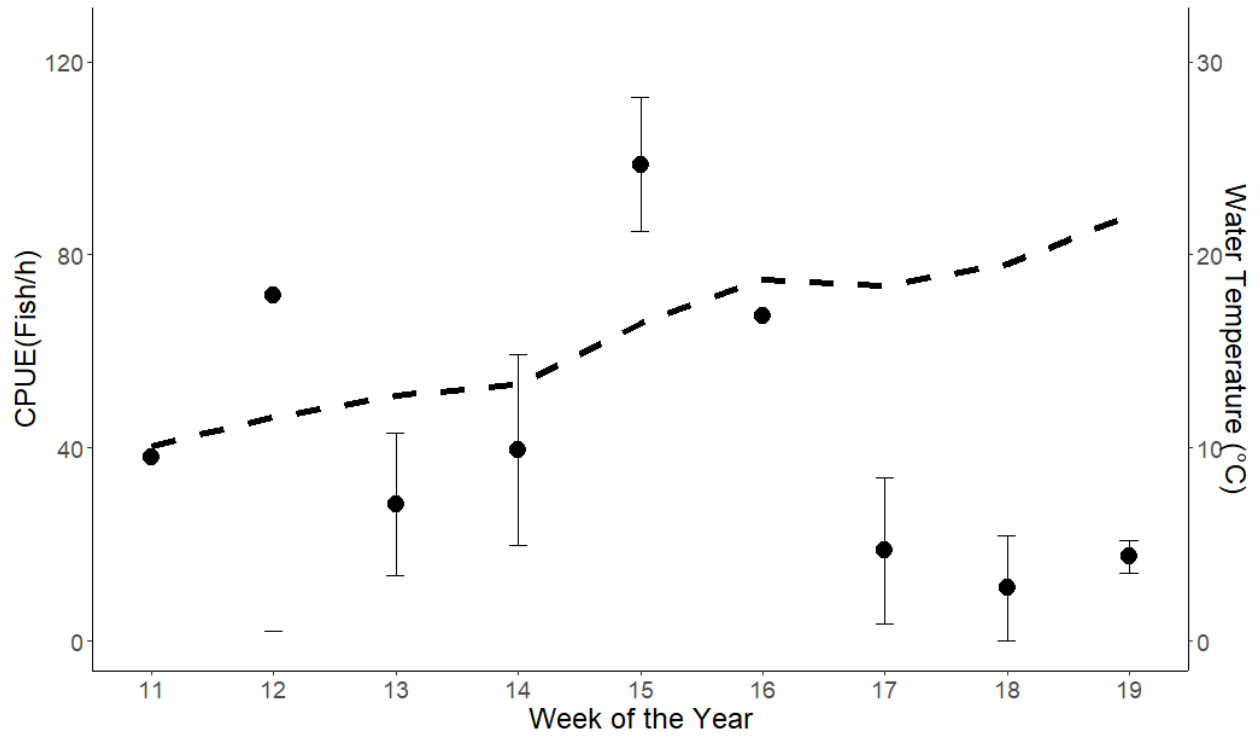


FIGURE 2. Mean weekly catch per unit effort (fish/h; circles) of American Shad and water temperature (°C; dashed line) by week of the year for 2019. Error bars denote standard errors.

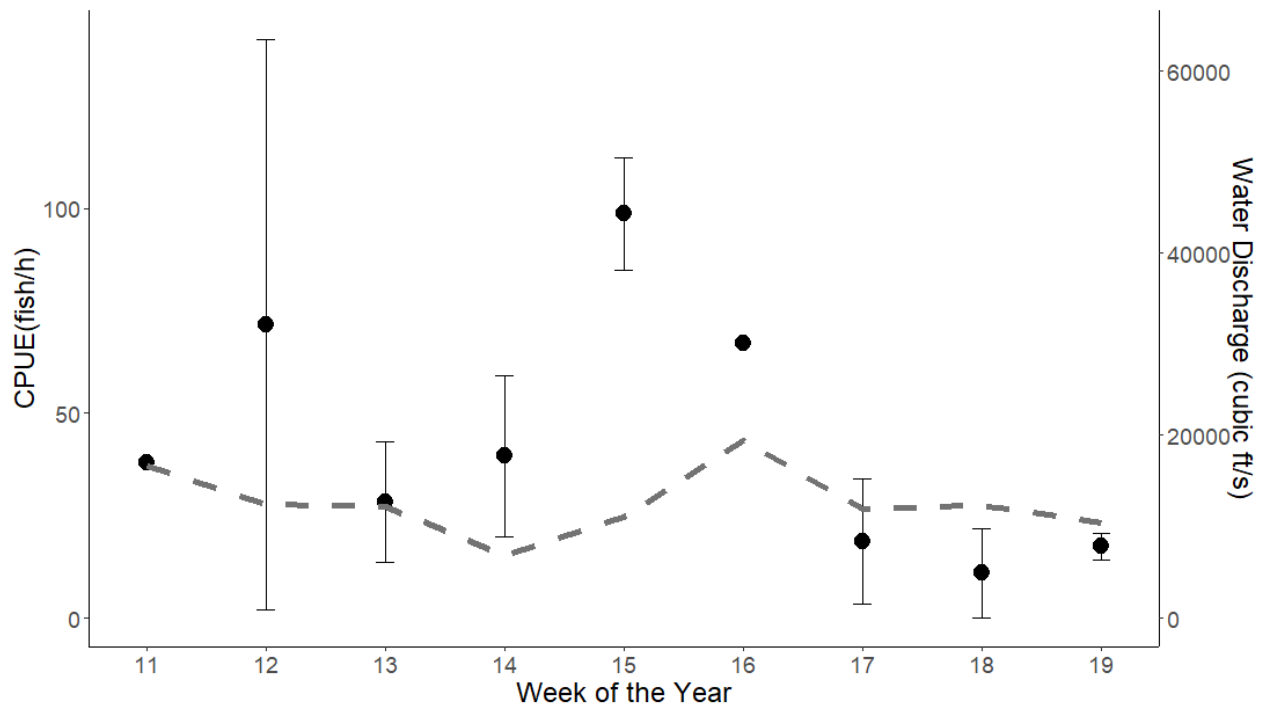


FIGURE 3. Mean weekly catch per unit effort (fish/h; circles) of American Shad and water discharge (CFS; dashed line) by week of the year for 2019. Error bars denote standard errors. Discharge data were collected from USGS gage numbers 02105769 (located at Lock & Dam 1), 02105500 (located at William O. Huske Lock & Dam), and 02102500 (located on the Cape Fear River in Lillington, NC)

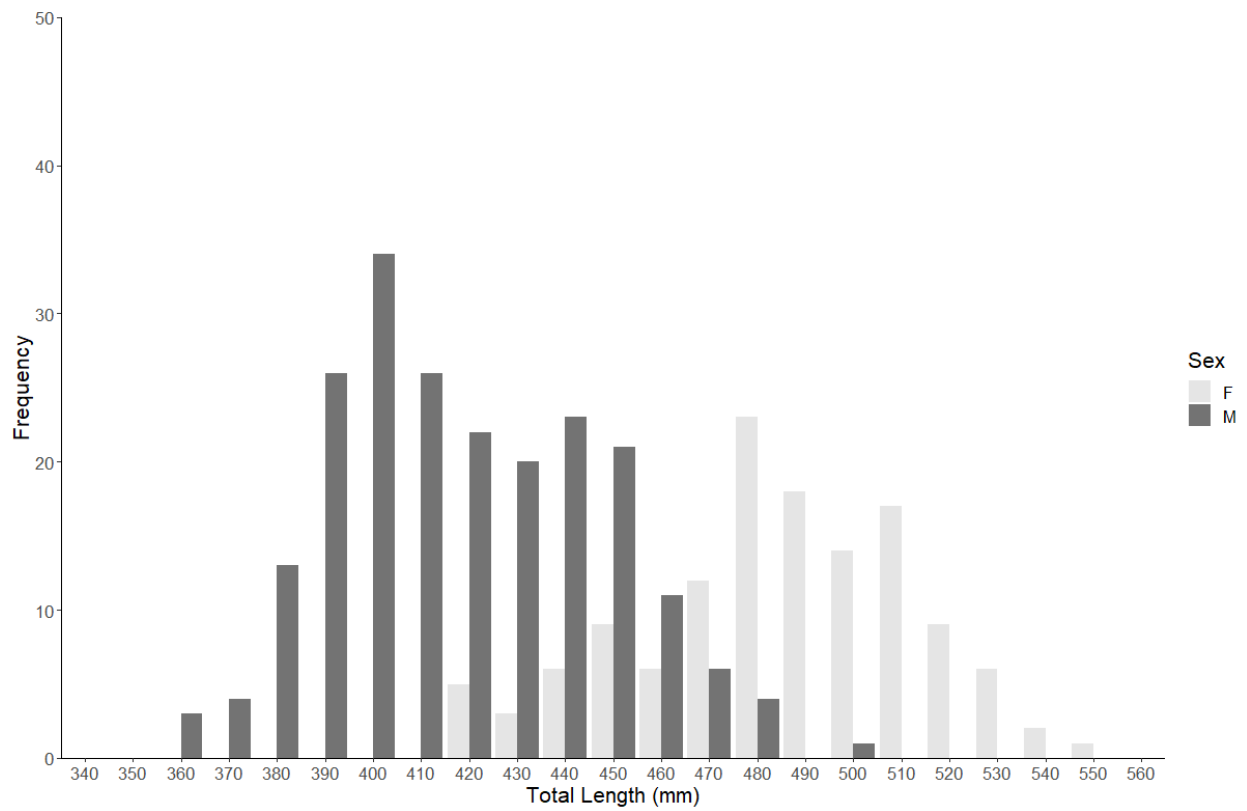


FIGURE 4. Length frequency for male (n = 214) and female (n = 131) American Shad collected from Cape Fear River in 2019.

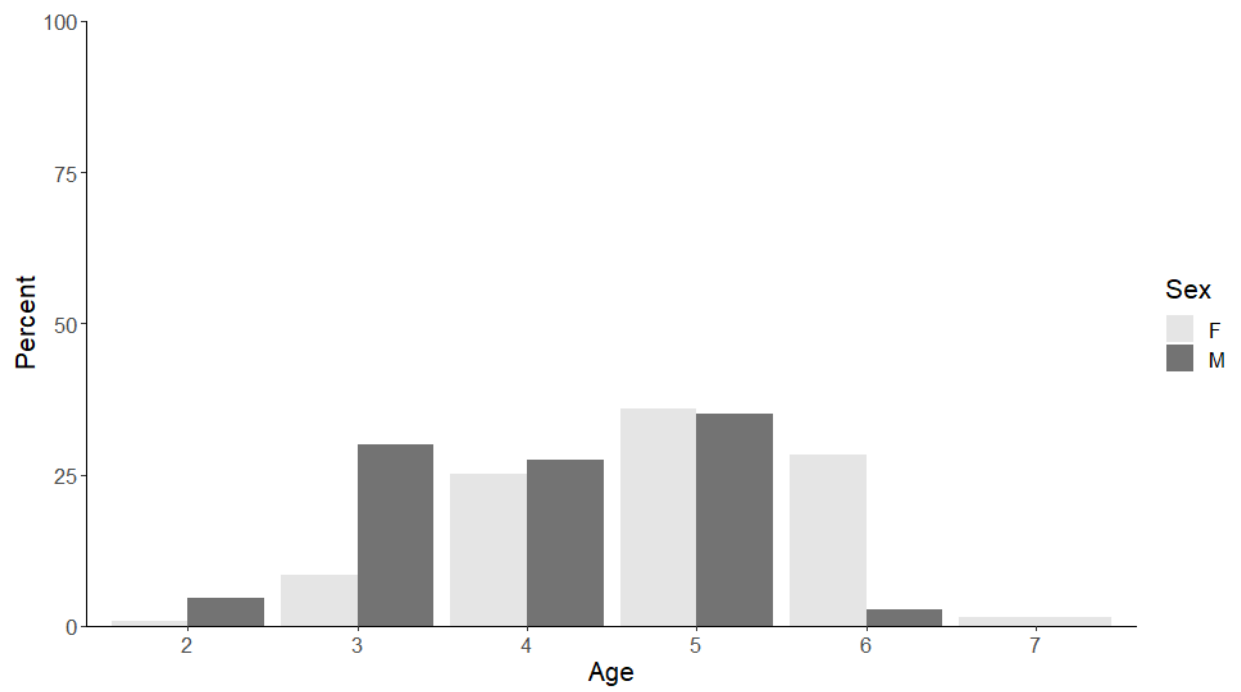


FIGURE 5. Percent of male and female American Shad in each age-class for 2019.

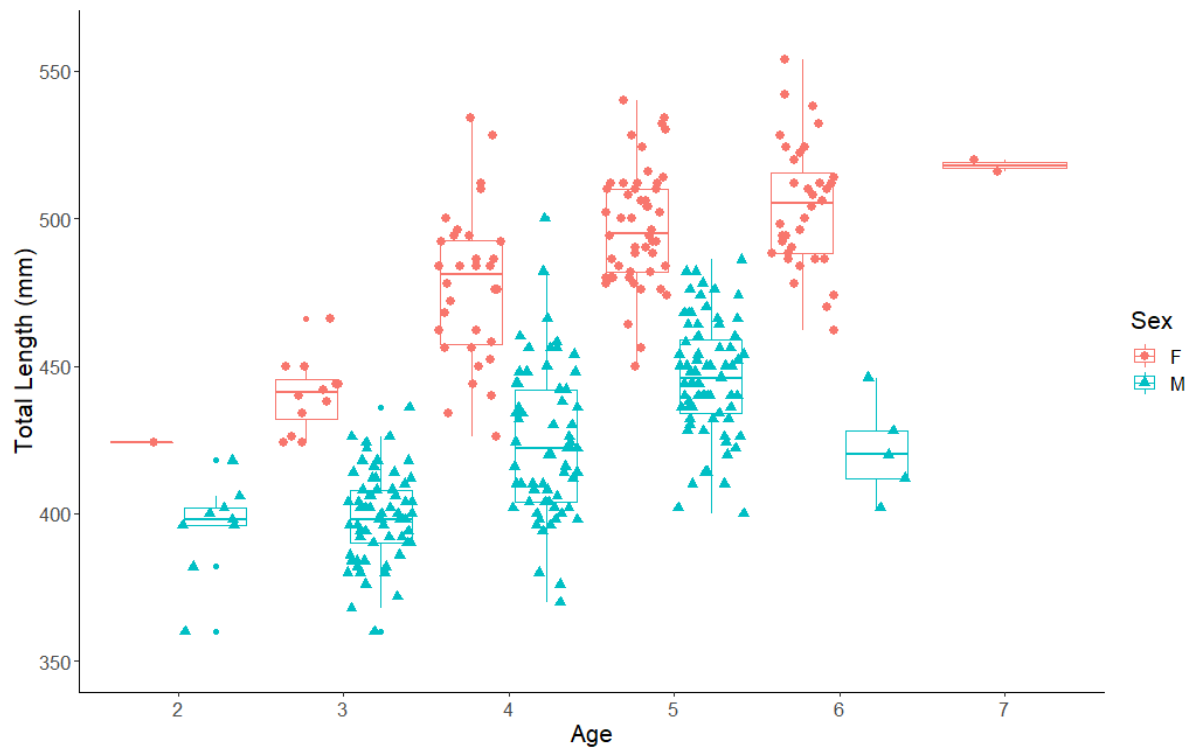


FIGURE 6. Box plot of length-at-age for male and female American Shad collected during 2019.

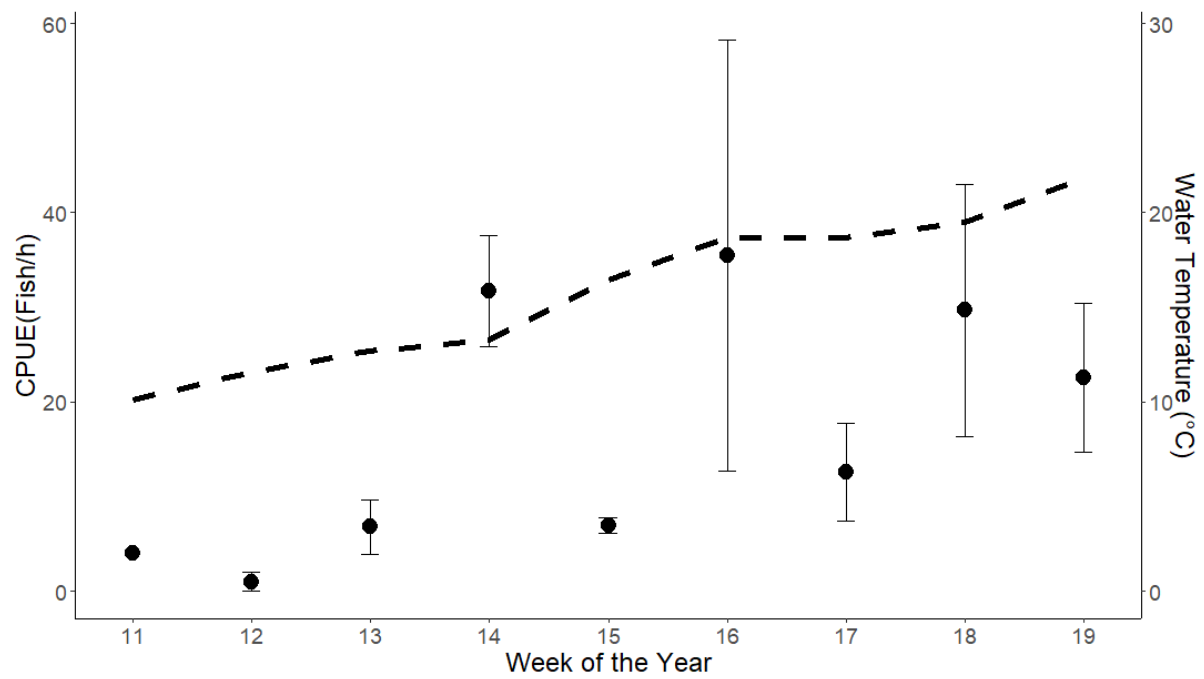


FIGURE 7. Mean weekly catch per unit effort (fish/h; circles) of Striped Bass and water temperature (°C; dashed line) by week of the year for 2019. Error bars denote standard error.

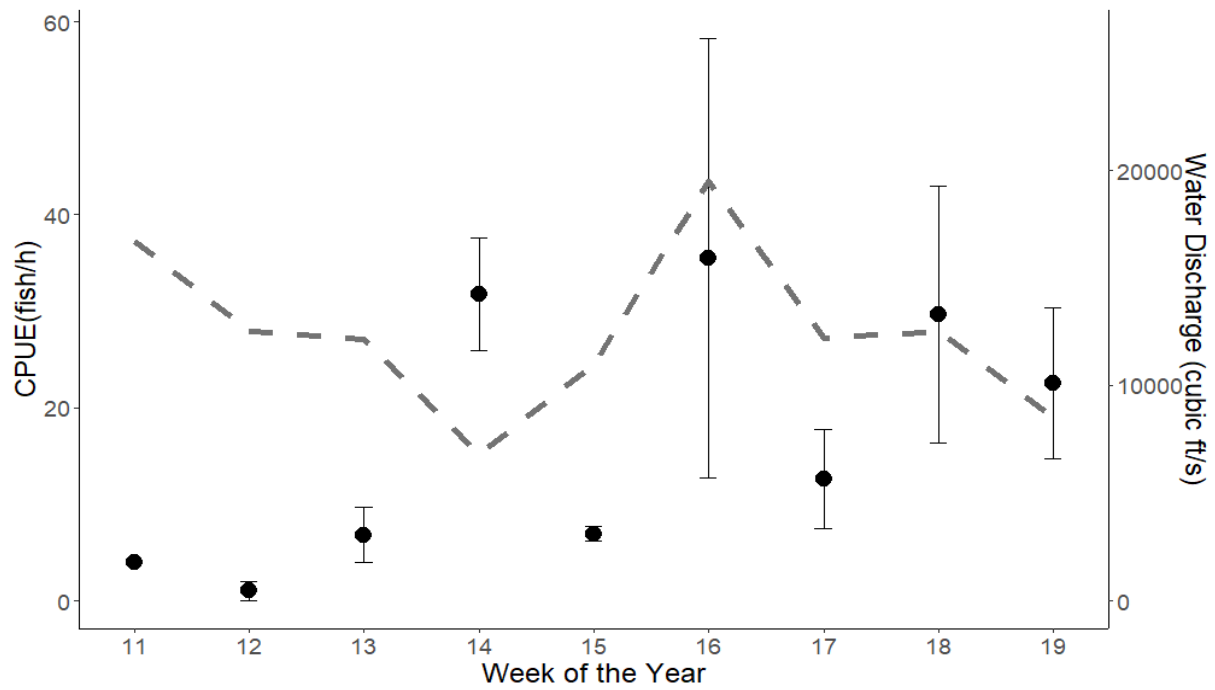


FIGURE 8. Mean weekly catch per unit effort (fish/h; circles) of Striped Bass and water discharge (CFS; dashed line) by week of the year for 2019. Error bars denote standard error. Discharge data were collected from USGS gage numbers 02105769 (located at Lock & Dam 1), 02105500 (located at William O. Huske Lock & Dam), and 02102500 (located on the Cape Fear River in Lillington, NC)

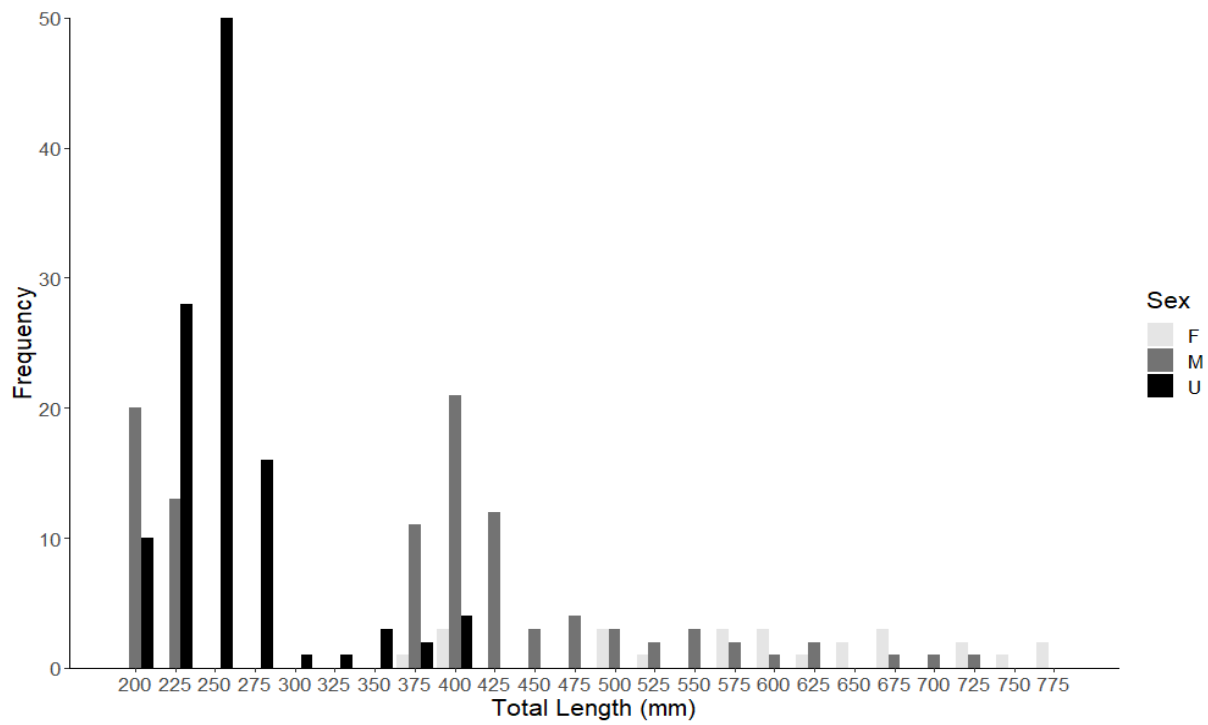


FIGURE 9. Length frequency for male (n = 106), female (n = 29), and unknown (n = 116) Striped Bass captured in 2019.

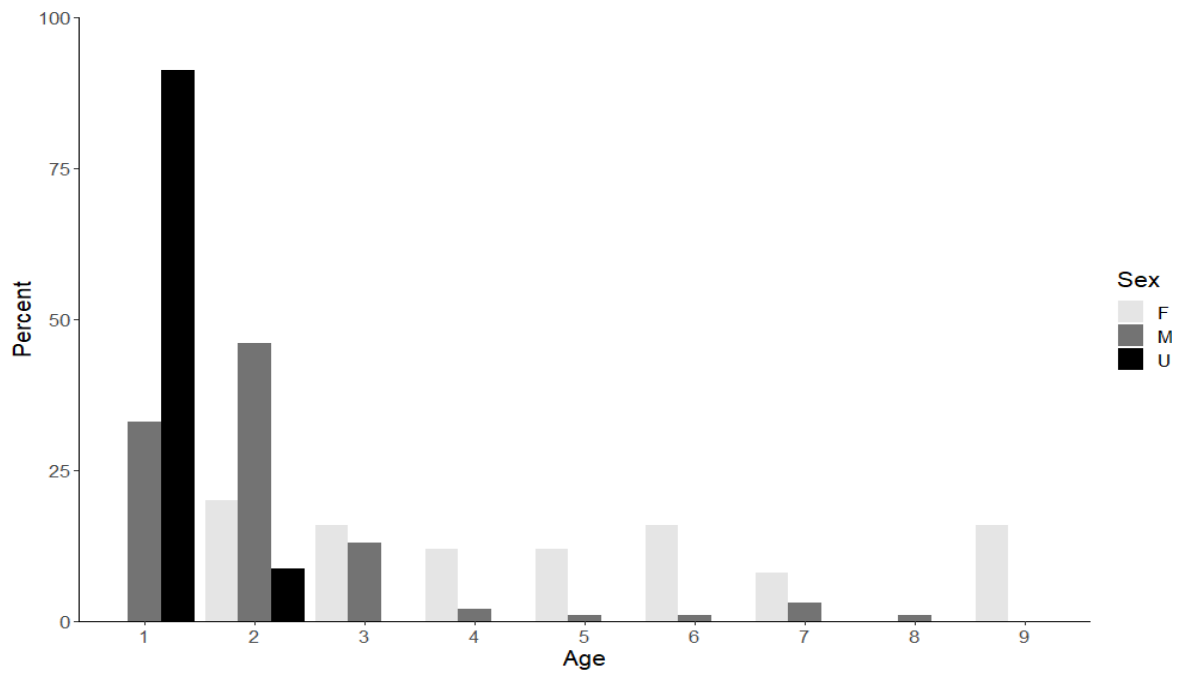


FIGURE 10. Percent of female, male, and unknown Striped Bass in each age-class for 2019.

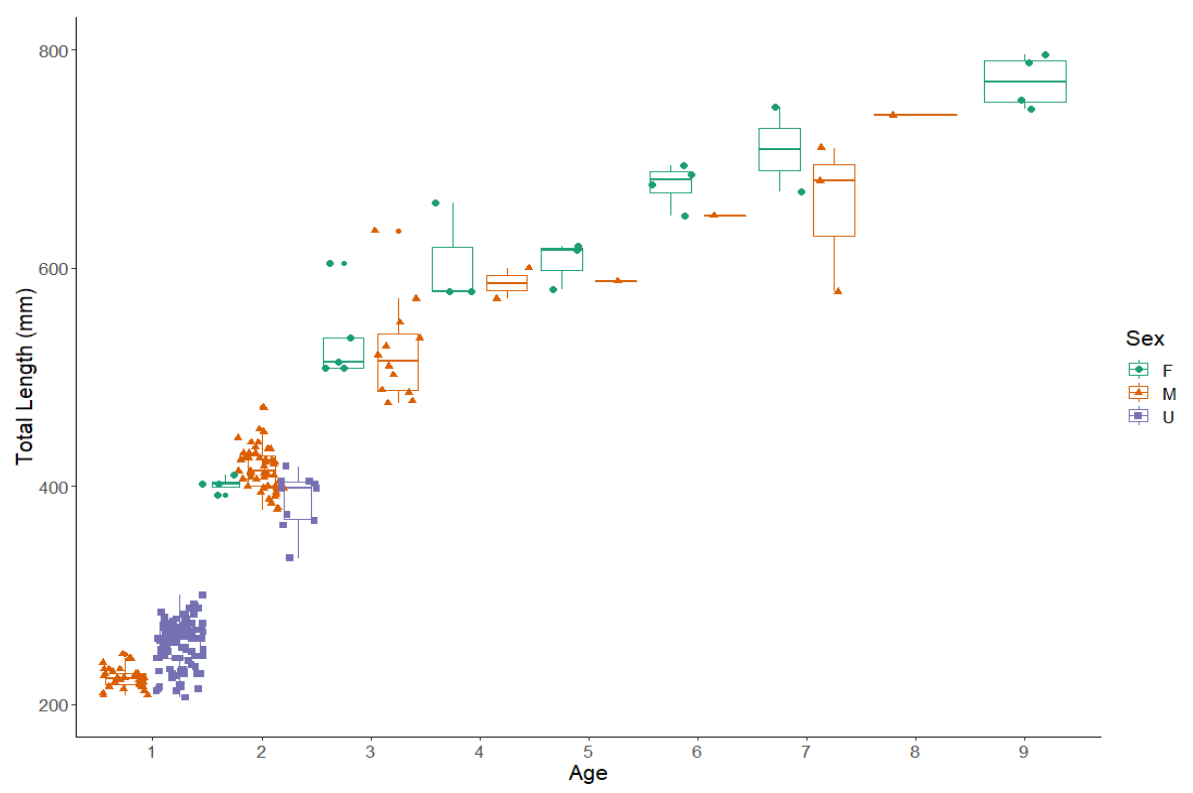


FIGURE 11. Box plot of length-at-age for male, female, and unknown Striped Bass collected during 2019.

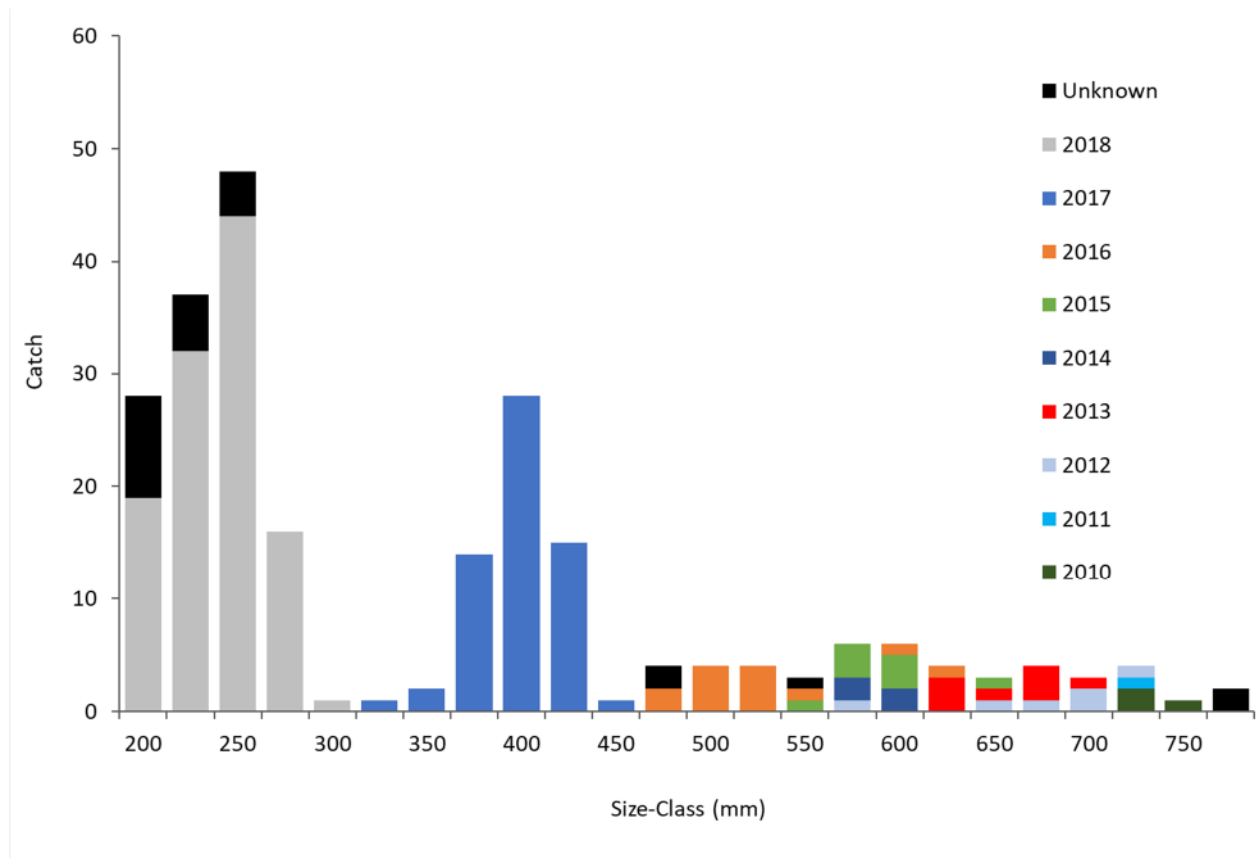


FIGURE 12. Year-class and length frequency of Striped Bass collected from the Cape Fear River in 2019. Parentage-based tagging analysis was used to determine the origin for 241 Striped Bass. Striped Bass with an “unknown” year-class were stocked before the use of PBT (older than the 2010 year-class), immigrated from areas not covered by the PBT program, or were the result of natural recruitment.