POST HURRICANE IRENE SPORTFISH RESPONSE IN THE NORTHEAST CAPE FEAR RIVER

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Abstract.—Coastal North Carolina offers diverse fishing opportunities for riverine sport fish populations that are often subject to hurricane induced fish kills. On 27 August 2011 Hurricane Irene made landfall at Cape Lookout, North Carolina, and caused widespread fish kills. These fish kills were a result of rapid declines in dissolved oxygen (DO) levels (<2 mg/L) immediately following hurricane passage. Northeast Cape Fear River sport fish populations were sampled in 2011 and 2012 to document recovery from fish kills caused by Hurricane Irene. Juvenile fish abundances were initially low; juvenile Largemouth Bass *Micropterus salmoides* mean catch-per-unit-effort (CPUE) increased from 0.2 fish/h (2SE = 0.4) in fall 2011 to 3.7 fish/h (2SE = 2.2) in fall 2012. Increased growth rates were observed post Hurricane Irene with juvenile Largemouth Bass having the highest recorded mean annual growth during fall 2012 (mean length-at-age at age 0, 153 mm; 2SE = 14). Largemouth Bass relative weights (Wr) decreased initially following Hurricane Irene, but had increased above pre-Irene conditions by fall 2012. Sunfish abundance decreased more than 70% post-Hurricane Irene; however, by fall 2012 abundance of Redear Sunfish *Lepomis microlophus* and Bluegill *L. macrochirus* had almost tripled 2011 abundances. Both adult Largemouth Bass and sunfish abundance decreased following Hurricane Irene but began to improve during 2012. In a cooperative venture among local bass clubs and the North Carolina Wildlife Resources Commission, a total of 305 adult Largemouth Bass were stocked in the Northeast Cape Fear River on two occasions, 3 November 2012 and 8 May 2013, in an effort to supplement the Largemouth Bass population affected by Hurricane Irene. Stocking efforts were evaluated during a tournament weigh-in and Commission recapture sampling during spring 2013. The Northeast Cape Fear River sport fish populations remain lower than pre-Irene conditions; however, recovery is likely to occur naturally barring any significant anoxic events.

Background

Coastal North Carolina offers a wide variety of angling opportunities most of which are located on streams and rivers. Anglers commonly fish coastal North Carolina rivers for 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 the most sought after sport fish, while sunfish are the most frequently harvested sport fish by anglers in coastal rivers based on North Carolina Wildlife Resource Commission (Commission) creel surveys (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 summer water temperatures, and increased salinity that can all limit sport fish growth and condition (Mallya 2007). North Carolina coastal rivers are also subject to cyclones during the Atlantic hurricane season, which runs from June 1 through November 30 each year (NOAA 2013). Hurricanes can further degrade water quality conditions in coastal rivers. Hurricane flood waters commonly recede into river channels carrying large quantities of suspended organic material that is decomposed by microbial bacteria. This decomposition uses oxygen which causes an increase in biological oxygen demand and a subsequent decrease in DO levels (McCargo et al. 2008). Fish occupying areas exposed to hypoxic and anoxic conditions cannot survive long if refugia are unavailable or dissolved oxygen levels do not increase relatively quickly. Prolonged periods of hypoxic (DO ≤2 mg/L) conditions can result in fish kills.

Hurricane Irene made landfall near Cape Lookout on 27 August 2011 and completely inundated a significant portion of eastern North Carolina's flood plain (Avila and Cangialosi 2011). As a result, the Northeast Cape Fear River and many other rivers throughout the coastal plain experienced hypoxic and anoxic conditions for up to 30 days as flood waters receded (Commission, unpublished data). The Northeast Cape Fear River is considered a blackwater system within the Cape Fear River Basin, which is located in southeastern North Carolina and drains 3274 km^2 of the coastal plain physiographic province. Headwaters of the Northeast Cape Fear River begin in Wayne County, North Carolina, and flow southward for approximately 209 km before joining the Cape Fear River as a large tributary just north of Wilmington (Figure 1). In response to fish kills following Hurricane Irene, sport fish surveys were conducted on the river soon after Hurricane Irene's passage in fall 2011 and one year later in fall 2012. To assist with population recovery, adult Largemouth Bass were stocked in fall 2012 and again in spring 2013. The objectives of this survey were to assess Hurricane Irene's initial effect on sport fish populations, monitor sport fish recovery one year after the storm, and conduct a preliminary evaluation of stocking efforts of adult Largemouth Bass.

Methods

To monitor anoxic conditions following Hurricane Irene, water quality variables were measured on two occasions on the Northeast Cape Fear River using an YSI Pro 2030 dissolved oxygen meter (Table 1). Water quality parameters monitored were dissolved oxygen (mg/L and % saturation), 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 consecutive fall seasons: 24 and 26 October 2011 and 10-11 October 2012. To allow for comparisons of population characteristics before and after Hurricane Irene, eight 1-km transects first sampled in the fall of 2006 were selected on the Northeast Cape Fear River. All sport fish were collected from seven transects and one transect sampled for Largemouth Bass only. Fish collected were identified to species, measured (TL, mm) and weighed (g).

During the fall 2012 sample season, a subsample of up to five Largemouth Bass per 25 mm length group ≤ 250 mm were sacrificed and otoliths removed for age and growth analysis. Ages were determined according to procedures outlined in Buckmeier and Howells (2003). Readers viewed otoliths on a Wolfe digital stereomicroscope with 10-40X magnification. Two readers independently aged each otolith to formulate an initial reader agreement and 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 ≤ 250 mm using the techniques outlined by Bettoli and Miranda (2001). Also in fall 2012, stomach contents were extracted via acrylic tubes (Van Den Avyle and Roussel 1980) and examined from Largemouth Bass > 200 mm. If Largemouth Bass stomach content was obtained, then content was identified to lowest taxa as possible, weighed (g) and measured (TL, mm).

Relative abundance of sampled sport fish species was expressed as the number of individuals collected per electrofishing hour and was indexed as catch-per-unit-effort (CPUE; fish/hour). Abundance was also calculated for Largemouth Bass at three size ranges: juveniles (< 200 mm), adults (≥ 200 mm), and harvestable (≥ 356 mm; pre-2012 regulation change). Size structure 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).

To supplement population abundance, adult Largemouth Bass were stocked into the Northeast Cape Fear River during two independent stocking events. The first occurred on 3 November 2012 and involved the release of hatchery reared, adult (≥ 200 mm) Largemouth Bass purchased with funds raised by local bass clubs . Commission staff assisted stocking efforts by tagging all hatchery reared Largemouth Bass. The hatchery fish were anesthetized with clove oil and implanted in the right cheek musculature with a 1.1-mm magnetic, coded wire tag (CWT) via a Mark IV© injector (Northwest Marine Technologies). In addition, the left pectoral fin was clipped to allow for visual identification of each hatchery fish. Tagged Largemouth Bass were scatter stocked from the Holly Shelter boating access area (BAA) with the assistance of local anglers between the NC 210 and NC 53 bridges near the town of Burgaw. Commission staff attended subsequent Largemouth Bass tournament weigh-ins at the Holly Shelter BAA on 8 December 2012 to scan fish for CWT tags and observe pectoral fins. The second stocking

occurred on 9 May 2013 and consisted of Largemouth Bass collected by Commission staff from a Piedmont reservoir (Lake Holt). Largemouth Bass collected from Lake Holt were released into the Northeast Cape Fear River at the Holly Shelter BAA without a CWT or fin clip due to limitations in staff time and hatchery space. During the spring 2013 Commission routine surveys, sportfish were collected following the same methods outlined above and all Largemouth Bass > 200 mm were scanned with a CWT hand held wand and visually inspected for fin clips to evaluate the contribution of hatchery fish.

Results

Post-Hurricane Irene Water Quality Assessment

Water quality data from the Northeast Cape Fear River was collected at various locations on 9 September 2011 (N=7) and again on 23 September 2011 (N=5). Lower reaches of the Northeast Cape Fear River experienced DO levels < 2 mg/L for 27 days following Hurricane Irene's landfall on North Carolina, while upper reaches of the river had documented DO levels < 4 mg/L for 27 days following landfall (Table 1).

Largemouth Bass

A total of 56 Largemouth Bass were collected during the two sample seasons following Hurricane Irene. During fall 2011, CPUE of Largemouth Bass less than stock length (200 mm) was 0.2 fish/h (2SE= 0.4). However, mean CPUE increased to 3.7 fish/h (2SE= 2.2) during fall 2012. Mean CPUE of greater than stock length Largemouth Bass was 2.7 fish/h (2SE= 1.6) during fall 2011 and increased to 3.5 fish/h (2SE= 2.2) in fall 2012. However, mean CPUE was still lower than the last pre-hurricane sample during fall 2007 (4.5 fish/h, 2SE= 1.8; Figure 2). Three harvestable length fish (mean CPUE 0.7 fish/h, 2SE= 1.0) were collected fall 2011, and six harvestable length fish (mean CPUE 1.0 fish/h, 2SE= 0.8) were collected fall 2012 (Figure 2).

Length frequency histograms confirmed an increase in the number of Largemouth Bass < 200 mm between the fall 2011 and fall 2012 samples; only one fish less than stock length was collected in fall 2011, whereas this number increased to 22 in fall 2012 (Figure 3). Largemouth Bass PSD and PSD-P both decreased between fall 2011 and fall 2012 (PSD fall 2011=83, PSD fall 2012=38; PSD-P fall 2011=25, PSD-P fall 2012=14). Largemouth Bass PSD-M was calculated from a pre-hurricane sample conducted in 2007 (PSD-M=3), while no memorable sized Largemouth Bass were collected in 2011 or 2012 to calculate PSD-M (Table 2).

Mean Wr of all sizes of Largemouth Bass sampled increased from 90 in fall 2011 to 98 in fall 2012 following Hurricane Irene. Average Wr of stock length Largemouth Bass increased from 89 in fall 2011 to 97 in fall 2012 and Wr of quality length fish increased from 91 in fall 2011 to 96 in fall 2012. Preferred length Largemouth Bass Wr stayed constant at 90 in both fall 2011 and 2012. All mean Wr values during fall 2012 were above fall 2007 pre-Irene conditions. Lowest mean Wr values were documented in fall 2011 (Figure 4).

A total of 22 Largemouth Bass ≤ 250 mm from the Northeast Cape Fear River were sacrificed for age and growth determination. Total lengths of aged Largemouth Bass ranged 108–221 mm. Initial reader agreement was 96% and after a concert read observers were able

to reach 100% consensus on all Largemouth Bass ages. Ninety-one percent (N = 20) of the Largemouth Bass aged were age 0, while nine percent (N = 2) were age 1. Total lengths of age-0 Largemouth Bass ranged 108–209 mm, while age-1 Largemouth Bass total length ranged 201–221 mm. Twenty Largemouth Bass greater than 200 mm were examined for stomach content: 50% (N=10) were empty, 20% (N=4) contained crawfish, and 30% (N = 6) contained fish (i.e., Pirate Perch, *Gambusia sp.*, cyprinid; Figure 5).

Preliminary Largemouth Bass Stocking Evaluation

During the first stocking event, a total of 153 hatchery reared, age-1 Largemouth Bass were stocked in the Northeast Cape Fear River. On 8 December 2012 staff biologists attended a tournament weigh-in at the Holly Shelter BAA to wand Largemouth Bass for CWT. Of the eight Largemouth Bass weighed in by anglers, none tested positive for a coded wire tag or showed signs of fin clipping. During the second stocking event, Commission staff stocked 152 adult Largemouth Bass electrofished from Holt Lake. Due to hatchery space and time limitations, Largemouth Bass stocked did not receive any tags or fin clips. Commission staff returned to the Northeast Cape Fear River in spring 2013 on four sampling occasions between 14 and 28 May. All Largemouth Bass ≥ 200 mm collected during these four survey events were scanned for a CWT and checked for visual signs of fin clipping. Seventy-three Largemouth Bass were collected during the 2013 spring sample, of which 37 were ≥ 200 mm; none tested positive for a CWT or showed signs of fin clipping. Though Lake Holt Largemouth Bass did not receive tags, catch rates of adult (≥ 200 mm) Largemouth Bass collected during the 2013 spring sample (CPUE = 6.4/hr) did not increase markedly; this data will be fully described in a separate report.

Sunfish

A total of 543 sunfish (predominantly Bluegill and Redear Sunfish) were collected during the two sample seasons following Hurricane Irene; 145 sunfish in fall 2011 and 398 sunfish in fall 2012. Bluegill were the most abundant sunfish representing 48% (N=260) of the sunfish population, followed by Redear Sunfish at 13% (N=150; Figure 6). During a fall 2007 sample season, 535 sunfish were collected with Bluegill and Redear Sunfish observed as the dominant sunfish species with similar percent species distribution (Figure 6). Catch-per-unit-effort of all sunfish decreased post-Irene during the 2011 sample season with Bluegill CPUE of 18.3 fish/h (2SE= 12.3) and Redear Sunfish CPUE of 10.5 fish/h (2SE= 7.6; Figure 7). Sunfish abundance increased markedly during the fall 2012 sample season, surpassing the 2007 values with Bluegill CPUE = 36.4 fish/h and Redear Sunfish increasing to 21.3 fish/h (2SE= 18.5; Figure 7).

Length frequency histograms suggested little change in sunfish size distribution in the Northeast Cape Fear River following Hurricane Irene. Bluegill ranged in length from 23–223 mm (Figure 8) and Redear Sunfish ranged in length from 35–289 mm (Figure 9). Compared to fall 2007, Bluegill PSD increased during fall 2011 and 2012 sampling seasons with values of 20 and 18. Both Redear Sunfish PSD and PSD-P decreased during fall 2011 and 2012 sampling seasons compared to fall 2007 with PSD values of 39 and 22, and a PSD-P value of 1 fall 2012. During both fall sample seasons, only two memorable sized Redear Sunfish and no Bluegill in this length category were collected (Table 2).

Discussion

Hurricane Irene had an adverse effect on sport fish populations within the Northeast Cape Fear River. The extent and duration of hypoxic conditions were not as drastic and prolonged as on neighboring river systems (Homan and Dycus 2013a, 2013b), but were severe enough to cause temporary reductions in sport fish condition and abundance. Largemouth Bass abundance in the Northeast Cape Fear River has been historically low, as defined by abundance values < 6 fish/h for fish $\geq$ 200 mm sampled in 2006 and 2007. Values observed in fall 2011 fell outside of the standard error estimates from fall 2006, a likely function of hurricane impacts. Although fall 2012 adult Largemouth Bass abundance appeared to trend higher than 2011 estimates, these annual estimates were not significantly different based on analysis of standard errors. Similarly, fall 2012 values were within the range of values calculated in both pre-hurricane samples (2006 and 2007). Relative abundance estimates of adult Largemouth Bass populations in coastal North Carolina that approach or exceed 25 fish/h are usually an indication of a quality sport fishery within the region (Ricks and McCargo 2011). With abundance estimates in the Northeast Cape Fear River prior to Hurricane Irene already much lower than desired, management efforts should attempt to markedly increase the numbers of adult Largemouth Bass in this system.

Mean CPUE estimates of sport fish abundance post-hurricane (2011 and 2012) were more variable than pre-hurricane estimates. This variability could be attributed to a smaller sample size (N = 8) post-hurricane compared to pre-hurricane work conducted in fall 2007 (N = 13). During the fall 2011 sampling season, the observed declines in relative abundance could have resulted from emigration from sample transects. Adult sport fish that inhabited areas with degraded water quality could have moved upstream to avoid hypoxia, but then returned as conditions improved prior to fall 2012 collections. Movement in response to episodic reductions in DO confounds fish kill evaluations; decreases in sport fish relative abundance was presumably due to Hurricane Irene fish kills, but could also be attributed to emigration away from areas with poor water quality. Future studies on the Northeast Cape Fear River should include more sample sites over a broader area to account for spatial differences in water quality and to improve precision of mean CPUE estimates.

Successful reproduction following fish kill events is critical to recovery of Largemouth Bass populations. Age-0 Largemouth Bass were absent or collected at very low numbers during fall 2011. Hypoxic conditions are more detrimental on smaller, younger fish (ESA 2008) and are capable of completely eliminating a year class within a system. During fall 2011 only one Largemouth Bass < 200 mm was collected in Northeast Cape Fear River (Figure 3). Future examination of Largemouth Bass age and growth data for this river 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 analysis revealed age-0 Largemouth Bass collected in fall 2012 had the highest annual growth of young-of-the-year Largemouth Bass reported from the Northeast Cape Fear River to date (Figure 10). Increased growth of age-0 Largemouth Bass during periods of decreased relative abundance suggests density-dependent mechanisms may influence coastal river Largemouth Bass populations (Schindler et al. 1997).

In contrast to increases observed in age-0 Largemouth Bass growth rates, condition was slightly lower in the fall 2011 sample following Hurricane Irene. The high percentage of empty stomachs (50%) and the absence of juvenile sunfish in Largemouth Bass diet analysis coupled with high numbers of crayfish found in gut contents may explain the initial decline in Wr (Figure 5). Crayfish, crabs and other crustacea are more costly to digest and their presence in Largemouth Bass diets could explain a decrease in Wr (Yako et al. 2000). Largemouth Bass exhibited an increase in average Wr in fall 2012 indicating that there were increased feeding opportunities or higher predation on more nutritious prey species (e.g., minnows, sunfish). Average relative weights may have also been influenced by the abundance and size structure of Northeast Cape Fear River Largemouth Bass. Fall 2011 Largemouth Bass abundance decreased to a third of the pre-Irene abundance with less variability in size distribution. Fall 2012 Largemouth Bass abundance exceeded the 2007 pre-Irene sample with a large pulse of younger individuals achieving record annual growth. Future sampling is warranted to better evaluate the abundance and size structure effect on Largemouth Bass average Wr.

Natural recovery of fish populations following large scale fish kills such as the one experienced after Hurricane Irene on the Northeast Cape Fear River usually takes several years. McCargo et al. (2008) found that two years after Hurricane Isabel both fish species composition and relative abundance were similar to pre-hurricane conditions on the lower Roanoke River suggesting fish assemblage recovery. However, the percent similarity index (PSI) presented in the study suggested the fish assemblage had not fully recovered due to higher portions of smaller fish present two years after Hurricane Isabel compared to pre-hurricane PSI on the lower Roanoke River where size and age structure of available species were more diverse. Consistent with these findings, CPUE in the Northeast Cape Fear River returned to pre-Irene levels two years following the fish kills, although the size and age structure was comprised of younger, smaller fish. In an effort to reduce this response time and increase angler catch rates; Commission staff attempted to supplement the Largemouth Bass population via stockings of adult fish. Adult Largemouth Bass stocked have been documented to increase survivability due to lower vulnerability to predation and potentially higher forage availability (Wahl et al 1995; Porak et al. 2002). Hoxmeier and Wahl (2002) predicted an increase in Largemouth Bass survival rates in systems with lower densities of native Largemouth Bass, which is evident in the Northeast Cape Fear River. However, of the 153 at-large tagged Largemouth Bass of hatchery origin, there have been no confirmed recaptures. Thomas and Dockendorf (2009) found that Largemouth Bass reared in hatchery ponds may have implanted adaptive mechanisms favoring competition which may be disadvantageous in a riverine environment. Furthermore, supplemental stockings in both the Chowan and Roanoke rivers after a hurricane induced fish kill was ultimately considered unnecessary for population recovery as natural reproduction was deemed adequate in those systems. Despite lack of documented increases in angler catch rates and reduced response time, strategic stockings or transplants of adult Largemouth Bass may be warranted to address population recovery in the Northeast Cape Fear River.

Adult Largemouth Bass can expedite recovery by contributing to spawning the following spring. Though indiscernible, if stocked adult Largemouth Bass managed to survive and spawn in subsequent years, then stockings could contribute to population recovery in the Northeast Cape Fear River. Adult Largemouth Bass that survived the fish kill managed to spawn in 2012, and their progeny exhibited good growth. Preliminary recapture sampling to evaluate

contribution of stocked adult Largemouth Bass in the Northeast Cape Fear River remains inconclusive. While the impacts of adult stocking to population dynamics require additional examination, there were indirect benefits realized as a result of the stocking efforts. Specifically, Commission biologists were able to interact with local bass angling groups throughout the process. Additional opportunities to collaborate with local bass anglers were identified and will be explored as efforts to enhance fisheries populations on the Northeast Cape Fear River continue.

Along with Largemouth Bass, hurricane induced hypoxia impacted many aquatic species, including other freshwater sport fish. Results from this study indicated that the Northeast Cape Fear sunfish community experienced similar population trends as Largemouth Bass following Hurricane Irene. Sunfish abundance decreased post-Irene compared to the 2007 sample season. Only two memorable sized Redear Sunfish and few preferred sized Bluegill and Redear Sunfish were collected during this study; further exploration in factors limiting sunfish growth is warranted. Absence of sunfish less than stock size during the fall 2011 sample season could have been directly related to Hurricane Irene fish kills, while absence of less than stock size sunfish during fall 2012 is likely a result of poor recruitment. Furthermore, increased salinity and decreased DO could have limited sunfish reproduction.

Management Recommendations

1. Monitor sport fish growth and abundance on an annual basis to assess population trends following effects of Hurricane Irene.

2. Increase total number of transects to cover more available habitat and obtain a more accurate estimate of sport fish size and abundance.

3. Evaluate the potential to increase the abundance of sport fish on the Northeast Cape Fear River beyond levels observed prior to Hurricane Irene.

4. Increase outreach efforts with local angling groups to provide research updates and collaborate on future sport fish enhancement efforts.

5. Follow regional hurricane response plan guidelines. Specifically, increase water quality monitoring following anoxic events to determine extent of potential environmental factors on recovery of sport fish populations (e.g., salinity concentration, pH, DO).

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Literature Cited

Avila, L. A., and J. Cangialosi. 2011. Tropical Cyclone Report Hurricane Irene (AL092011) 21-28 August 2011. pp. 1-45.

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.

Buckmeier, D. L., and R. G. Howells. 2003. Validation of otoliths for estimating ages of Largemouth Bass to 16 years. North American Journal of Fisheries Management 23:590-593.

Dockendorf, K. J., C. D. Thomas, and J. W. Kornegay. 2004. Chowan River recreational angling creel survey, 2001-2002. North Carolina Wildlife Resources Commission, Federal Aid in Sport Fish Restoration, Final Report, Raleigh.

ESA (Ecological Society of America). 2008. Hypoxia Fact Sheet. Available: http://www.esa.org/esa/wp-content/uploads/2012/12/hypoxia.pdf. (March 2014).

Gabelhouse, D. W., Jr. 1984. A length-categorization system to assess fish stocks. North American Journal of Fisheries Management 4:273-285.

Guy, C. S., R. M. Neumann, D. W. Willis, and R. O. Anderson. 2007. Proportional size distribution (PSD): A further refinement of population size structure index terminology. Fisheries 32:7.

Homan, J. M., and J. C. Dycus. 2013a. Neuse and Trent River sport fish community recovery following Hurricane Irene. North Carolina Wildlife Resources Commission, Federal Aid in Sport Fish Restoration, Final Report, Raleigh.

Homan, J. M., and J. C. Dycus. 2013b. Tar River sport fish community response to a fish kill following Hurricane Irene. North Carolina Wildlife Resources Commission, Federal Aid in Sport Fish Restoration, Final Report, Raleigh.

Homan, J. M., R. D. Barwick, and K. R. Rundle. 2006. Tar-Pamlico River Basin sport fishery creel survey, 2002-2003. North Carolina Wildlife Resources Commission, Federal Aid in Sport Fish Restoration, Final Report, Raleigh.

Hoxmeier, R. J., and D. H. Wahl. 2002. Evaluation of supplemental stocking of Largemouth Bass across reservoirs: effects of predation, prey availability, and natural recruitment. Pages 639–648 *in* D. P. Philipp and M. S. Ridgway, editors. Black bass: ecology, conservation, and management. American Fisheries Society, Symposium 31. Bethesda, Maryland.

Mallya, Y. J. 2007. The effects of dissolved oxygen on fish growth in aquaculture. Kingolwira National Fish Farming Center, Fisheries Division Ministry of Natural Resources and Tourism, Final Project, Tanzania.

McCargo, J. W., K. J. Dockendorf, and C. D. Thomas. 2008. Fish assemblage response following a hurricane-induced fish kill in the lower Roanoke River, North Carolina. North Carolina Wildlife Resources Commission, Federal Aid in Sport Fish Restoration, Final Report, Raleigh.

NOAA (National Oceanic and Atmospheric Administration). 2013. Hurricane Season. Available: http://www.nhc.noaa.gov/climo/#bac . (January 2013).

Porak, W. F., W. E. Johnson, S. Crawford, D. J. Renfro, T. R. Schoeb, R. B. Stout, R. A, Krause, and R. A. DeMauro. 2002. Factors affecting survival of Largemouth Bass raised on artificial diets and stocked into Florida lakes. Pages 649–665 *in* D. P. Philipp and M. S. Ridgway, editors. Black bass: ecology, conservation, and management. American Fisheries Society, Symposium 31. Bethesda, Maryland.

Ricks, B., and J. McCargo. 2011. Largemouth Bass electrofishing survey on the Roanoke River and Cashie River, North Carolina–2010. North Carolina Wildlife Resources Commission, Federal Aid in Sport Fish Restoration, Final Report, Raleigh.

Rundle, K. R., C. T. Waters, and R. D. Barwick. 2004. Neuse River Basin sport fishery creel survey, 2002-2003. North Carolina Wildlife Resources Commission, Federal Aid in Sport Fish Restoration, Final Report, Raleigh.

Schindler, D. E., J. R. Hodgson, and J. F. Kitchell. 1997. Density-dependent changes in individual foraging specialization of Largemouth Bass. Oecologia 110:592-600.

Thomas, C. D., and K. J. Dockendorf. 2009. Contribution of stocked Largemouth Bass following hurricane-induced fish kills in two North Carolina coastal rivers. North Carolina Wildlife Resources Commission, Federal Aid in Sport Fish Restoration, Final Report, Raleigh.

Van Den Avyle, M. J., and J. E. Roussel. 1980. Evaluation of a simple method for removing food items from live black bass. The Progressive Fish-Culturist 42**:**222–223.

Wahl, D. H., R. A. Stein, and D. R. DeVries. 1995. An ecological framework for evaluating the success and effect of stocked fishes. Pages 176–189 *in* H. L. Schramm, Jr., and R. G. Piper, editors. Uses and effects of cultured fishes in aquatic ecosystems. American Fisheries Society, Symposium 15, Bethesda, Maryland.

Wege, G. W., and R. O. Anderson. 1978. Relative weight (Wr): a new index of condition for Largemouth Bass. Page 78-97 *in* G. D. Novinger and J. G. Dillard, Fisheries Society, North Central Division. Special publication 5, Bethesda, Maryland.

Yako, L. A., M. E. Mather, and F. Juanes. 2000. Assessing the contribution of anadromous herring to Largemouth Bass growth. Transaction of American Fisheries Society. 129:77-88.

TABLE 1.—Dissolved oxygen measurements on the Northeast Cape Fear River by date and site after Hurricane Irene September 2011.

Date	Site	DO (mg/L)	DO (% saturation)
9-Sep	Chinquapin	4.90	56.7
	Wayne's Landing	4.40	51.0
	Sawpit Landing	2.92	34.7
	Holly Shelter BAA	2.23	26.3
	Lanes Ferry	1.20	14.1
	Castle Hayne	0.33	4.0
	Shelter Creek	1.58	18.3
23-Sep	Holly Shelter BAA	3.18	36.9
	Lanes Ferry	2.35	27.4
	Castle Hayne	1.76	19.9
	Sawpit Landing	3.71	42.7
	Shelter Creek	2.30	26.0

TABLE 2.—Proportional stock distribution, PSD-preferred and PSD-memorable sized Largemouth Bass, Bluegill, and Redear Sunfish before (2007), immediately after (2011), and one year after (2012) Hurricane Irene.

		2007	2011	2012
Largemouth Bass	PSD	67	83	38
	PSD-P	24	25	14
	PSD-M	3	—	—
Bluegill	PSD	16	20	18
	PSD-P	1	2	1
	PSD-M	—	—	—
Redear Sunfish	PSD	44	39	22
	PSD-P	19	—	1
	PSD-M	1	—	1

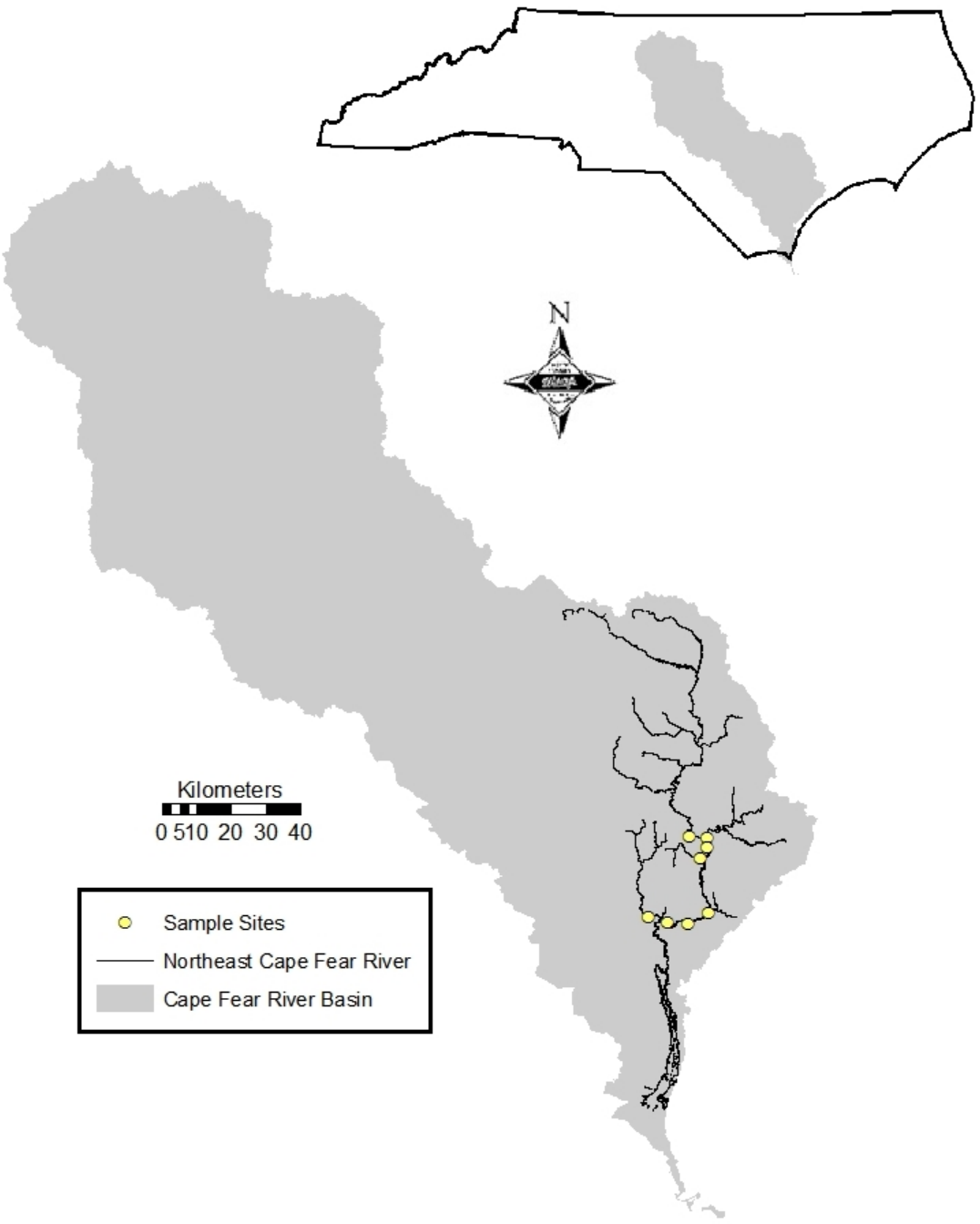

FIGURE 1.—Location of Northeast Cape Fear River within the Cape Fear River basin and 2011-2012 sample sites.

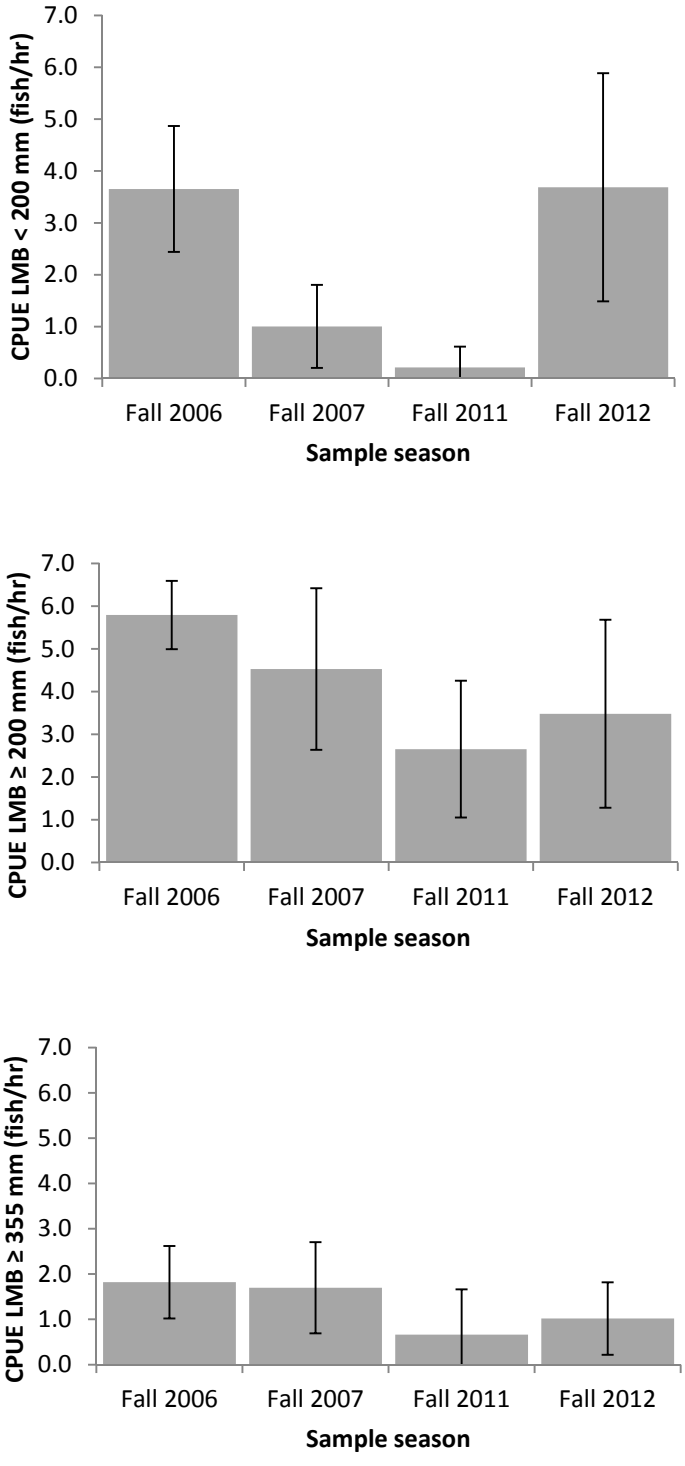

FIGURE 2.—Catch-per-unit-effort of Largemouth Bass < 200 mm (top chart), ≥ 200 mm (middle chart), and ≥ 356 mm (bottom chart) during fall 2006–2012 on the Northeast Cape Fear River. Error bars are ± 2 SE.

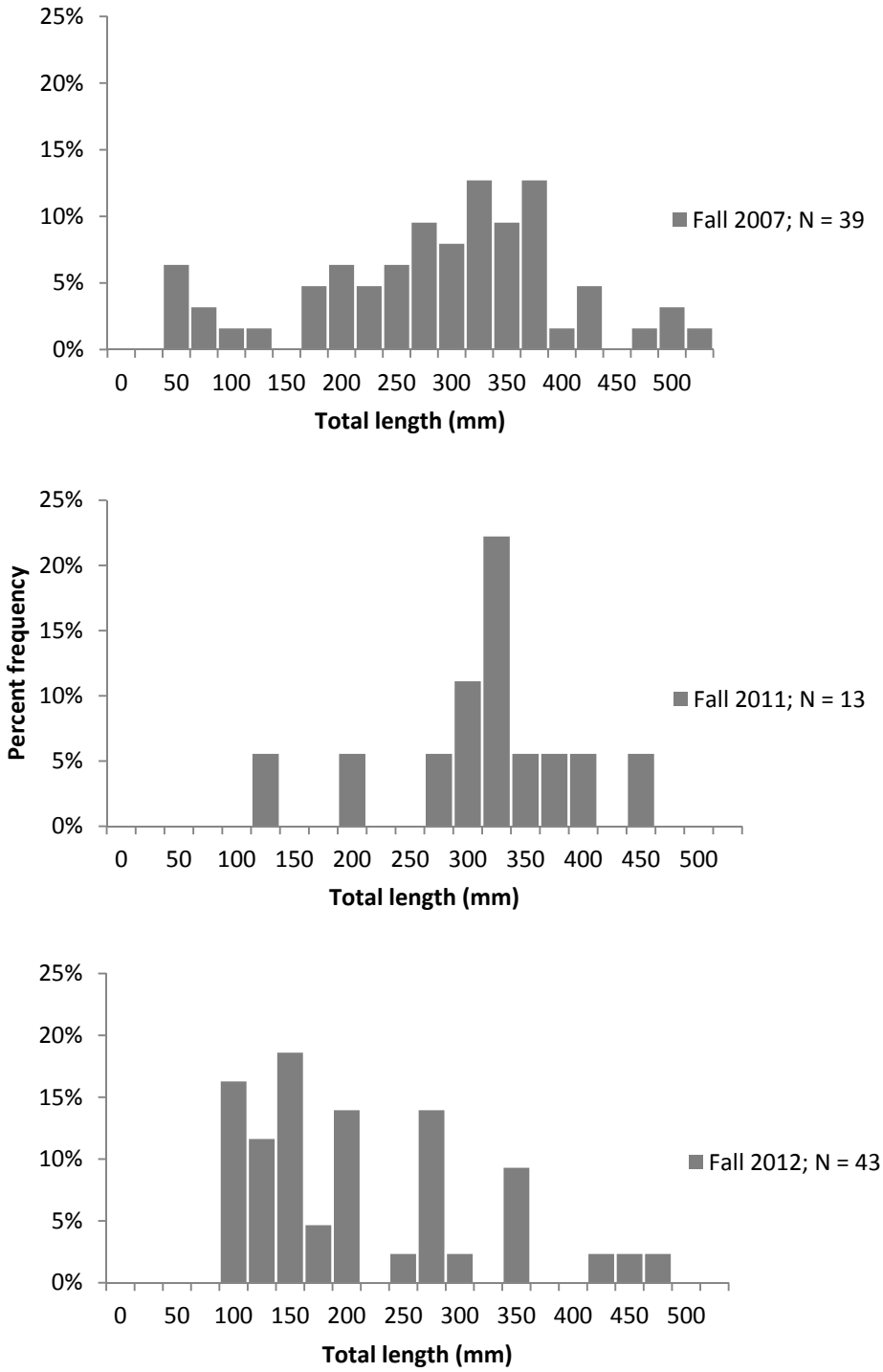

FIGURE 3.—Length-frequency distribution of Largemouth Bass collected by electrofishing in the Northeast Cape Fear River before (top chart, 2007), immediately after (middle chart, 2011), and one year after (bottom chart, 2012) Hurricane Irene.

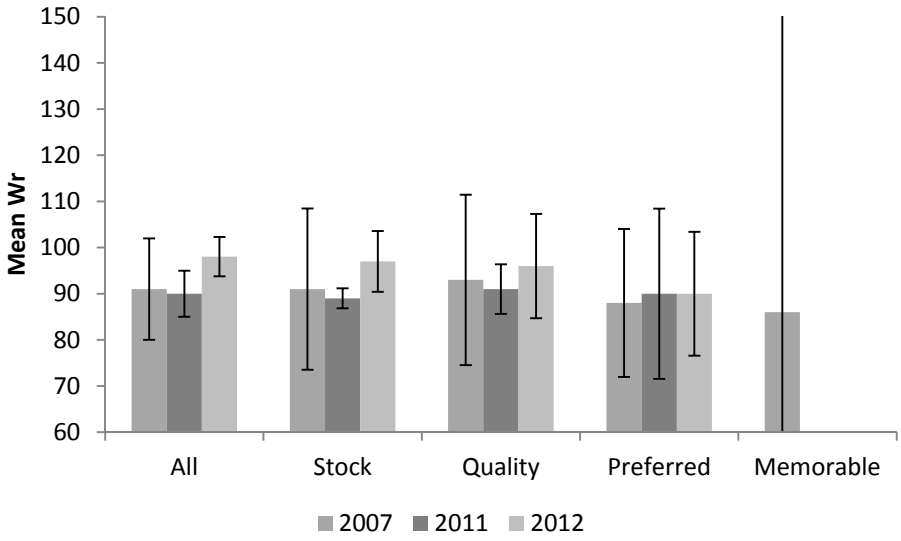

FIGURE 4.—Mean Wr of all Largemouth Bass and stock, quality, preferred, and memorable size Largemouth Bass before (2007), immediately after (2011), and one year after (2012) Hurricane Irene. Error bars are ± 2 SE.

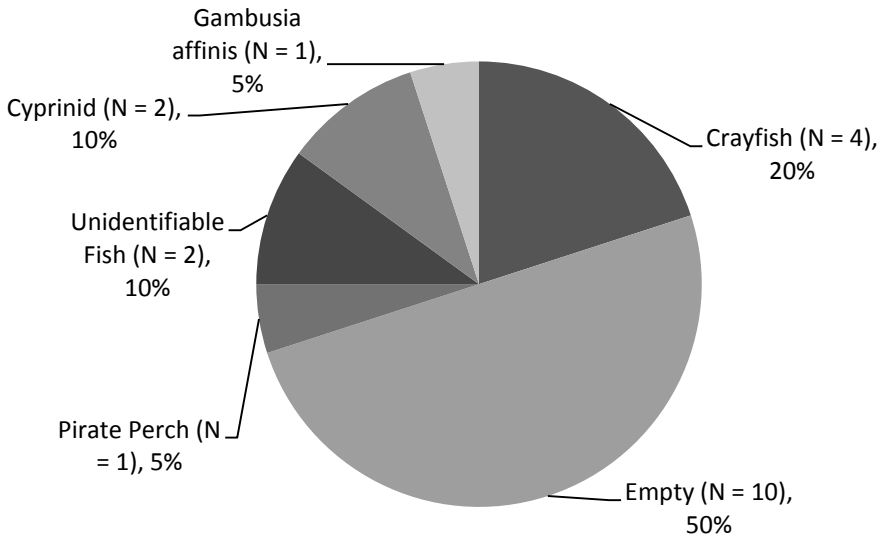

FIGURE 5.—Diet composition of Largemouth Bass ≥ 200 mm collected by electrofishing in the Northeast Cape Fear River fall 2012.

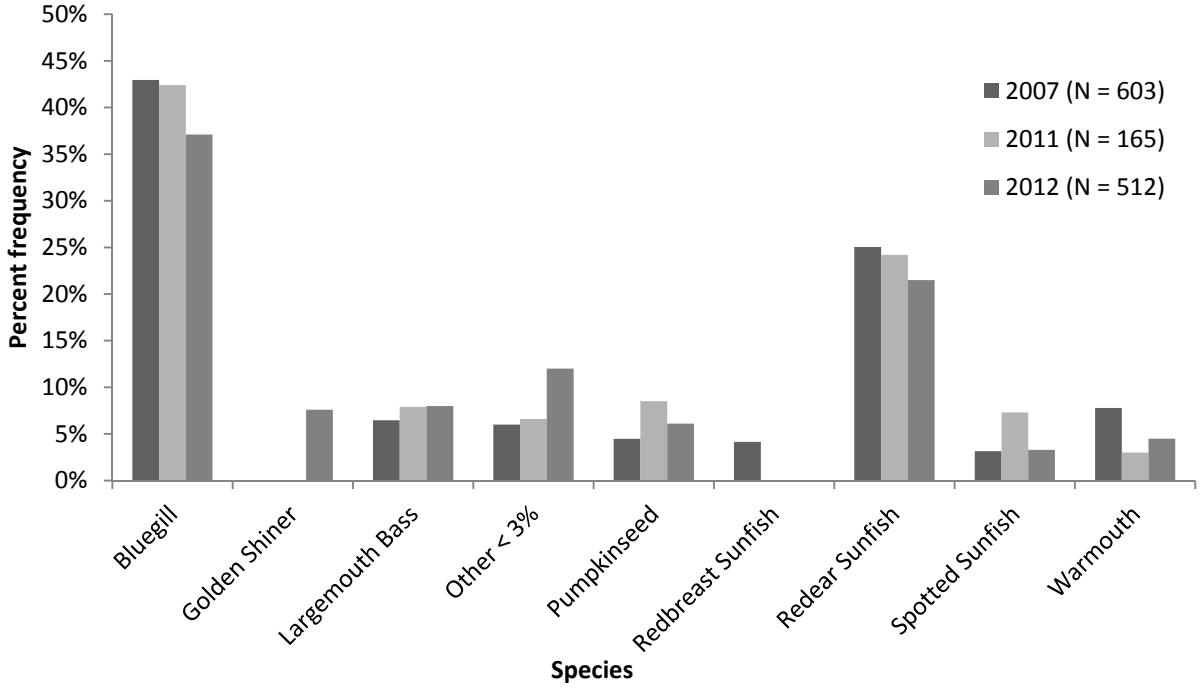

FIGURE 6.—Species composition of Northeast Cape Fear River electrofishing sample before (2007), immediately after (2011), and one year after (2012) Hurricane Irene. The Other < 3% column represents 11 species in 2007, 9 species in 2011 and 13 species in 2012.

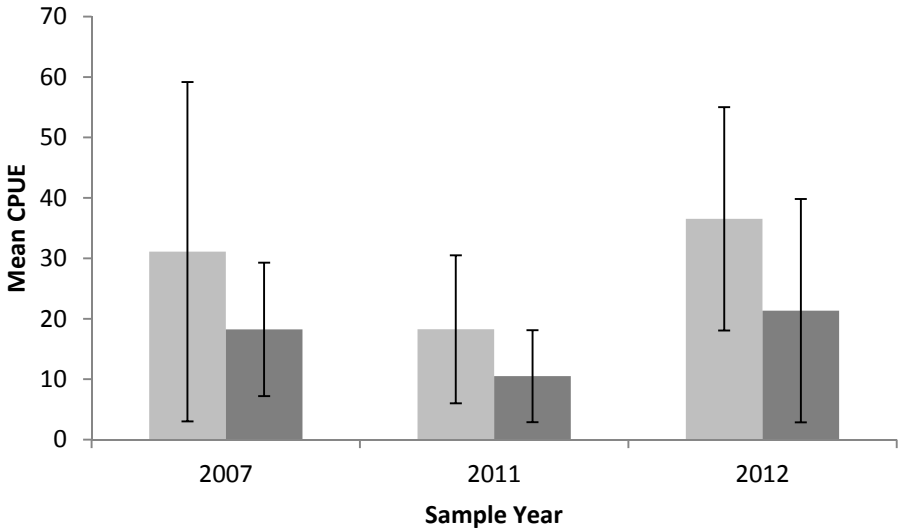

FIGURE 7.—Mean CPUE of Bluegill (light gray) and Redear Sunfish (dark gray) collected during the fall by electrofishing in Northeast Cape Fear River 2007 and 2011–2012. Error bars are ± 2 SE.

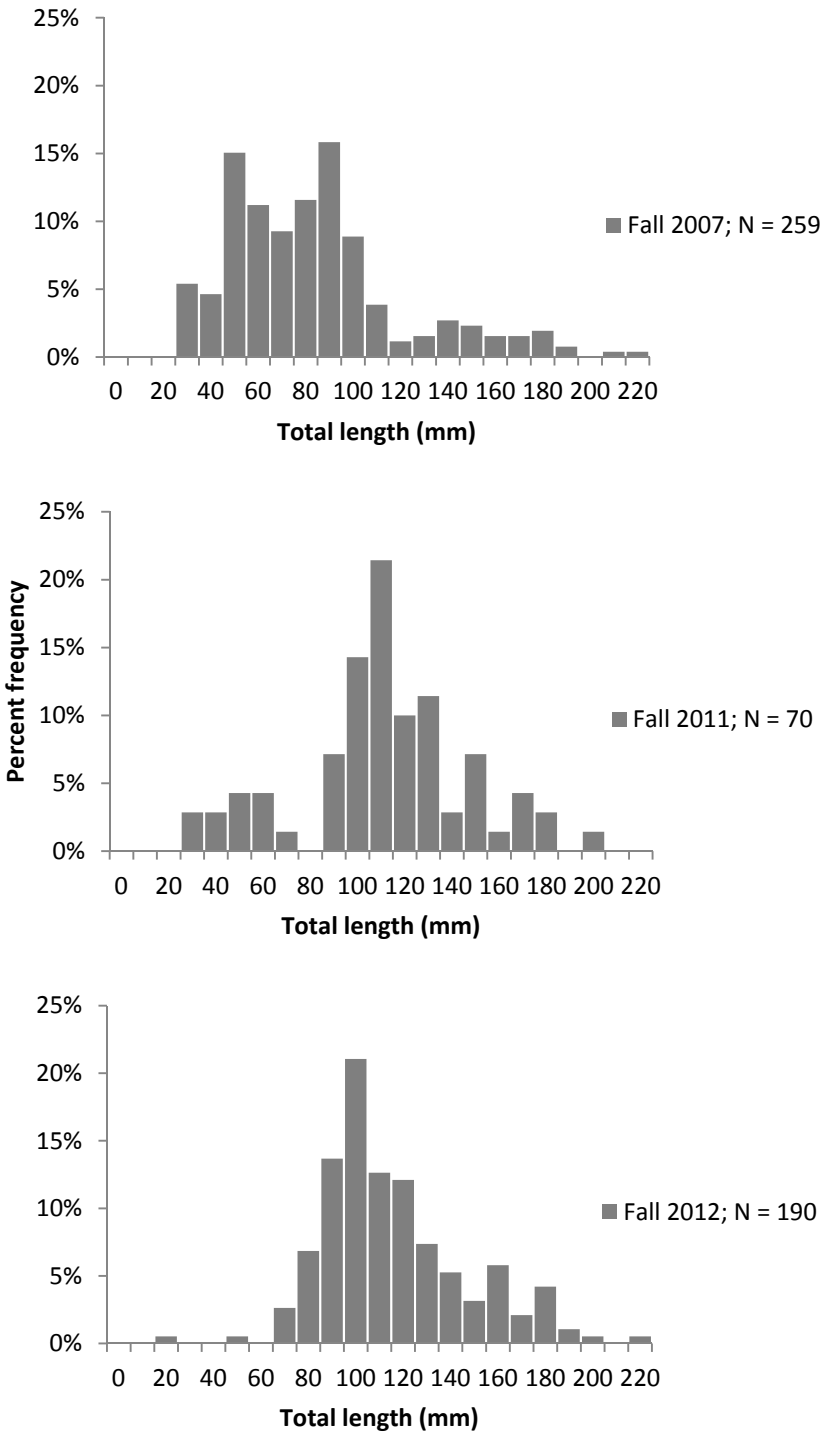

FIGURE 8.—Length-frequency distribution of Bluegill collected by electrofishing before (top chart, 2007), immediately after (middle chart, 2011), and one year after (bottom chart, 2012) Hurricane Irene.

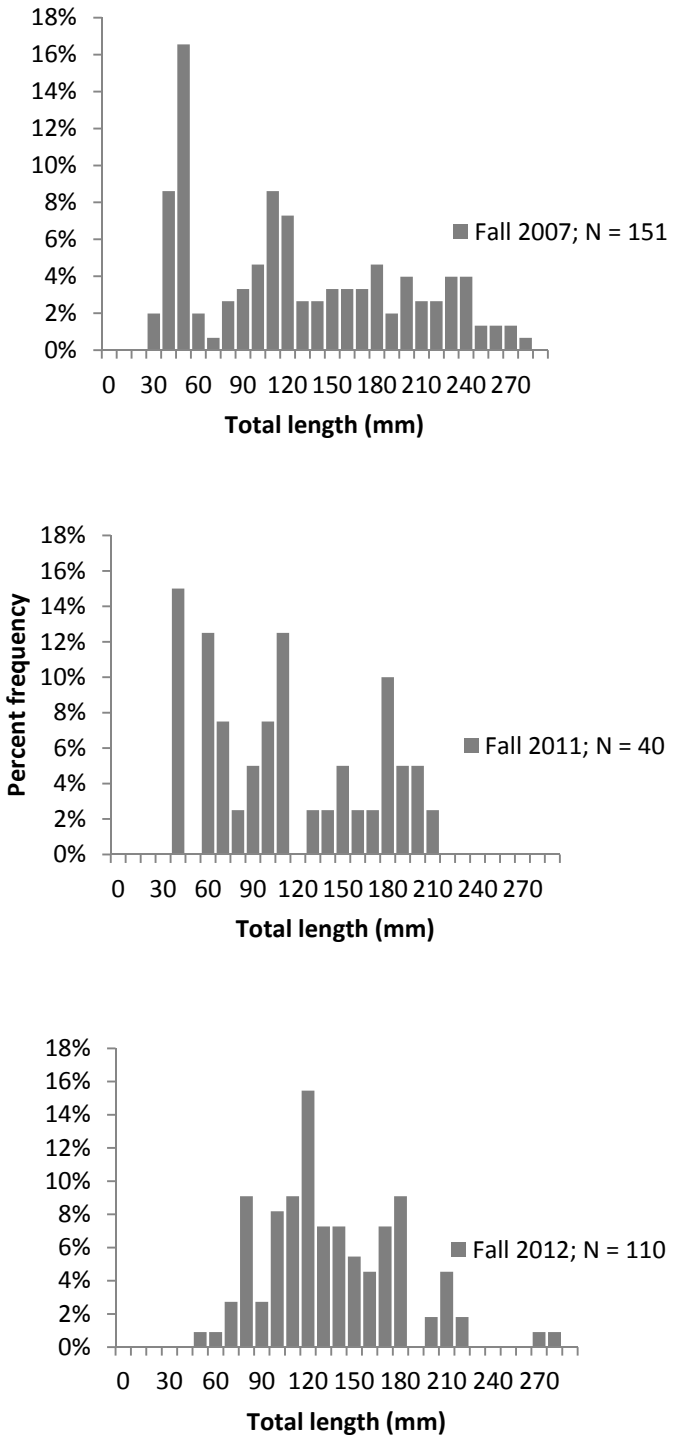

FIGURE 9.—Length-frequency distribution of Redear Sunfish collected by electrofishing before (top chart, 2007), immediately after (middle chart, 2011), and one year after (bottom chart, 2012) Hurricane Irene.

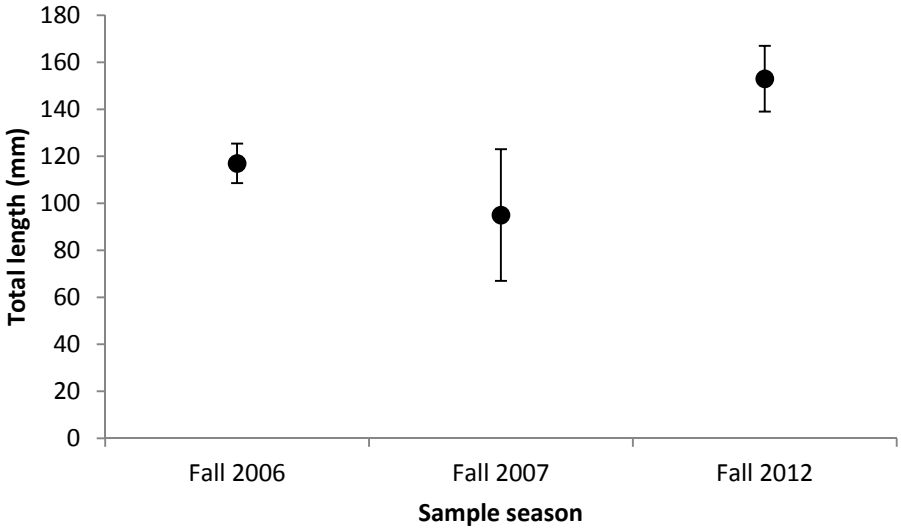

FIGURE 10.—Mean length-at-age of age-0 Largemouth Bass from the Northeast Cape Fear River 2006 (n = 38), 2007 (n = 9) and 2012 (n = 26). Error bars are ± 2 SE.