POST HURRICANE IRENE SPORTFISH RESPONSE FOR NEW AND WHITE OAK RIVERS

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Abstract.—On 27 August 2011 Hurricane Irene made landfall on North Carolina's coast causing wide spread fish kills. The New and White Oak rivers experienced fish kills as a function of hypoxic conditions following Hurricane Irene as dissolved oxygen (DO) dropped below 2 mg/L. The sport fish populations in both rivers were sampled by boat electrofishing in fall 2011 and fall 2012 to document any change in fish abundance and condition. Juvenile sport fish were initially most affected by Hurricane Irene; juvenile Largemouth Bass *Micropterus salmoides* mean catch-per-unit-effort (CPUE) increased from 1.3 fish/h (SE = 0.7) in fall 2011 to 4.3 fish/h (SE = 2.2) in fall 2012 on the White Oak River and increased from 0 fish/h (SE = 0) in fall 2011 to 2.6 fish/h (SE = 0.7) in fall 2012 on the New River. Juvenile Largemouth Bass had the highest mean annual growth during 2012 on both New and White Oak rivers with mean length-at-age for age-0 Largemouth Bass at 150-mm (SE = 24) and 153-mm (SE = 11). Very few juvenile sunfish were collected on the White Oak River, while no juvenile sunfish were collected on the New River post-Hurricane Irene. Both adult Largemouth Bass and sunfish abundance decreased following Hurricane Irene but appeared to improve during the 2012 sample season. With sportfish populations below abundance levels prior to Hurricane Irene, continued monitoring of these populations is warranted to assess recovery time.

Background

North Carolina offers annual fishing opportunities to over 1.5 million anglers (ASA 2013). Anglers may catch a wide variety of sport fish in water bodies ranging from high elevation mountain streams all the way to the Atlantic Ocean. The coastal plain region of North Carolina offers anglers the opportunity to fish multiple non-impounded, large scale river systems. Anglers commonly fish coastal North Carolina rivers for resident sport fish such as Largemouth Bass *Micropterus salmoides*, Bluegill *Lepomis macrochirus*, Redear Sunfish *L. microlophus*, Pumpkinseed *L. gibbosus*, Warmouth *L. gulosus*, Flier *Centrarchus macropterus,* Redbreast Sunfish *L. auritus*, Black Crappie *Pomoxis nigromaculatus*, White Perch *Morone americana*, White Catfish *Ameiurus catus*, Channel Catfish *Ictalurus punctatus*, Blue Catfish *I. furcatus*, and Flathead Catfish *Pylodictis olivaris*. Of these species, Largemouth Bass have been documented as one of the most sought after sport fish, while sunfish are the most frequently harvested sport fish by anglers in most coastal rivers (Dockendorf et al. 2004; Rundle et al. 2004; Homan et al. 2006).

Fish populations in coastal rivers are frequently exposed to harsh environmental conditions such as low dissolved oxygen (DO), elevated water temperatures and increased salinity that can each limit sport fish population size and condition (Mallya 2007). North Carolina coastal rivers are also subject to tropical storm systems during the Atlantic Hurricane Season, which runs from 1 June through 30 November each year (NOAA 2012). Hurricane passage can degrade water quality. Hurricane flood waters have been documented to inundate floodplains and then recede into river channels carrying large quantities of suspended organic material that is then decomposed by microbial bacteria. This decomposition process causes an increase in biological oxygen demand and a subsequent decrease in DO levels (McCargo et al. 2008). Fish exposed to hypoxic and anoxic conditions cannot survive if refugia are unavailable or if dissolved oxygen levels do not increase. Prolonged periods of hypoxic (DO $\leq$2 mg/L) conditions can result in fish kills. Usually, little can be done to enhance water quality while river systems experience these conditions, but biologists should attempt to document the alteration in fish populations and quantify the effect as conditions improve.

Hurricane Irene made landfall on North Carolina's coast 27 August 2011 and completely inundated a significant portion of eastern North Carolina's floodplain (Avila and Cangialosi 2011). Within the White Oak River Basin, both the New River and White Oak River experienced hypoxic and anoxic conditions and fish kills were reported in each system. In response, Commission staff conducted sport fish surveys on each river following Hurricane Irene in fall 2011, and one year later in fall 2012. The objectives of these surveys were to assess Hurricane Irene's initial effect on sport fish population metrics, and to monitor sport fish recovery one year after storm passage.

Study Site

The White Oak River Basin is located in central coastal North Carolina and drains 3,274 km^2 of the coastal plain physiographic province. The basin contains both the White Oak River and the New River. Both rivers are considered blackwater systems that originate and end in the coastal plain, before draining into the Atlantic Ocean. Headwaters of the White Oak River begin in Jones County, North Carolina, and the river flows southeastward for approximately 64 km creating the border between Carteret and Onslow counties. New River is located south of White Oak River, flowing southeastward for approximately 80 km, and is completely contained within Onslow County, North Carolina (Figure 1).

Methods

To monitor hypoxic conditions following Hurricane Irene, water quality variables were measured on six occasions on the White Oak River (Table 1) with a YSI Pro 2030 dissolved oxygen meter. New River water quality was measured by a U.S. Geological Survey (USGS) stream gage (02093000) at Jacksonville. Water quality parameters monitored included dissolved oxygen (mg/L), temperature (°C), conductivity (µS/cm), and salinity (ppt).

To determine the impact of the fish kills, sport fish were collected using boat-mounted electrofishing gear (Smith Root 7.5 GPP; 170–1000 V pulsed DC; 60–120 pulses-per-second; 4.5-–30 A) in fall 2011 (October 20-21) and fall 2012 (November 15-16). Six 500-m and four 400-m sport fish sample transects were selected on White Oak River and New River, respectively. Transects were selected that corresponded with previous sample locations to quantify the variation in sport fish populations following Hurricane Irene. All sport fish encountered were collected, identified to species, enumerated, measured (TL, mm) and weighed (g).

During the fall 2012 sample season, otoliths were removed from a subsample of up to five Largemouth Bass per 25-mm length group up to 250 mm for age and growth analysis. Fish age was determined according to Buckmeier and Howells (2003) using a Wolfe digital stereomicroscope with 10–40X magnification. Two readers independently aged each otolith to formulate an initial reader agreement. If readers failed to reach 100% initial reader agreement on fish ages, a concert read was conducted to reach 100% reader agreement. Mean length-at-age was calculated after applying a length-at-age key to the entire sample of Largemouth Bass up to 250-mm using the techniques outlined by Bettoli and Miranda (2001). Stomach content was examined on all Largemouth Bass greater than 200 mm following the procedures outlined in (Van Den Avyle and Roussel 1980) during the fall 2012 sample season. If Largemouth Bass stomach content was obtained, then content was identified to lowest taxa possible, weighed (g) and measured (TL, mm).

Relative abundance of each species was expressed as the number of individuals collected per electrofishing hour and was indexed as catch-per-unit-effort (CPUE; fish/hr). Abundance was also calculated for Largemouth Bass at three size ranges: juveniles (< 200 mm), adults (≥ 200 mm), and harvestable (≥ 356 mm). Size structures of sport fish populations were evaluated with length frequency histograms as well as proportional size distribution (PSD) and proportional size distribution preferred (PSD-P; Gabelhouse 1984, Guy et al. 2007). Largemouth Bass condition was assessed with the relative weight index (Wr; Wege and Anderson 1978).

Results

Water quality data was collected during six sample events on the White Oak River, while New River instantaneous data were recorded on the USGS stream gage at Jacksonville. White Oak River DO levels were less than 2 mg/L for at least 12 consecutive days following Hurricane Irene's landfall in North Carolina (Table 1), while New River's stream gage documented DO levels less than 2 mg/L for seven consecutive days following Irene's landfall (Figure 2).

Largemouth Bass Growth and Diet Analysis

A total of four Largemouth Bass from the New River and 20 Largemouth Bass from the White Oak River were sacrificed for age and growth determination. Total lengths of aged New River Largemouth Bass ranged 93–188 mm, while aged White Oak River Largemouth Bass ranged 87–245 mm. Initial reader agreement was 97% and after a concert read, observers were able to reach 100% consensus on all ages. One hundred percent of the New River Largemouth Bass aged were age-0, while 11 Largemouth Bass from White Oak River were estimated age-0 and nine were estimated to be age-1. Total lengths of age-0 White Oak River Largemouth Bass ranged 87–205 mm, while age-1 Largemouth Bass ranged 186–245 mm. Of the 27 Largemouth Bass sacrificed for age determination in the White Oak River, 41% (N=11) were estimated as age 0, while 59% (N=16) were estimated to be age 1.

On the New River, 12 Largemouth Bass greater than 200 mm were examined for stomach content. Of the 12 Largemouth Bass, 83% (N=10) were empty, while 17% (N=2) contained fish. Forty-two Largemouth Bass greater than 200 mm were examined for stomach content on the White Oak River. Of the 42 Largemouth Bass, 18% (N=8) contained shrimp, 15% (N=7) contained fish, 11% (N=5) contained crab, 7% (N=3) contained crayfish, and 49% (N=22) were empty. Because stomachs of three Largemouth Bass contained two prey species each, percent composition was considered out of 45 possible prey items and not 42 in the diet analyses (Figure 3).

New River Largemouth Bass

A total of 23 Largemouth Bass was collected from the New River during the two sample seasons following Hurricane Irene. During fall 2011, CPUE of Largemouth Bass less than stock size (200 mm) was 0 fish/h. However, mean CPUE increased to 2.6 fish/h (2 SE = 1.4) during fall 2012. Mean CPUE of Largemouth Bass > 200 mm was 8.4 fish/h (2 SE = 8.6) during fall 2011 and increased to 11.0 fish/h (2 SE = 6.2) in fall 2012. However, mean CPUE was still much lower than the most recent pre-hurricane sample conducted in spring 2011 (20.3 fish/h, 2 SE = 10; Figure 4). For harvestable size fish, two (mean CPUE 2.1 fish/hr, 2 SE = 2.4) were collected fall 2011, and five (mean CPUE 3.6 fish/hr, 2 SE = 4.0) were collected in fall 2012 (Figure 4).

Length frequency histograms showed an alteration in year class strength between fall sampling seasons, and fish less than stock size were only collected in fall 2012 (Figure 5). Largemouth Bass ranged in length from 93–453 mm. Largemouth Bass PSD decreased from 68 during spring 2011 to 38 during fall 2011, but increased markedly in fall 2012 to 91. Proportional size distribution of preferred (PSD-P) fish increased from 22 during spring 2011 to 36 during fall 2012 (Table 2). Proportional size distribution of preferred-sized Largemouth Bass could not be calculated for fall 2011 because no preferred-sized Largemouth Bass were collected that season. No memorable-sized Largemouth Bass were collected after Irene, while one memorable-sized Largemouth Bass was collected in spring 2011.

Mean Wr of all Largemouth Bass decreased between spring 2011 (pre-hurricane) and fall 2011 following Hurricane Irene. Average Wr of stock-sized Largemouth Bass decreased from 103 in spring 2011 to 86 in fall 2011. Average Wr of quality-sized Largemouth Bass decreased from 95 in spring 2011 to 89 in fall 2011. No preferred-sized Largemouth Bass were collected in fall 2011; however, mean Wr of preferred-size fish collected in fall 2012 increased from spring 2011 to a value of 100. Mean Wr values during fall 2012 were similar to pre-Irene conditions. Lowest mean Wr values were documented in fall 2011 (Figure 6).

White Oak River Largemouth Bass

A total of 84 Largemouth Bass was collected from the White Oak River during the two sample seasons following Hurricane Irene. Thirty Largemouth Bass were collected in fall 2011, while 54 were collected during fall 2012. During fall 2011, CPUE of Largemouth Bass less than stock size was 1.3 fish/hr (2 SE = 1.4). However, mean CPUE increased to 4.3 fish/hr (2 SE = 4.4) during fall 2012. Mean CPUE of Largemouth Bass > 200 mm was 17.1 fish/hr (2 SE = 17) during fall 2011, but decreased slightly to 15.3 fish/hr (2 SE = 7) in fall 2012. However, mean CPUE was still much lower than the most recent pre-hurricane sample collected during spring 2011 (31.5 fish/hr, 2 SE = 7; Figure 7). Ten harvestable-sized Largemouth Bass were collected during the two fall sample seasons. Four (mean CPUE 3.1 fish/hr, 2 SE = 5.4) of the 10 harvestable-sized fish were collected in fall 2011, and six (mean CPUE 2.4 fish/hr, 2 SE = 3.6) were collected in fall 2012 (Figure 7).

Length frequency histograms showed a wide range of Largemouth Bass size distributions each sampling season (Figure 8). Largemouth Bass ranged in length from 87 to 546 mm with the widest range collected during fall 2012. Largemouth Bass PSD decreased from 64 in spring 2011 to 46 in fall 2011, and continued to decline to 21 during fall 2012. Proportional size distributions of preferred (PSD-P) fish also decreased between sampling seasons from 18 in spring 2011, to eight in fall 2011, and then seven in fall 2012. No memorable-sized (510-629 mm) Largemouth Bass were collected during fall 2011, but PSD-M decreased from 13 spring 2011 to 2 fall 2012 (Table 3). Mean Wr of all Largemouth Bass increased from spring 2011 to fall 2012 (Figure 9).

New River sunfish

The most abundant sunfish species collected during this study were Redear Sunfish, Pumpkinseed and Bluegill. Two hundred and twenty-three sunfish were collected during the spring 2011 sample season, while 53 sunfish were collected during the two sample seasons following Hurricane Irene. Of the 53 sunfish collected following Hurricane Irene, 34 sunfish were collected in fall 2011 and 19 in fall 2012. Redear Sunfish were the most frequently collected sunfish representing 47% (N=129) of the sunfish population, followed by Pumpkinseed (42%, N=116) and Bluegill (6%, N=16). Percent species distribution was similar each season for Redear Sunfish, Pumpkinseed and Bluegill. Catch-per-unit-effort estimates of all sunfish were higher in pre-Irene surveys with Bluegill 7.3 fish/hr (2 SE = 7), Redear Sunfish 52 fish/hr (2 SE = 36), and Pumpkinseed 47.1 fish/hr (2 SE = 52; Figure 10).

Length frequency histograms showed there was an absence of sunfish less than stock length collected from the New River following Hurricane Irene. Bluegill ranged in total length from 47 mm to 226 mm (Figure 11), Redear Sunfish total lengths ranged from 13 mm to 262 mm (Figure 12), and Pumpkinseed total lengths ranged from 62 mm to 195 mm (Figure 13). Redear Sunfish PSD and PSD-P increased between sampling seasons with PSD values of 69, 86 and 100 and PSD-P values of 31, 36 and 58 for spring 2011, fall 2011 and fall 2012, respectively. Bluegill PSD could only be calculated during spring 2011 and fall 2012 sampling seasons with values of 69 and 100. Pumpkinseed PSD increased between sampling seasons with values of 31, 35 and 50. No memorable-size sunfish were collected during this study (Table 2).

White Oak River sunfish

The most abundant sunfish species collected during this study from the White Oak River were Bluegill, Redear Sunfish and Pumpkinseed. Three hundred and forty-four sunfish were collected during the spring 2011 sample season, while 365 sunfish were collected during the two sample seasons following Hurricane Irene. Of the 365 sunfish collected following Hurricane Irene, 126 sunfish were collected in fall 2011 and 238 in fall 2012. Bluegills were the most frequently collected sunfish representing 51% (N=360) of the sunfish population, followed by Redear Sunfish (34%, N=239) and Pumpkinseed (12%, N=83). Percent species distribution was similar each season for Bluegill, Redear Sunfish and Pumpkinseed. Catch-per-unit-effort of all sunfish was higher in the spring 2011 pre-Irene surveys with Bluegill abundance of 69.3 fish/hr (2 SE = 24.0), Redear Sunfish 55.6 fish/hr (2 SE = 35) and Pumpkinseed 18.3 fish/hr (2 SE = 11.6; Figure 14). Redear Sunfish CPUE continuously decreased from spring 2011 to 29.5 fish/hr (2 SE = 46.0) in fall 2011 and 15.1 fish/hr (2 SE = 11) in fall 2012. Bluegill and Pumpkinseed CPUE gradually increased, approaching pre-Irene catch rates during fall 2012 with Bluegill CPUE 47.3 fish/hr (2 SE = 20.6) and Pumpkinseed 15.8 fish/hr (2 SE = 17.0; Figure 14).

Length frequency histograms indicated few sunfish smaller than stock size were collected from the White Oak River following Hurricane Irene. Bluegill ranged in length from 46 mm to 219 mm (Figure 11), Redear Sunfish lengths ranged from 62 mm to 275 mm (Figure 12), and Pumpkinseed lengths ranged from 110 mm to 185 mm (Figure 13). Redear Sunfish and Pumpkinseed PSD values dropped following Hurricane Irene from values of 71 and 26 to values of 3 and 17, respectively. Both Redear Sunfish and Pumpkinseed PSD values during fall 2012 exceeded pre-hurricane estimates in spring 2011. Bluegill PSD stayed fairly constant between sampling seasons with values of 23 (pre-hurricane, spring 2011), 26 (fall 2011) and 26 (fall 2012). No memorable-size sunfish were collected during this study and only Redear Sunfish were collected of quality-size each sampling period (Table 2).

Discussion

Hurricane Irene negatively impacted sport fish populations within the New and White Oak rivers. The extent and duration of hypoxic conditions were not as drastic and prolonged as those observed in proximal or regional coastal river systems, e.g., Neuse (Homan and Dycus 2013a) and Tar (Homan and Dycus 2013b) rivers or Roanoke and Chowan rivers (NCWRC unpublished data), but were severe enough to cause reductions in sport fish condition and abundance. Relative abundance estimates of stock and harvestable-size Largemouth Bass in both the New and White Oak rivers were less than 50% of those found prior to Hurricane Irene (Figures 4 and 7). While relative abundance of Largemouth Bass was low; there was an increase in relative abundance between sampling events during this study, indicating recovery towards levels prior to Hurricane Irene.

The post-hurricane (2011 and 2012) mean CPUE estimates were more variable than pre-hurricane estimates. This variation is most likely due to a smaller post-hurricane sample size (New River N= 4; White Oak River N = 6) compared to the pre-hurricane spring 2011 surveys (New River N= 13; White Oak River N = 14). Cooler water temperatures (16.8—20.0°C fall 2011; 9.5—13.7°C fall 2012) could have reduced the capture efficiency of our electrofishing equipment during post-hurricane sport fish sampling in the fall as well. As water temperatures decrease, fish will leave shoreline habitat and occupy deeper waters, which are more difficult to sample with electrofishing gear (Reynolds 1996). During the fall 2011 sampling season, low relative abundance may have been a function of temporary emigration from sample transects. Adult Largemouth Bass and sunfish that inhabited areas of hypoxia following the hurricane could have moved upstream to avoid degraded water quality, but then returned as habitat conditions improved prior to the fall 2012 season. Decreases in relative abundance were likely a function of poor water quality, fish kills, and emigration out of sample transects. Future studies on the New and White Oak rivers should include more sample sites over a broader area to account for changes in water quality and to minimize variability in mean CPUE estimates.

Young of year (YOY) Largemouth Bass were absent or collected at very low numbers during fall 2011 in both river systems. Hypoxic conditions are more detrimental to smaller, younger fish (Tom 1998, ESA 2013) and are capable of completely eliminating a year class within a system. During fall 2011, no Largemouth Bass <200 mm were collected in New River (Figure 5), while only four were collected in White Oak River (Figure 8). Future analysis of Largemouth Bass age and growth for these rivers should note the potential year class failure of the 2011 cohort. Age-0 Largemouth Bass spawned during spring 2012 were collected during fall 2012 indicating successful reproduction of adult fish that survived Hurricane Irene. Mean length-at-age of age-0 Largemouth Bass from the New and White Oak rivers was the highest annual growth of YOY Largemouth Bass observed in these systems to date (NCWRC unpublished, Figure 15). Increased growth of YOY Largemouth Bass during periods of decreased relative abundance of Largemouth Bass indicates a potential density-dependent relationship within these coastal river Largemouth Bass populations (Schindler et al. 1997).

White Oak River Largemouth Bass average Wr decreased between the fall 2011 and fall 2012 sample seasons, which could indicate: 1) reduced feeding opportunities from lack of prey; 2) an increase in intraspecific competition; or 3) a diet change to increased consumption of less nutritious prey items. The paucity of small (<80 mm) sunfish could be attributed to decreased feeding opportunities. Diet analysis revealed crayfish, crabs and crustacean made up a large portion of White Oak River Largemouth Bass diets (Figure 3). Crayfish, crabs and crustacean are more costly to digest and could have caused a decrease in Wr (Yako et al. 2000). New River Largemouth Bass exhibited an increase in average Wr indicating that there were adequate feeding opportunities for Largemouth Bass in New River, while lower fall 2011 Wr could have resulted from decreased feeding opportunities after the fish kill or decreased feeding due to stress from prolonged hypoxic conditions. White Oak River Largemouth Bass PSD values varied little and were within the accepted range of a balanced population (Gabelhouse 1984). Results from this study indicated that sunfish abundance decreased in both the White Oak and New rivers compared to pre-hurricane sample seasons (NCRWC unpublished data). New River sunfish Wr increased while White Oak River sunfish Wr decreased between the fall 2011 and fall 2012 sampling seasons. Decreased Wr of White Oak River sunfish could be due to increased competition as abundance of sunfish was higher than the New River; six times more sunfish were collected from the White Oak River than collected from the New River. No memorable and only a few preferred-sized sunfish were collected within both rivers during this study and no memorable sunfish were collected in two pre-hurricane spring surveys (2009 and 2011). These observations may suggest a biological process limiting sunfish growth. Both black water systems can have higher salt concentrations due to their close proximity to the Atlantic Ocean and often exhibit lower levels of dissolved oxygen (NCWRC unpublished data). Increased salinity and decreased DO levels can adversely affect the metabolic rate of fish and decrease the maximum obtainable size of each species (Mallya 2007). Of utmost concern is the very limited number of small sunfish collected during all three sample seasons. Absence of less than stock length sunfish during the fall 2011 sample season could have been directly related to Hurricane Irene fish kills, whereas the, absence of YOY sunfish during fall 2012 is potentially a function of poor spawning success in spring 2012. Increased salinity and decreased DO could have limited reproduction, or decreased prey abundance in response to the fish kill could have led to increased predation on YOY sunfish by fish and other predators (e.g., piscivorous birds and mammals).

Management Recommendations

1. Increase water quality monitoring following future hypoxic events to determine potential environmental factors that impair the recovery of affected sport fish populations (e.g. salinity, pH, DO).

2. Continue monitoring sport fish growth and abundance in the New and White Oak rivers to document improvement to pre-Irene conditions.

3. Increase total number of transects and/or transect lengths to cover more available habitat and obtain a more accurate estimate of sport fish size and abundance.

4. Supplement recovering Largemouth Bass populations with advanced fingerling stockings in suitable habitats within the New River.

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TABLE 1.—White Oak River water quality samples collected in August and September, 2011.

Date	Location	DO (mg/L)	% Saturation	Conductivity (uS)	Salinity (ppt)	Temperature (°C)
8/25/2011	Haywood Landing	3.9	51	12620	6.9	27.3
8/30/2011	Stella	2.7	33	1097	0.5	26.1
9/12/2011	Haywood Landing	0.16	1.9	360	0.2	25.5
9/12/2011	Long Point Landing	0.93	11.5	817	0.4	26.7
9/16/2011	Haywood Landing	1.61	19.2	402	0.2	24.5
9/23/2011	Haywood Landing	1.85	21.5	530	0.3	23.0

TABLE 2.—New River proportional size distribution (PSD), PSD-preferred, and PSD-memorable of Largemouth Bass, Bluegill, Redear Sunfish and Pumpkinseed before (spring 2011), immediately after (fall 2011), and one year following (fall 2012) Hurricane Irene.

Species		Spring 2011	Fall 2011	Fall 2012
Largemouth Bass	PSD	68	38	91
	PSD-P	22	—	36
	PSD-M	1	—	—
Bluegill	PSD	69	—	100
	PSD-P	15	—	—
Redear Sunfish	PSD	69	86	100
	PSD-P	31	36	58
Pumpkinseed	PSD	31	35	50

TABLE 3.—White Oak River proportional size distribution (PSD), PSD-preferred (PSD-P), and PSD-memorable (PSD-M) of Largemouth Bass, Bluegill, Redear Sunfish and Pumpkinseed before (spring 2011), immediately after (fall 2011), and one year after (fall 2012) Hurricane Irene.

Species		Spring 2011	Fall 2011	Fall 2012
Largemouth Bass	PSD	69	46	31
	PSD-P	18	8	7
	PSD-M	13	—	2
Bluegill	PSD	23	26	26
	PSD-P	3	—	—
Redear Sunfish	PSD	71	55	74
	PSD-P	21	3	4
Pumpkinseed	PSD	26	17	71

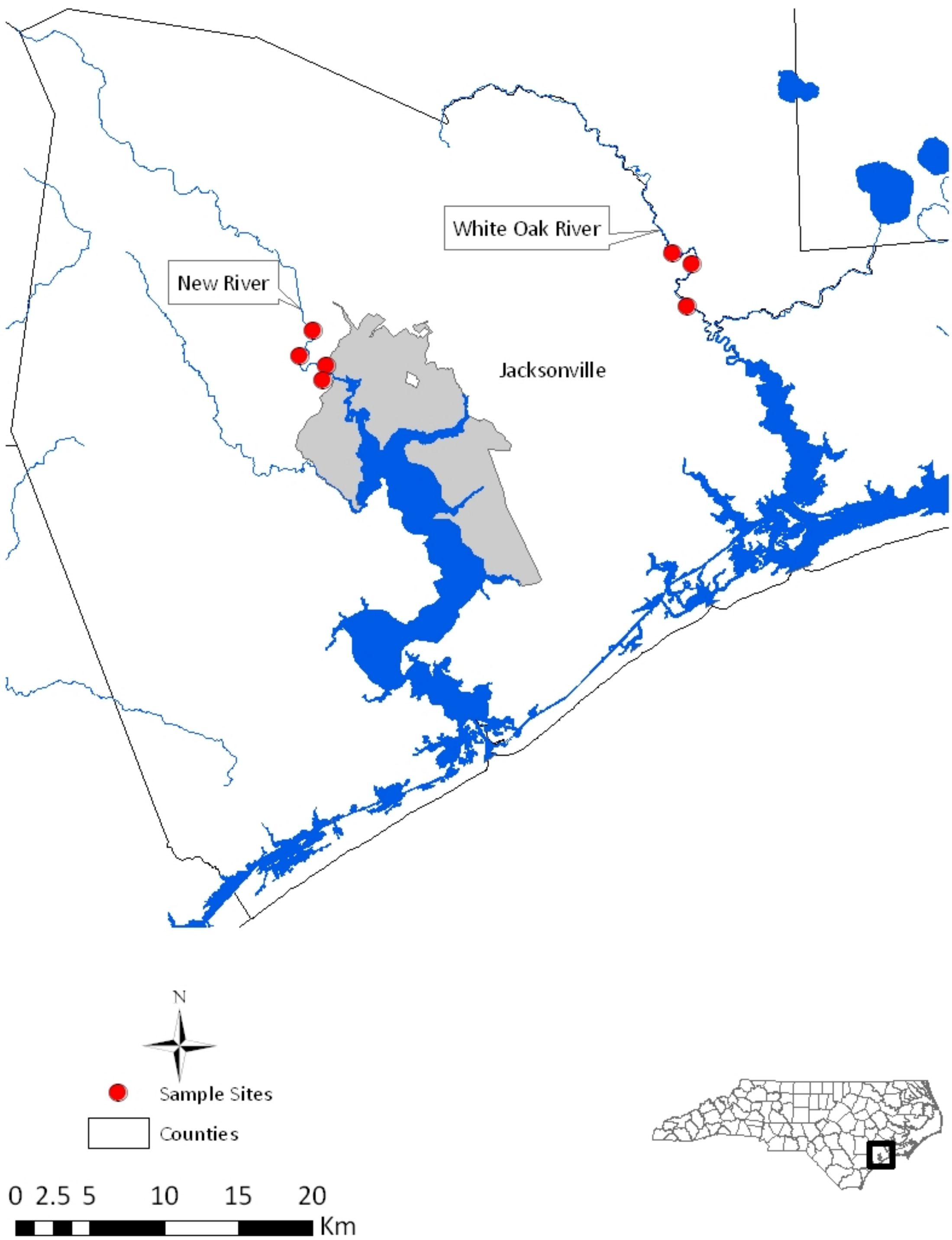

FIGURE 1.—Locations of electrofishing survey locations within the New and White Oak rivers, North Carolina in 2011 and 2012.

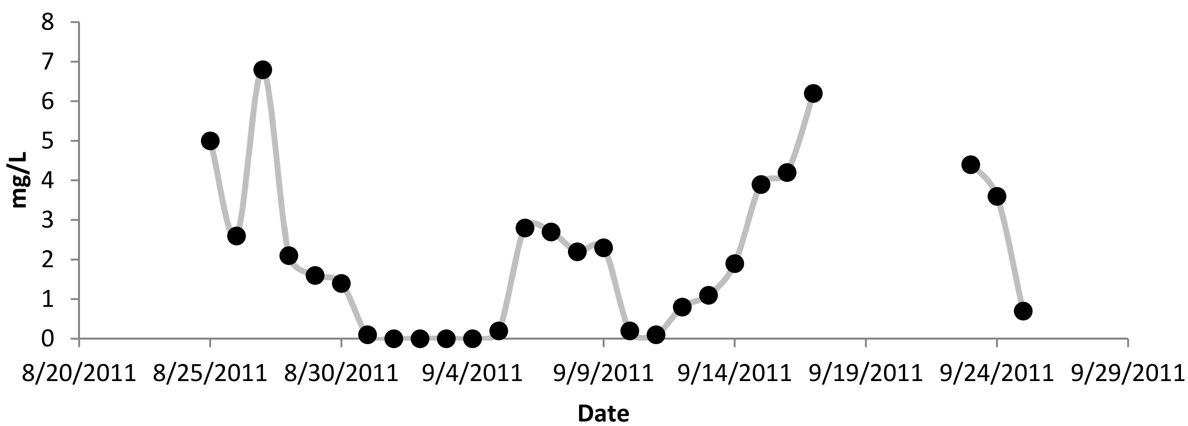

FIGURE 2.—New River dissolved oxygen levels (mg/L) pre- and post-Hurricane Irene collected by USGS stream gage 0209303205. From September 19 to September 22, 2011, no DO data was collected.

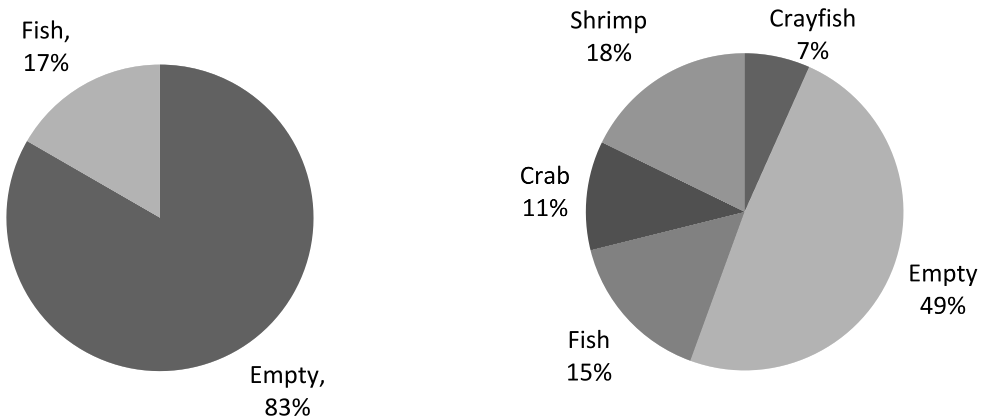

FIGURE 3.—New River (left) and White Oak River (right) Largemouth Bass diet analysis from samples collected in the fall of 2012.

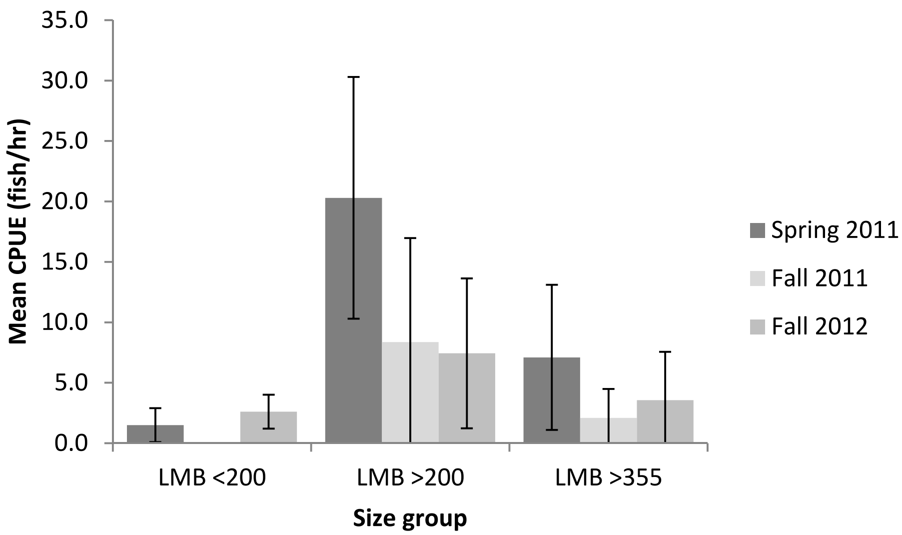

FIGURE 4.—Catch-per-unit-effort of Largemouth Bass four months before (spring 2011), 55 days after (fall 2011) and one year after (fall 2012) Hurricane Irene on the New River. Error bars are ± 2 SE.

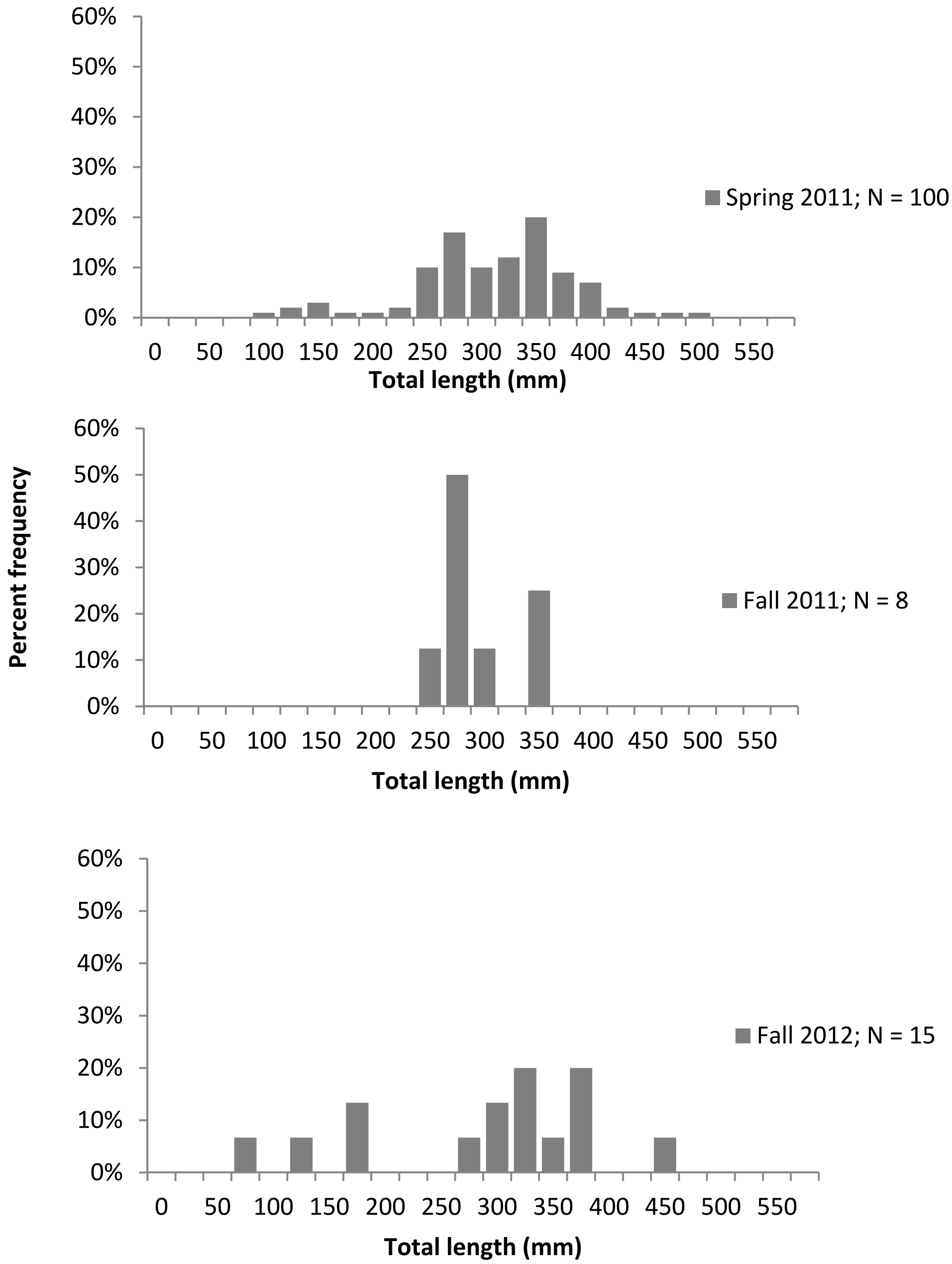

FIGURE 5.—New River Largemouth Bass length frequency before (spring 2011, top chart), immediately following (fall 2011, middle), and one year after (fall 2012, bottom) Hurricane Irene.

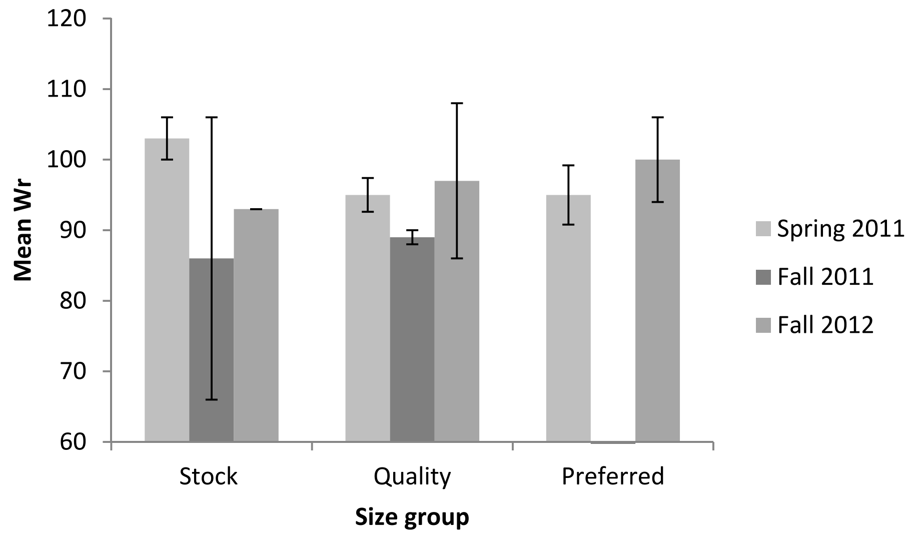

FIGURE 6.— New River mean Wr of stock, quality, and preferred-sized Largemouth Bass collected during spring 2011, fall 2011, and fall 2012 following Hurricane Irene. Error bars are ± 2 SE.

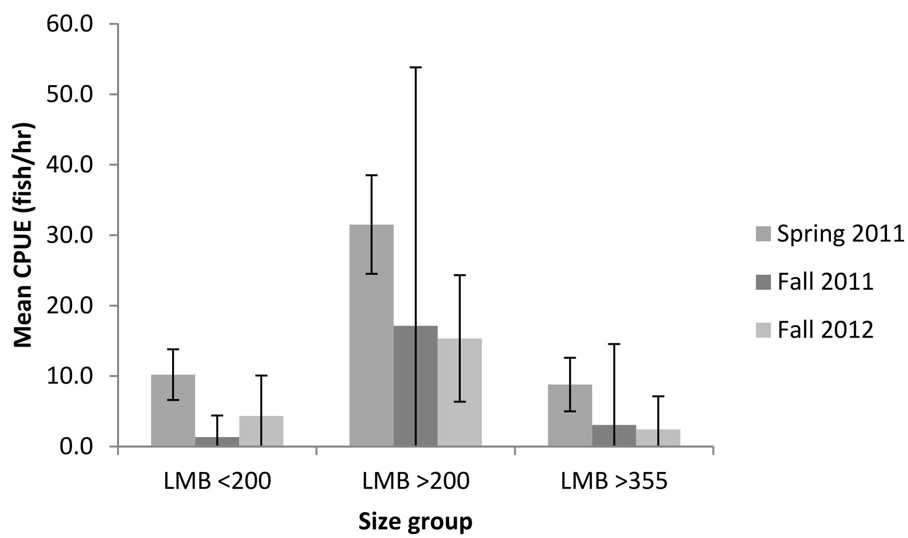

FIGURE 7.—Catch-per-unit-effort of Largemouth Bass before (spring 2011), initially after (fall 2011) and one year after (fall 2012) Hurricane Irene on the White Oak River. Error bars are ± 2 SE.

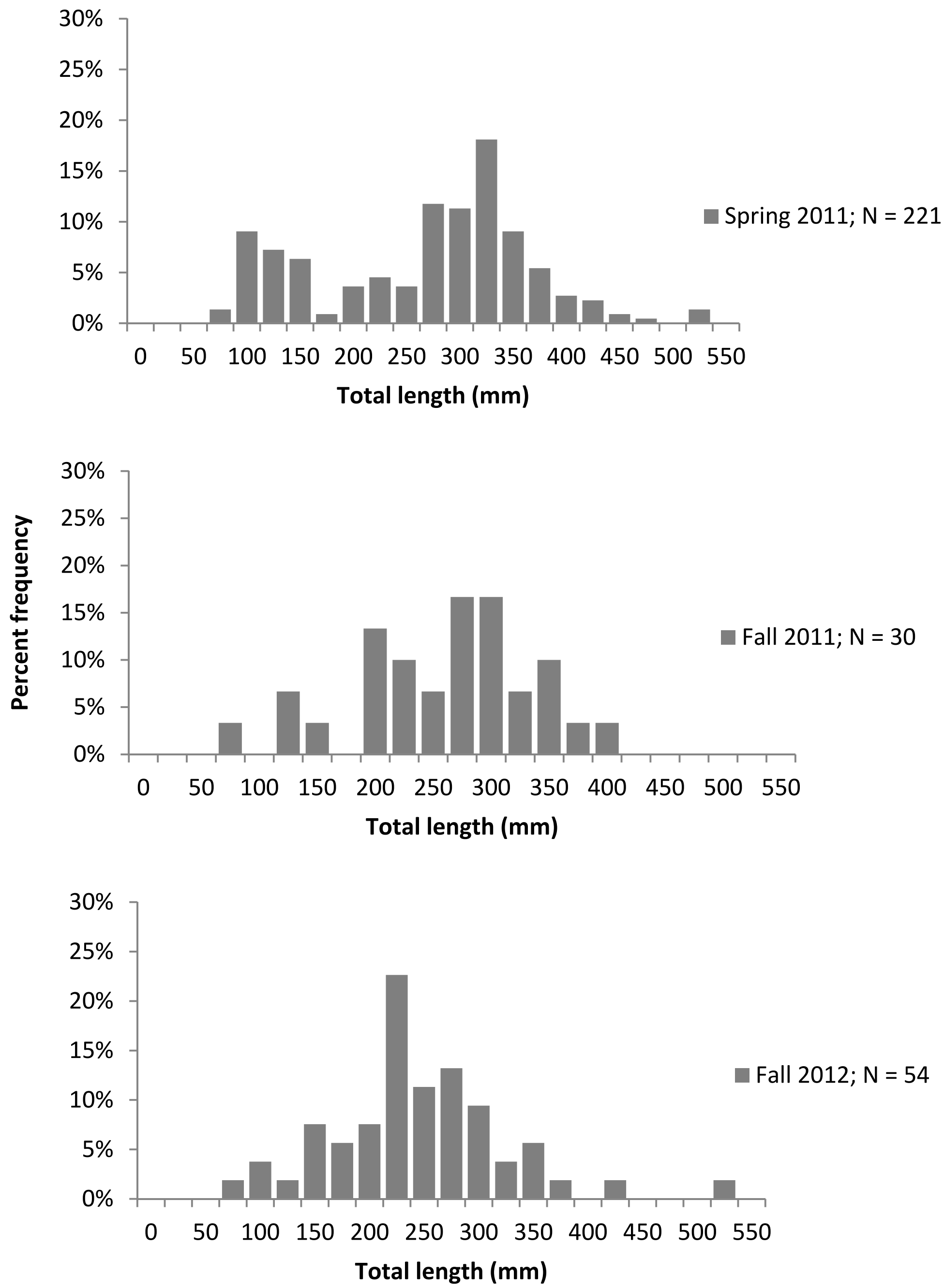

FIGURE 8.—White Oak River Largemouth Bass length frequency before Hurricane Irene (spring 2011, top chart), immediately following Hurricane Irene (fall 2011, middle), and one year after (fall 2012, bottom) Hurricane Irene.

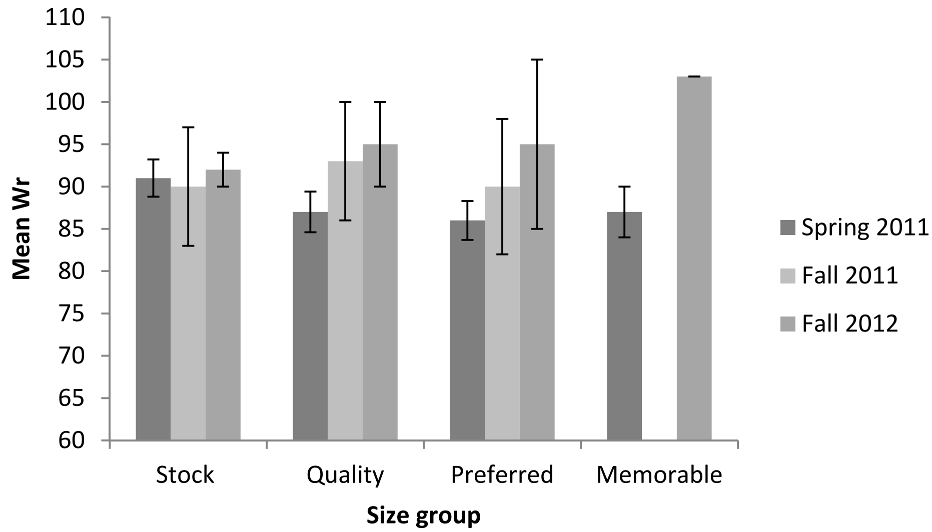

FIGURE 9.— Mean Wr of White Oak River stock, quality, preferred, and memorable-sized Largemouth Bass collected during spring 2011, fall 2011, and fall 2012 following Hurricane Irene. Error bars are ± 2 SE.

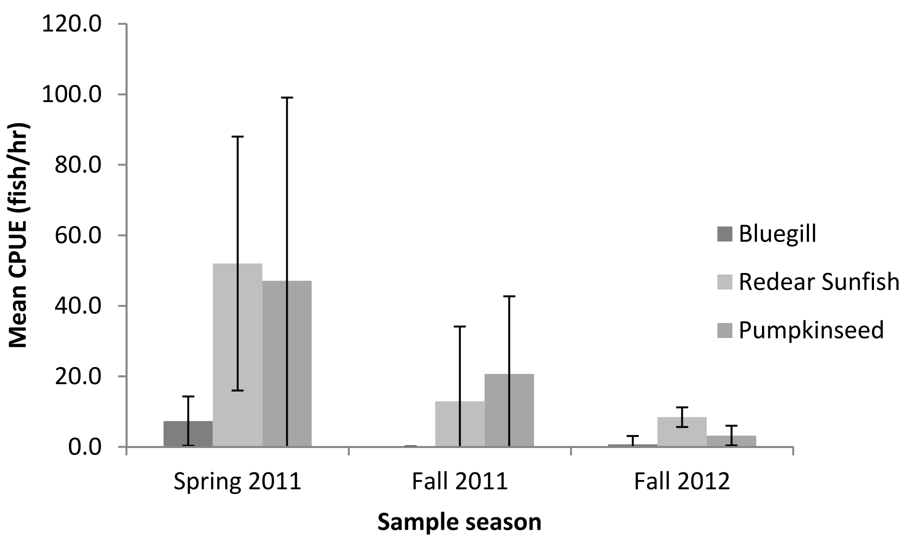

FIGURE 10.—Catch-per-unit-effort of Bluegill, Redear Sunfish and Pumpkinseed on the New River before (spring 2011), initially after (fall 2011) and one year after (fall 2012) Hurricane Irene. Error bars are ± 2 SE.

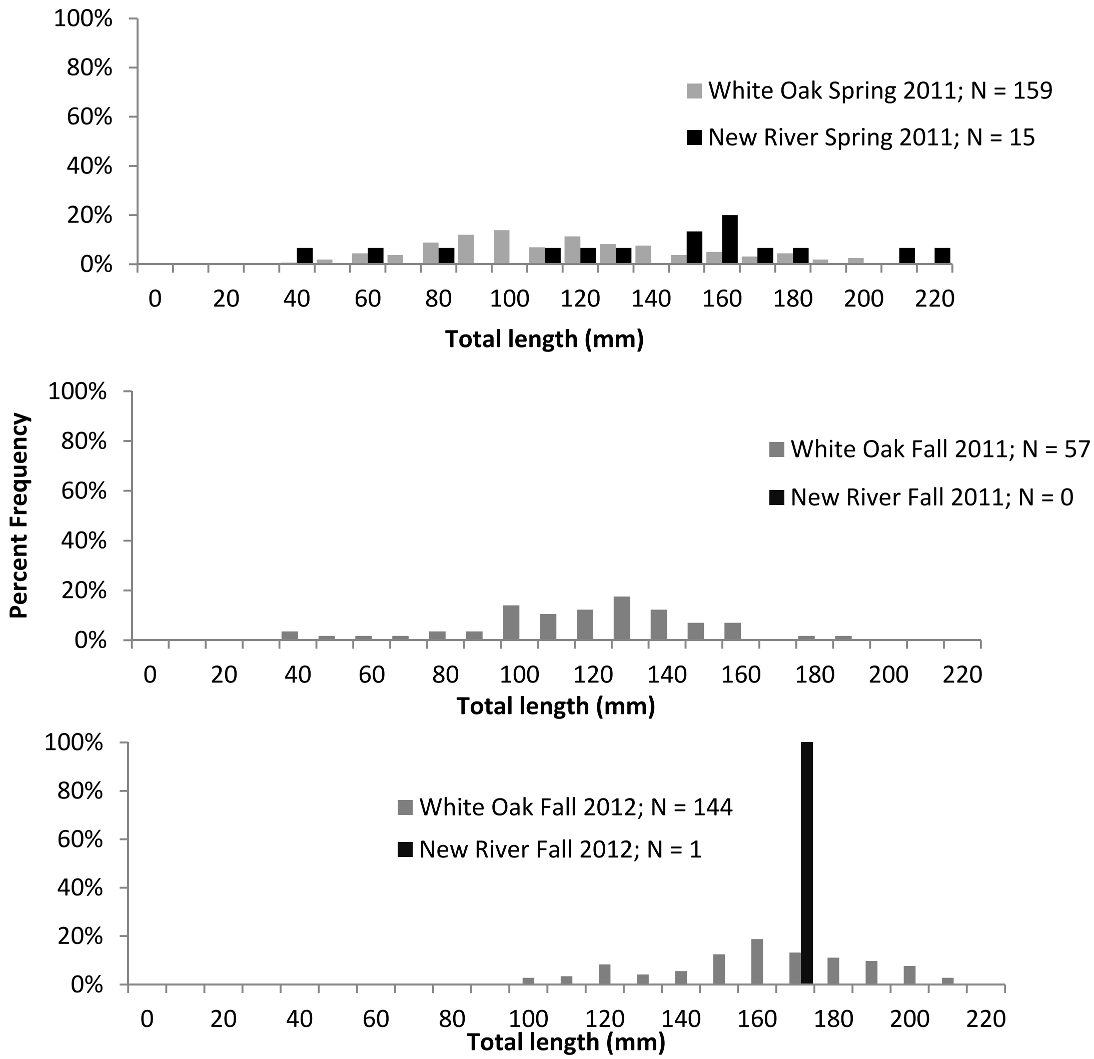

FIGURE 11.—White Oak River and New River Bluegill length frequency before (spring 2011, top chart), immediately following (fall 2011, middle), and one year after (fall 2012, bottom) Hurricane Irene.

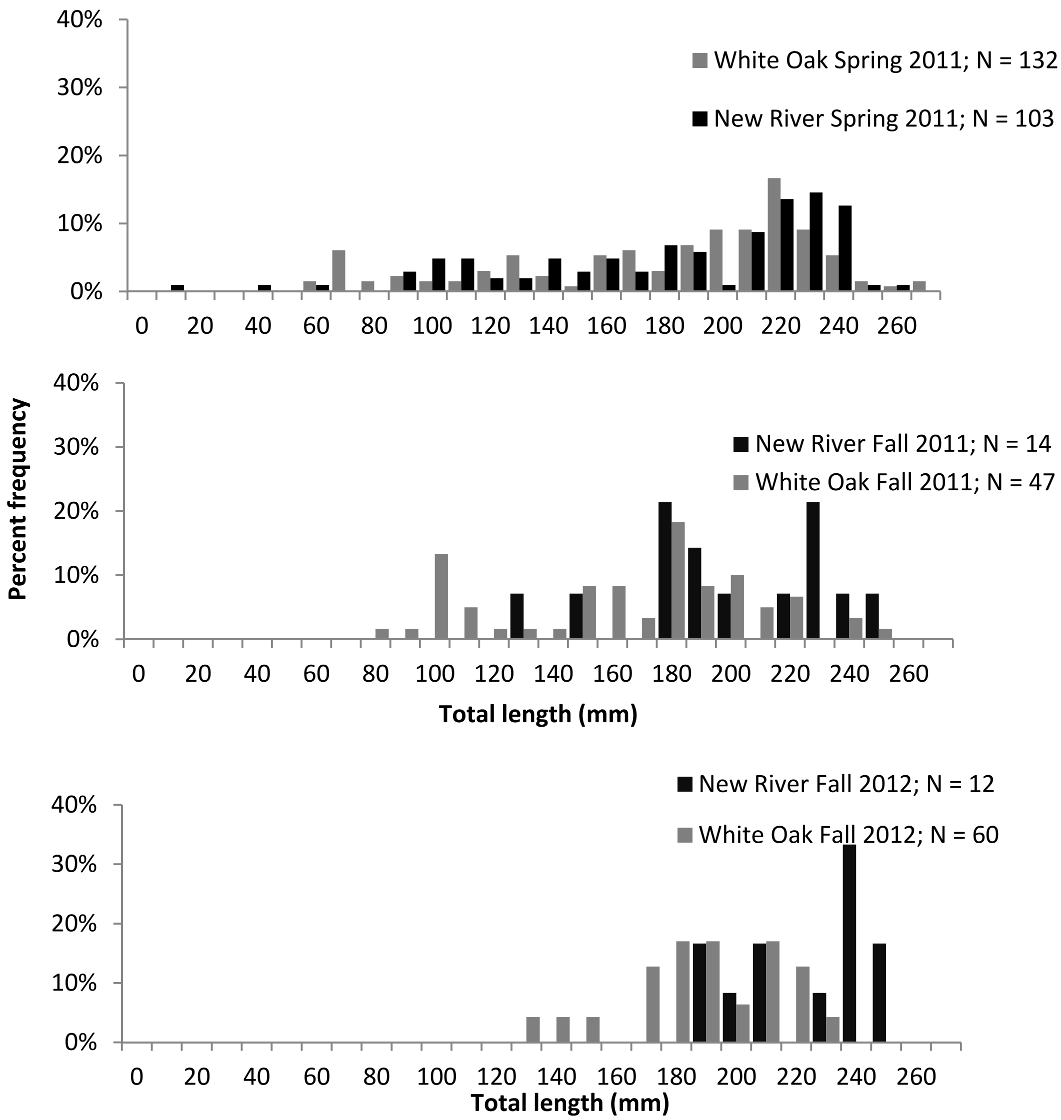

FIGURE 12.—White Oak River and New River Redear Sunfish length frequency before (spring 2011, top chart) immediately following (fall 2011, middle), and one year after (fall 2012, bottom) Hurricane Irene.

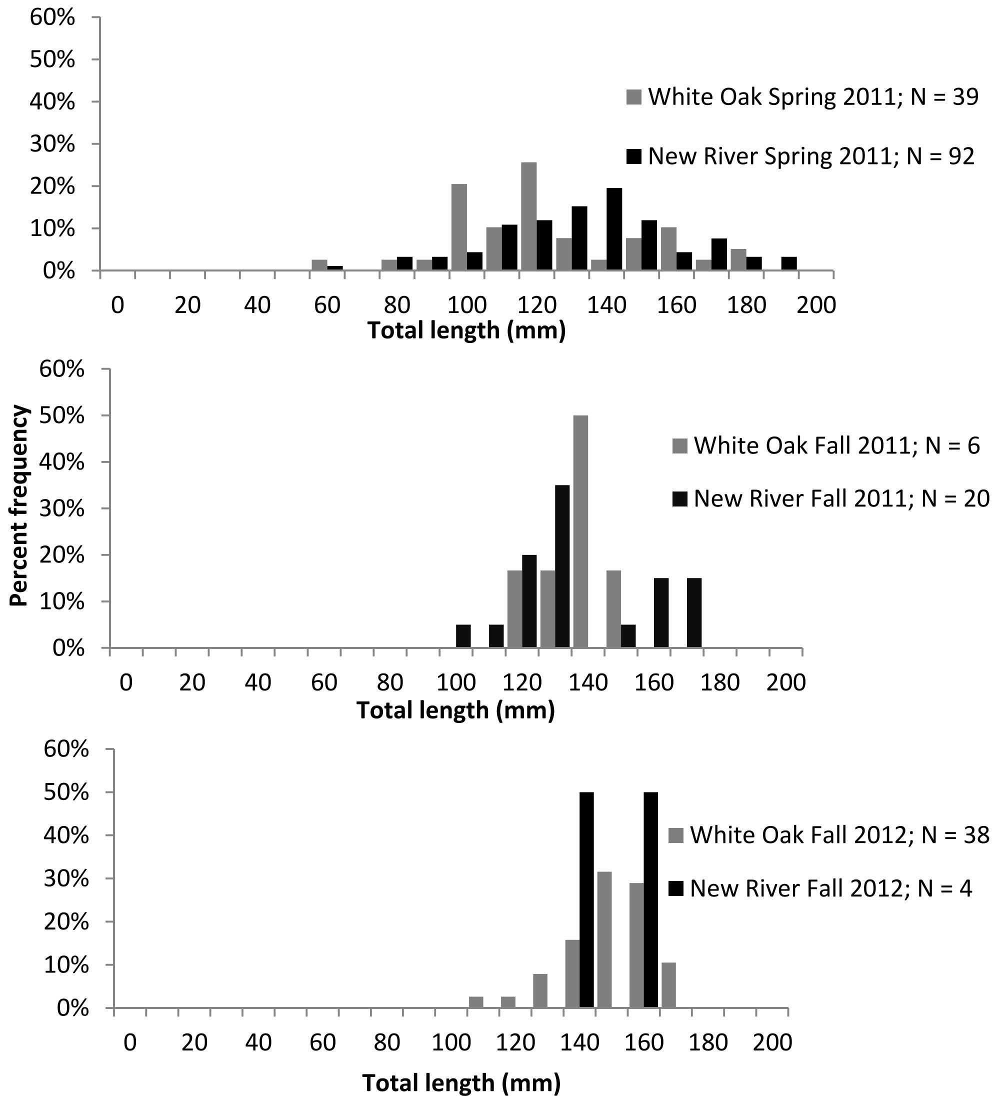

FIGURE 13.—White Oak River and New River Pumpkinseed length frequency before (spring 2011, top chart), immediately following (fall 2011, middle), and one year after (fall 2012, bottom) Hurricane Irene.

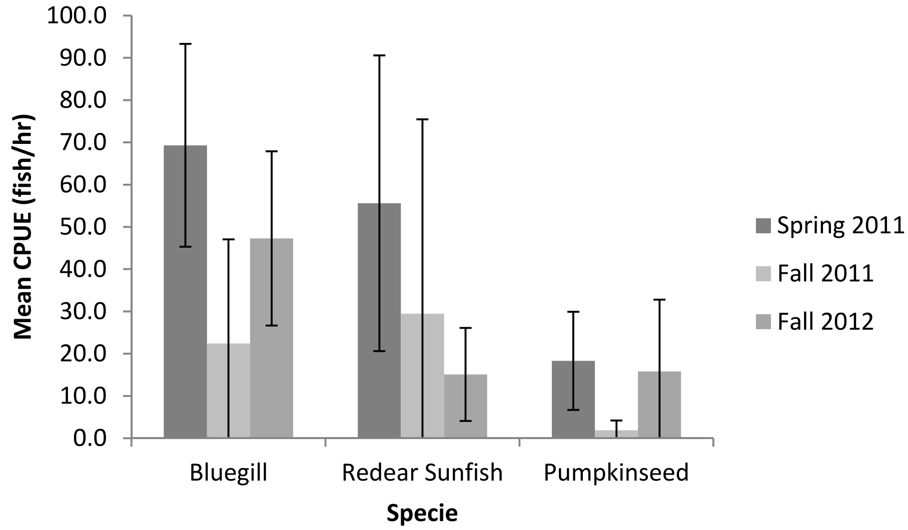

FIGURE 14.—Catch-per-unit-effort of Bluegill, Redear Sunfish and Pumpkinseed from the White Oak River before (spring 2011), initially after (fall 2011) and one year after (fall 2012) Hurricane Irene. Error bars are ± 2 SE.

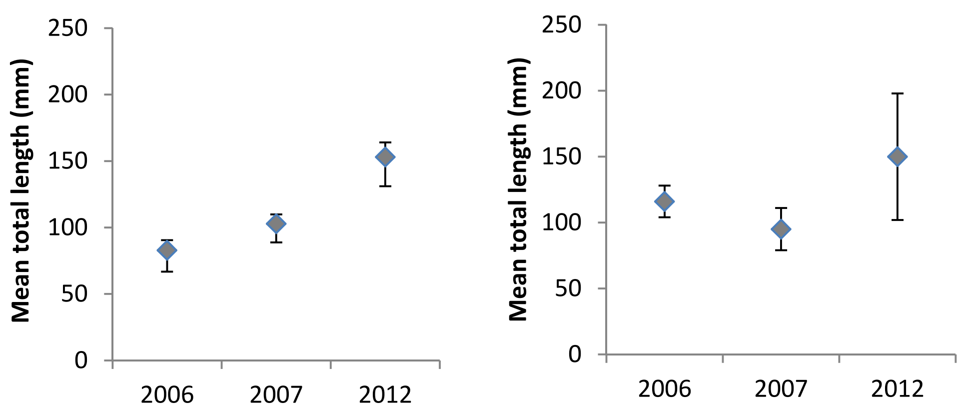

FIGURE 15.—White Oak River (left) and New River (right) age-0 mean length-at-age before (fall 2006 and fall 2007) and after (Fall 2012) Hurricane Irene. Error bars are ± 2 SE.