NEUSE AND TRENT RIVER SPORT FISH COMMUNITY RECOVERY FOLLOWING HURRICANE IRENE

Federal Aid in Sport Fish Restoration
Project F-108
Final Report

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Division of Inland Fisheries
Raleigh

2013

Keywords: Largemouth Bass, sunfish, Neuse River, Trent River, electrofishing, dissolved oxygen

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

Abstract.—After Hurricane Irene made landfall on 27 August 2011, dissolved oxygen (DO) concentrations in the Neuse and Trent River rapidly declined and a fish kill occurred. Dissolved oxygen concentrations were monitored in these rivers to document the extent and duration of anoxic and hypoxic conditions. Sport fish populations were surveyed with boat electrofishing in 2011 and 2012 to document the response to the associated fish kill. Anoxic and hypoxic conditions covered almost 65-km of the main stem Neuse River from NC state highway 55 bridge in Lenoir County to New Bern and at least 17-km of main stem Trent River. Dissolved oxygen at some sites was < 1 mg/L in excess of 21 days. Mean catch-per-unit-effort (CPUE) of juvenile Largemouth Bass *Micropterus salmoides* was higher in both rivers one year after the hurricane. Mean CPUE of adult and harvestable size Largemouth Bass was stable or increased slightly. Length distribution of Largemouth Bass consisted of mostly large individuals following the hurricane in 2011, yet expanded to include a strong mode of age-0 fish in 2012. Mean length-at-age in 2012 for age-0 Largemouth Bass was 138 mm (2 SE = 10) on the Neuse River and 113 mm (2 SE = 14) on the Trent River. Sunfish abundance decreased following the hurricane but began to recover in 2012, albeit not to pre-hurricane levels. Sunfish size structure also declined in 2011 but recovered to pre-hurricane levels in 2012. While the Neuse and Trent River sport fish population showed signs of recovery, we documented little increase in adult Largemouth Bass abundance one year after the hurricane, particularly on the Trent River. Stockings of age-1 and larger Largemouth Bass may be necessary to expedite recovery on the Trent River.

Background

Fish kills following hurricanes have been well documented throughout the southeastern United States (Tabb and Jones 1962, Alford et al. 2009, Vrancken and O'Connell 2010) and in

North Carolina (McCargo et al. 2008, Thomas and Dockendorf 2009). These widespread kills are often a result of increased biological oxygen demand which causes a decrease in dissolved oxygen (DO). The increase in biological oxygen demand is usually caused by decomposition of high inputs of natural material, re-suspension of bottom sediments, or wastewater system overflows (Bales and Childress 1996). All of these scenarios can occur during and following a hurricane due to heavy rainfall, storm surge, and power outages. In North Carolina, the minimum acceptable instantaneous DO concentration is 4.0 mg/L (NCDENR 2007). Sport fish like Largemouth Bass *Micropterus salmoides* and Bluegill *Lepomis macrochirus* may stress at DO levels less than 5.0 mg/L (Katz et al. 1959), avoid DO levels less than 4.5 mg/L (Whitmore et al. 1960) and concentrations less than 1 mg/L are known to be fatal (Moss and Scott 1961). Dissolved oxygen concentrations at or below these levels are known to occur following hurricanes in eastern North Carolina.

On 27 August 2011, Hurricane Irene made landfall near Cape Lookout. Heavy wind from the storm caused a storm surge of 8–11 feet in the Pamlico Sound and rainfall amounts in excess of 12 inches were common throughout eastern North Carolina (Avila and Cangialosi 2011). The U.S. Geological Survey (USGS, Station 02092000) gaging station on Swift Creek near Vanceboro recorded a storm surge of about four feet (Figure 1). Within a few days of landfall, water levels in the lower Neuse River basin started to rise and DO in the river started to decline. Dissolved oxygen levels below 4.0 mg/L were common. Therefore, it was necessary to document the extent and duration of any anoxic or hypoxic conditions.

The Neuse River basin supports a warmwater fish assemblage which supports a recreational fishery, previously valued around $4,000,000 during a year-long angler survey (Rundle et al. 2004). Any significant changes to the fish assemblage in the Neuse River could have drastic impacts on recreational angling success and subsequently the local economy. Therefore, it is important for fishery managers to monitor changes in assemblage following hurricanes. Past studies by the North Carolina Wildlife Resources Commission (NCWRC) have suggested that fish community response to hurricane-induced fish kills should be monitored for a year following the hurricane to gauge natural recovery and determine if additional management actions are needed to aid recovery (Thomas and Dockendorf 2009). The objectives of this study were to document the extent and duration of anoxic and hypoxic conditions following Hurricane Irene, evaluate the sport fish population in fall 2011 and fall 2012, and to determine if alternative management actions were needed to augment natural recovery.

Methods

Dissolved oxygen was measured at access areas along the Neuse and Trent rivers between 30 August and 23 September 2011 with an YSI Pro 2030 DO meter (Table 1). Dissolved oxygen was also measured prior to the hurricane on 25 August. To assess the impacts of the fish kills to the sport fish community, eight 1-km sample sites on the Neuse River and six 500-m sites on the Trent River were sampled (Figure 2). Prior to Hurricane Irene, these sites were sampled during annual Commission sport fish surveys on the Neuse River and during spring 2010 on the Trent River. These sites were sampled following Hurricane Irene in fall 2011 and again one year later in fall 2012. Shoreline habitat within each site was sampled in a downstream direction using a boat-mounted electrofisher (Smith-Root 7.5 GPP). All sport fish encountered were collected and were identified to species, enumerated, measured to the nearest mm, TL and weighed to the nearest g. To examine Largemouth Bass diet in fall of 2012, all Largemouth Bass ≥ 200 mm were examined for gut contents using tapered acrylic tubes according to Van Den Avyle and Roussel (1980) and Cailteux et al. (1990). To determine contribution of the 2012 year-class to electrofishing catch rates in 2012, five Largemouth Bass from each 25-mm size group under 250-mm were sacrificed and otoliths removed for ageing. Otoliths were aged according to Buckmeier and Howells (2003) using a dissecting microscope at 5–33X magnification. Age was determined independently by two readers and discrepancies in age assignment were resolved in a concert read. Ages were expanded to the rest of the population (< 250-mm) using an age-length key, and mean length-at-age of age-0 fish was determined according to Bettoli and Miranda (2001).

To examine change in species composition in fall 2011 and fall 2012, abundance was examined and compared to pre-hurricane samples collected in the fall of 2010. Abundance of Largemouth Bass and sunfish (Bluegill, Pumpkinseed *L. gibbosus*, and Redear Sunfish *L. microlophus*) was indexed as catch-per-unit effort (CPUE) and was expressed as number of fish collected per hour of electrofishing. Abundance was also calculated for Largemouth Bass of three size ranges: juveniles (< 200-mm), adults (≥ 200-mm), and harvestable (≥ 356-mm). Population size structure was analyzed using length-frequency distributions (25-mm length groups for Largemouth Bass and 10-mm length groups for sunfish), proportional size distribution (PSD) and proportional size distribution-preferred (PSD-P; Gabelhouse 1984, Guy et al. 2007). Trends in body condition were assessed using relative weights (Wr) of Largemouth Bass (Wege and Anderson 1978). Relative weight was also calculated separately for stock, quality, preferred, and memorable total length groups of Largemouth Bass (Gabelhouse 1984).

Results and Discussion

Dissolved Oxygen.—Two days prior to the landfall of Hurricane Irene (25 August) DO levels in the Neuse and Trent rivers were at or above 4.0 mg/L (Table 1). Following Hurricane Irene, DO concentrations started to fall and were less than 2.0 mg/L by 30 August at most locations. All recorded DO measurements were less than 1.0 mg/L by 31 August and anoxic conditions were recorded on 1 September as far upstream as the NC 55 bridge in Lenoir County on the Neuse River and Snow Hill in Greene County on Contentnea Creek (Figure 3). Dissolved oxygen concentrations began to recover around 12 September in the Fort Barnwell area on the Neuse River and around 19 September in the New Bern area (Table 1). Measurements of DO were still less than 2 mg/L on 23 September at Pollocksville on the Trent River.

Anoxic conditions and DO concentrations less than 1.0 mg/L covered approximately 65 km of the main stem Neuse River from New Bern to NC 55 in Lenoir County as well as about 52 km of Contentnea Creek from Snow Hill in Greene County downstream to its confluence with the Neuse River in Lenoir County (Figure 3). Anoxic conditions were prevalent on the Trent River, extending from New Bern upstream 17 km to Pollocksville (Figure 3). Dissolved oxygen concentrations remained below 1.0 mg/L for about 14 days in the upper Neuse River and at Pollocksville on the Trent River, while DO measurements near New Bern did not increase above 1.0 mg/L for 21 days following the storm (Figure 3). After 21 days, DO concentration in Swift Creek in Craven County was still less than 1.0 mg/L.

Species Composition.—On the Neuse River during fall of 2010, the year before the hurricane, 13 species and 694 individuals were collected at three 1-km sample sites. The majority of the sample was comprised of Bluegill, Redear Sunfish, Largemouth Bass, and Redbreast Sunfish (Figure 4). During fall of 2011, after the hurricane, only four species and 46 individuals were collected at three 1-km sample sites with the sample mostly comprised of Bluegill and Largemouth Bass (Figure 4). During 2012, Bluegill and Largemouth Bass still represented the majority of the sample; however 17 total species and 593 individuals were collected at four 1-km sample sites. While number of species and individuals collected declined after the hurricane for the fall 2011 sample, it appears that the river started to recover in 2012 as the number of species and total numbers of individuals were more similar to the pre-hurricane sample of 2010.

On the Trent River during spring 2010 (pre-hurricane), 11 species and 463 individuals were collected at four 500-m sample sites. The sample was mostly comprised of sunfish including Pumpkinseed, Bluegill, and Redear Sunfish (Figure 5). After the hurricane during fall 2011, only 5 species and 37 individuals were collected at four 500-m sample sites. The majority of the sample was also sunfish; however, Redear Sunfish accounted for a larger portion of the sample in 2011 (Figure 5). In fall 2012, the sample sites were expanded to six 500-m sample sites, and 11 species and 259 individuals were collected. The sample in 2012 was also mostly comprised of sunfish and Largemouth Bass (Figure 5). Like the Neuse River, number of species and individuals collected declined on the Trent River following the hurricane in 2011; however, an increase in number of species and individuals was observed during 2012. These increases indicate that the Trent River sport fish community began to recover one year after the hurricane, but densities may still be low as total number of individuals was about half what was collected during 2010.

Largemouth Bass.—Catch-per-unit-effort of Largemouth Bass declined following the hurricane for all sizes of fish analyzed except harvestable size (≥ 356 mm) fish on the Trent River (Figure 6). Mean CPUE of juvenile fish (< 200 mm) was especially low during fall of 2011; only 0.2 fish/h (2 SE = 0.6) on the Neuse River and 0.0 fish/h (2 SE = 0.0) on the Trent River. However CPUE rebounded during fall of 2012 to about 29.1 fish/h (2 SE = 7.8) on the Neuse River and 11.6 fish/h (2 SE = 11.3) on the Trent River. Mean CPUE of Neuse River juvenile Largemouth Bass was the highest recorded to date during the fall 2012 sample (Figure 6). Before the hurricane, CPUE of adult Largemouth Bass (≥ 200 mm) averaged 17.0 fish/h on the Neuse River, however CPUE dropped to 2.7 fish/h (2 SE = 2.0) during fall 2011. The Neuse River exhibited signs of recovery as CPUE of adult Largemouth Bass (≥ 200 mm) increased to 7.4 fish/h (2 SE = 2.4) during fall 2012. Mean CPUE of adult Largemouth Bass (≥ 200 mm) on the Trent River declined from 11.1 fish/h (2 SE = 6.3) in spring 2010 (pre-hurricane) to 2.8 fish/h (2 SE = 3.0) in fall 2011, then increased slightly to 4.1 fish/h (2 SE = 2.6) during fall 2012 (Figure 6). On the Neuse River, CPUE of harvestable size fish (≥ 356 mm) averaged about 5.0 fish/h before the hurricane, but declined to less than 2.0 fish/h during fall 2011 and fall 2012 (Figure 6). Mean CPUE of harvestable size Largemouth Bass (≥ 356 mm) on the Trent River did not decrease following the hurricane in fall 2011 (3.2 fish/h, 2 SE = 4.3), but dropped to 0.4 fish/h (2 SE = 0.9) during fall 2012. Good CPUE of juvenile Largemouth Bass in both systems and adult bass in the Neuse River indicate that both systems began to recover during 2012. Therefore, we do not recommend stocking Largemouth Bass in the Neuse River; however, stockings in the Trent River may be warranted due to a lack of increase in CPUE of adult or harvestable size fish.

While mean CPUE of post-hurricane samples in fall 2011 was typically lower than CPUE before the hurricane, CPUE of juvenile fish recovered to pre-hurricane levels in both rivers suggesting good recruitment during 2012. Mean CPUE of adult Largemouth Bass also improved on the Neuse River from fall 2011 to fall 2012, indicating good recovery from the fish kills following Hurricane Irene. We did not document increases in CPUE of adult Largemouth Bass on the Trent River or harvestable size fish on either river. This lack of increase is most likely due to the magnitude and extent of the fish kill following the hurricane. Very few juvenile Largemouth Bass were collected during fall 2011; therefore there were few young fish available to grow to adult size during 2012. Also, because the anoxic and hypoxic conditions covered such a large area, movement of Largemouth Bass from outside of the affected area into the sample area is likely to occur at a slow pace. The only individuals of adult and harvestable size Largemouth Bass collected in 2012 most likely survived the fish kill and therefore the amount of individuals in those size classes is likely static or decreasing due to mortality. Mean CPUE of these size classes should increase in coming years as individuals from the 2012 year-class grow to catchable size. Also, the apparent survival of adult Largemouth Bass indicates a need to document areas of refugia during future hypoxic events. If these areas can be identified, resource managers should work to protect these habitats since they are important to the Largemouth Bass populations of the Neuse and Trent rivers.

The post-hurricane (2011 and 2012) mean CPUE estimates were more variable than pre-hurricane estimates, especially on the Trent River. This variation is most likely due to a smaller sample size (Neuse River N= 8; Trent River N = 6) post-hurricane compared to pre-hurricane (Neuse River N = 12; Trent River N = 13) as well as influences on electrofishing from higher conductivity due to high salinity at downstream sample sites on the Trent River. Conductivity at the most downstream sample site on the Trent River during fall 2012 was 9,600 µS, near the maximum operating conductivity of 11,000 µS of the boat electrofishing gear (7.5 GPP electrofisher, Smith-Root 2006), which may have limited capture efficiency of the electrofishing equipment. Future studies on the Neuse and Trent rivers should include more sample sites over a broader area to account for changes in conductivity and to minimize variability in mean CPUE estimates due to small sample size.

Thomas and Dockendorf (2009) recommended that post-hurricane stockings of Largemouth Bass should focus on larger individuals (143–196 mm) or transplanting of adults from recovered locations to areas more severely impacted. The potential to move adults into systems that may be recovering was concerning because of the possibility of intraspecific predation. However, we found no evidence of adult Largemouth Bass feeding on young of the same species in either river. Of 50 individuals examined for gut contents on the Neuse River, 50% consumed crayfish, 38% were empty, and 12% consumed fish, none of which were identified as Largemouth Bass (Figure 7). On the Trent River, gut contents of 9 Largemouth Bass were examined. Most Largemouth Bass had empty stomachs (56%), while 33% consumed fish, and one individual (11%) consumed crayfish. Therefore, adult Largemouth Bass stocked during fall in the Neuse and Trent rivers may be more likely to consume crayfish than fish items and intraspecific predation may not be a concern. However, diet examination during other times of the year is needed to determine if diet pattern changes over time.

The length frequency distribution of Neuse River Largemouth Bass during fall 2010 ranged from 50 to 475 mm and exhibited several modes representing several year-classes (Figure 8). However, during 2011 only 11 Largemouth Bass were collected and most of those fish were greater than 200 mm, suggesting that most of the fish that survived the fish kill were adults. During 2012, the length distribution expanded to include a strong mode at 125 mm and other peaks above 300 mm (Figure 8). Age determination of otoliths revealed that the peak at 125 mm was represented by a strong 2012 year-class. The mean length-at-age for the 2012 year-class was 139 mm (2 SE = 6) which is higher than any estimate for age-0 fish before the hurricane (Figure 9). During spring 2010 on the Trent River, Largemouth Bass length distribution range was 50–425 mm with several modes representing several age classes (Figure 8). After the hurricane (fall 2011), only four individuals were collected, all larger than 250 mm. Thirty-nine individuals were collected during fall 2012 and ranged ranging in length 50–375 mm. Age determination of otoliths revealed that the strong mode at 100-mm was representative of the 2012 year class; mean length at age for age-0 fish was 113 mm (2 SE = 14).

On the Neuse River, PSD increased from 53 in 2010 to 70 in 2011 and declined to 44 in 2012. This transition indicates a shift toward larger individuals in the length distribution of catchable size fish immediately after the hurricane. Values of PSD-P followed a similar pattern, increasing from 21 in 2010 to 30 in 2011 and then decreasing to 16 in 2012 (Table 2). Trent River Largemouth Bass exhibited a similar pattern as PSD increased from 57 in spring 2010 to 75 in 2011 and then decreased slightly to 70 in 2012 (Table 2). Values of PSD-P increased slightly after the hurricane from 22 in 2010 to 25 in 2011, but decreased to 10 in 2012. This indicates a decrease in harvestable size Largemouth Bass in the catchable population.

Mean Wr of most sizes of Largemouth Bass remained stable after the hurricane (2011) except for stock size Largemouth Bass on the Neuse River (Figure 10). The decline in Wr in 2011 may be a result of decline in condition due to stress from the extended anoxic conditions and a decline in forage caused by the fish kill. However, Wr rebounded in 2012 to pre-hurricane levels and in some cases exceeded pre-hurricane levels. This increase in Wr may be a result of decreased intraspecific competition as a result of the fish kills.

Sunfish.—Mean CPUE of most sunfish species examined declined during 2011 after the hurricane and increased during 2012. On the Neuse River, Bluegill CPUE three years before Hurricane Irene was around 100 fish/h but decreased to 19 fish/h (2 SE = 23) in 2011 and increased to 87 fish/h (2 SE = 54) in 2012 (Figure 11). Trent River Bluegill exhibited a similar pattern; mean CPUE declined from 87 fish/h (2 SE = 49) in 2010 to 3 fish/h (2 SE = 4) in 2011 and increased to 42 fish/h (2 SE = 18) in 2012. Redear Sunfish CPUE exhibited marginal to no increase following the hurricane. Mean CPUE on the Neuse River dropped to 0 fish/h (2 SE = 1) in 2011 but increased to 9 fish/h (2 SE = 8) in 2012 (Figure 12). On the Trent River, Redear Sunfish mean CPUE in 2011 was 23 fish/h (2 SE = 15) and mean CPUE decreased to 15 fish/h (2 SE = 11) in 2012. Mean CPUE of Neuse River Pumpkinseed decreased following Hurricane Irene to 0 fish/h (2 SE = 0) in 2011 and increased to 5 fish/h (2 SE = 1) in 2012. Trent River Pumpkinseed CPUE followed a similar pattern; mean CPUE was 2 fish/h (2 SE = 4) following Irene in 2011 and increased to 22 fish/h (2 SE = 10) in 2012 (Figure 13). Estimates of mean CPUE for all sunfish species are typically variable due a low number of sample sites and higher conductivities at downstream sample sites as discussed earlier. Again, more sites should be included in future surveys to lower variability in mean CPUE estimates.

The length frequency distribution of Neuse River Bluegill before the hurricane (2010) ranged 20–200 mm with 223 individuals collected from three 1-km sites and most of the fish caught were ≥ 100 mm (Figure 14). During 2011, 37 individuals were collected at three 1-km sites with the majority of those fish ≥ 90 mm (Figure 14). Fall 2012 appeared more similar to 2010 with 309 individuals collected from three 1-km sites and the majority of fish were larger than 90 mm (Figure 16). Trends in PSD indicate a shift toward larger catchable size fish in 2011 with a PSD of 46 while 2012 was more similar to 2010 with a PSD of 16 (Table 2). During 2010, the length frequency distribution of Trent River Bluegill ranged from 40–230 mm with several modes. However, only four individuals were collected in 2011, all larger than 100 mm (Figure 14). During fall 2012, length distribution was unimodal with a peak at 130 mm (Figure 14). Trends in PSD also indicate a shift toward larger catchable size individuals in 2011 with a PSD of 50; however PSD was more similar to pre-hurricane values in 2012 with a value of 20 (Table 2).

The length frequency distribution of Neuse River Redear Sunfish before the hurricane in 2010 was comprised of fish 30–280 mm with modes at 60, 90, and 180 mm (Figure 15). However, after the hurricane in 2011, only one individual was collected at three 1-km sites. The length frequency distribution of Neuse River Redear Sunfish improved in 2012 exhibiting modes at 60 mm and 180 mm (Figure 15). Neuse River Redear Sunfish PSD was not calculated in 2011 since only one individual was collected; however PSD in 2012 was 63, which indicates that of catchable-size fish, most individuals were larger (Table 2). Trent River Redear Sunfish length frequency distribution ranged from 40–260 in 2010 with modes at 50 mm, 90 mm, 150 mm, and 180 mm (Figure 15). Length frequency distribution was bimodal in 2011 with peaks at 50 mm and 210 mm (Figure 15). During 2012, the length frequency distribution was multi-modal with peaks at 50 mm, 140 mm, and 250 mm (Figure 15). Trends in PSD also indicated a shift toward larger catchable-size individuals during 2011 with a PSD of 94, while PSD decreased to 16 during 2012.

The Trent River Pumpkinseed length frequency distribution ranged 30–170 mm during spring 2011. After the hurricane in fall 2011, only 3 individuals were collected, but the size distribution expanded during fall 2012 to include 55 individuals that ranged 60–180 mm (Figure 16). Trent River Pumpkinseed PSD was 25 before the hurricane in spring 2010 and was 11 in fall 2012. Based on trends in CPUE and length distribution it appeared that the Neuse and Trent River sunfish populations declined after the fish kill and started to recover in 2012. Abundance is still at a lower level than before Hurricane Irene, but size structure was more similar to pre-hurricane patterns. Redear Sunfish abundance showed little to no increase during 2012 and size structure on the Neuse River did not include individuals larger than 200 mm. These populations should be monitored again during fall 2013 to ensure full recovery.

Management Recommendations

1. Stockings of Largemouth Bass should focus on the Trent River because abundance of adult Largemouth Bass did not increase after the hurricane and reproduction was lower and variable in the Trent River. Stockings should include age-1 or larger Largemouth Bass according to Thomas and Dockendorf (2009).
2. In this study we did not document Largemouth Bass intraspecific predation during fall 2012, however if stockings are planned for other times of the year, further diet studies may be

necessary to determine if predation of stocked adult Largemouth Bass on wild produced juveniles is a concern.

3. The resiliency of the Tar River sport fish population appears to be dependent upon the ability of adult fish to survive extended periods of anoxic conditions. Areas of refuge during future anoxic events should be identified and protected by fishery managers to insure the long-term sustainability of this valuable fishery.
4. To limit variability in mean CPUE estimates future studies should include more sites over a broader area to increase sample size and minimize effects of increased conductivity due to high salinities at downstream sample sites.

Literature Cited

Alford, J. B., D. M. O'Keefe, and D. C. Jackson. 2009. Effects of stocking adult Largemouth Bass to enhance fisheries recovery in Pascagoula River floodplain lakes impacted by Hurricane Katrina. Proceedings of the Annual Conference of the Southeast Association of Fish and Wildlife Agencies 63:104–110.

Avila, L. A. and J. Cangialosi. 2011. Tropical cyclone report, Hurricane Irene, 21–28 August 2011. National Oceanic and Atmospheric Administration, National Hurricane Center, Miami.

Bales, J. D. and C. J. O. Childress. 1996. Aftermath of Hurricane Fran in North Carolina-Preliminary data on flooding and water quality. U.S. Geological Survey. Open File Report 96-499.

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. W. Howells. 2003. Validation of otoliths for estimating ages of largemouth bass to 16 years. North American Journal of Fisheries Management 23:590-593.

Cailteux, R. L., W. F. Porak, and S. Crawford. 1990. Reevaluating the use of acrylic tubes for collection of Largemouth Bass stomach contents. Proceeds of the Annual Conference of the Southeast Association of Fish and Wildlife Agencies 44:126–132.

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):348.

Katz, M., A. Pritchard, and C. E. Warren. 1959. Ability of some salmonids and a centrachid to swim in water of reduced oxygen content. Transactions of the American Fisheries Society 88:88-95.

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, Project F-22, Final Report, Raleigh.

Moss, D. D. and D. C. Scott. 1961. Dissolved-oxygen requirements of three species of fish. Transactions of the American Fisheries Society 90:377-393.

NCDENR. 2007. Administrative code section 15A NCAC 2B .0200 Classifications and water quality standards applicable to surface waters and wetland of N.C. pp. 21.

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, Project F-22, Final Report, Raleigh.

Smith-Root Inc. 2006. User's manual GPP 5.0, 7.5, 9.0 (Gas Powered Pulsator). Vancouver, Washington. 42 pp.

Tabb, D. C., and A. C. Jones. 1962. Effect of Hurricane Donna on aquatic fauna of North Florida Bay. Transactions of the American Fisheries Society 91:375–378.

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, Project F-22, 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(4): 22–223.

Vrancken, J. V. and M. O'Connell. 2010. Effects of Hurricane Katrina on freshwater fish assemblages in a small coastal tributary of Lake Pontchartrain, Louisiana. Transactions of the American Fisheries Society 139:1723-1732.

Wege, G. W., and R. O. Anderson. 1978. Relative weight (*Wr*): a new index of condition for largemouth bass. Page 79-97 *in* G. D. Novinger and J. G. Dillard, editors. New approaches to the management of small impoundments. American Fisheries Society, North Central Division, Special Publication 5, Bethesda, Maryland.

Whitmore, C. M., C. E. Warren, and P. Doudoroff. 1960. Avoidance reactions of salmonid and centrachid fishes to low oxygen concentrations. Transactions of the American Fisheries Society 89:17-26.

TABLE 1.—Dissolved oxygen measurements on the Neuse and Trent rivers by date and site before and after Hurricane Irene August–September 2011.

Date	River	Site	DO (mg/L)
25 August	Neuse River	Bridgeton	5.3
	Neuse River	Maple Cypress	5.9
	Neuse River	Spring Garden	4.8
	Trent River	Pollocksville	4.0
30 August	Neuse River	Bridgeton	0.8
	Neuse River	Swift Creek	0.4
	Neuse River	Spring Garden	1.5
	Trent River	Lawsons Creek	4.8
	Trent River	Pollocksville	1.5
31 August	Neuse River	Contentnea Creek- Grifton	0.1
	Neuse River	Swift Creek	0.1
	Neuse River	Hatteras Yachts	0.1
	Neuse River	Mouth of The Gut	0.5
	Neuse River	Hog Island	0.1
	Neuse River	Railroad Trestle	0.2
	Neuse River	NC 43	0.1
	Neuse River	Spring Garden	0.7
1 September	Neuse River	Kinston- NC 55	0.1
	Neuse River	Kinston- US 70	4.8
	Neuse River	Kinston- NC 258	4.3
	Neuse River	Contentnea Creek- Snow Hill	0.8
6 September	Neuse River	Bridgeton	2.8
	Neuse River	Contentnea Creek- Grifton	0.0
	Neuse River	Swift Creek	0.0
	Neuse River	Spring Garden	0.0
	Trent River	Pollocksville	0.1
12 September	Neuse River	Bridgeton	1.1
	Neuse River	Contentnea Creek- Grifton	0.2
	Neuse River	Swift Creek	0.1
	Neuse River	Maple Cypress	2.1
	Neuse River	Spring Garden	0.8
	Trent River	Pollocksville	0.1
	Trent River	US 70	0.8
19 September	Neuse River	Bridgeton	2.6
	Neuse River	Contentnea Creek- Grifton	4.7
	Neuse River	Swift Creek	0.1
	Neuse River	Maple Cypress	5.6
	Neuse River	Spring Garden	3.2
	Trent River	Pollocksville	1.5
23 September	Trent River	Pollocksville	1.5

TABLE 2.—Proportional stock distribution and PSD-preferred of Largemouth Bass, Bluegill, Redear Sunfish, and Pumpkinseed before (2010), immediately after (2011), and one year after (2010) Hurricane Irene.

			2010	2011	2012
Neuse River	Largemouth Bass	PSD	53	70	44
		PSD-P	21	30	16
	Bluegill	PSD	14	46	16
		PSD-P	1	–	–
	Redear Sunfish	PSD	18	–	63
		PSD-P	6	–	–
Trent River	Largemouth Bass	PSD	57	75	70
		PSD-P	22	25	10
	Bluegill	PSD	24	50	20
		PSD-P	5	–	1
	Redear Sunfish	PSD	18	94	16
		PSD-P	9	31	13
	Pumpkinseed	PSD	25	–	11
		PSD-P	–	–	–

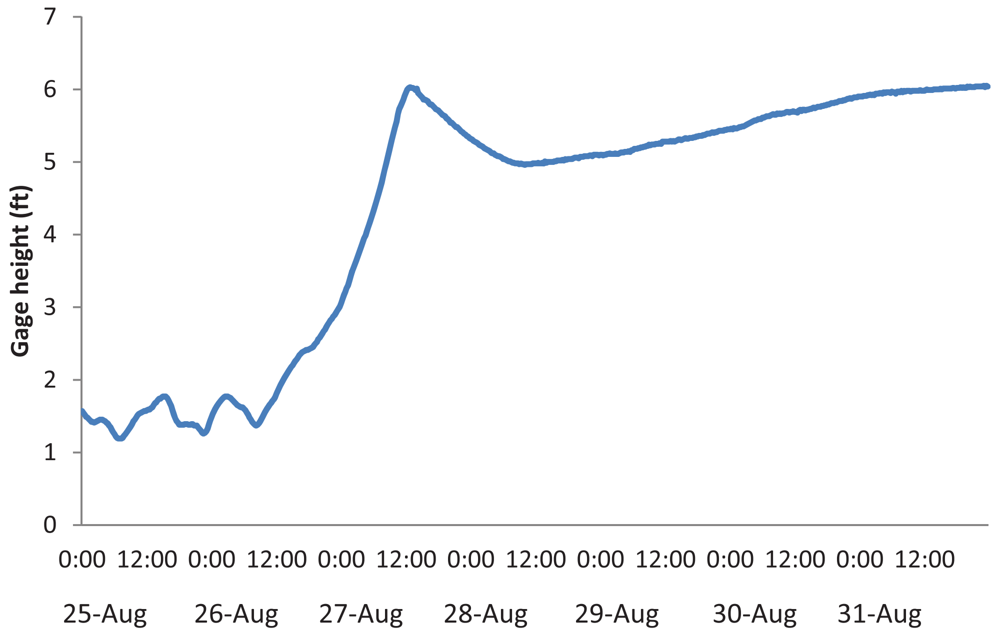


FIGURE 1.—Water level recorded at the Swift Creek USGS gaging station 02092000 during Hurricane Irene 25–31 August 2011.

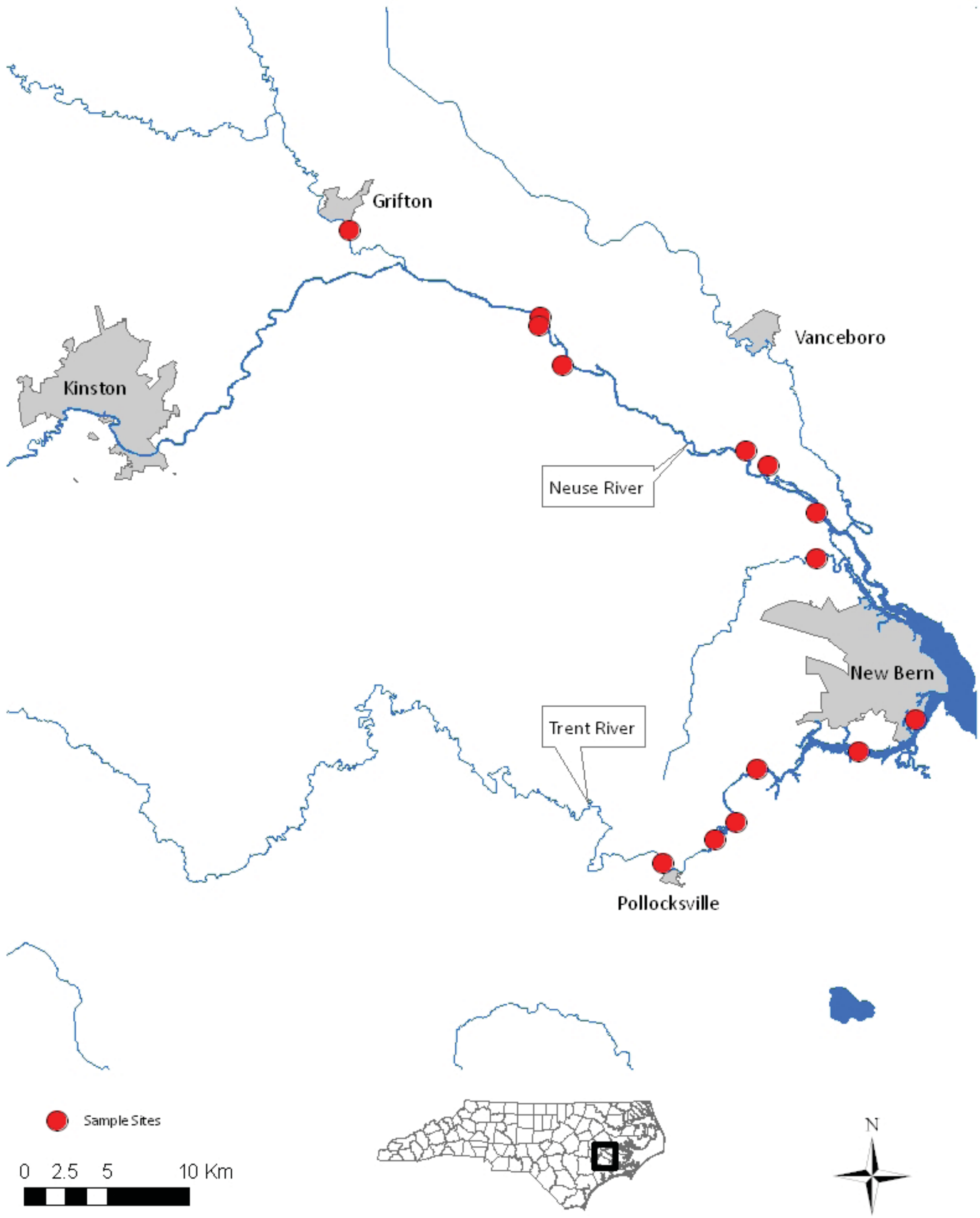


FIGURE 2.—Electrofishing sample sites on the Neuse and Trent rivers following Hurricane Irene.

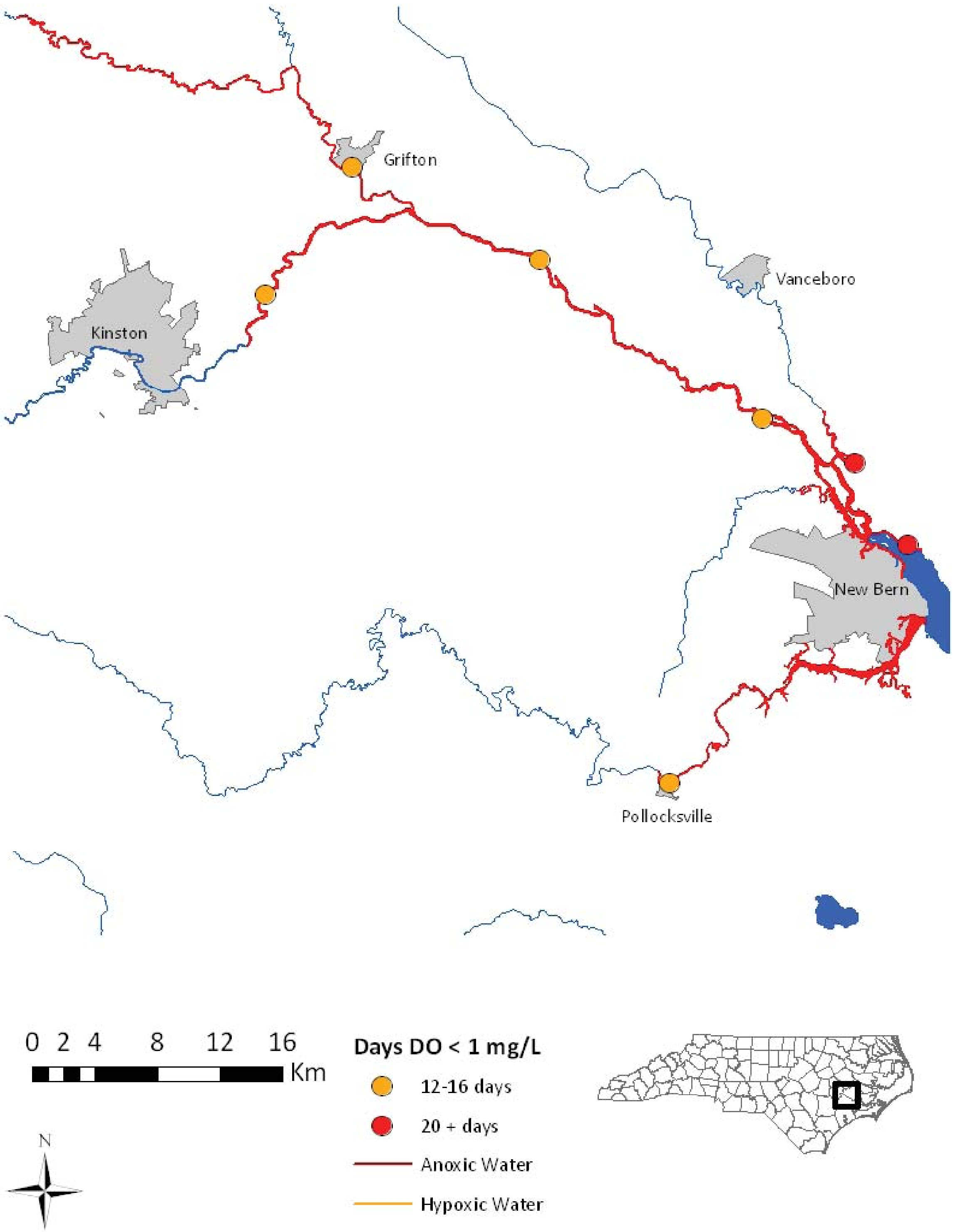


FIGURE 3.—Extent and duration of anoxic and hypoxic conditions in the Neuse and Trent rivers following Hurricane Irene.

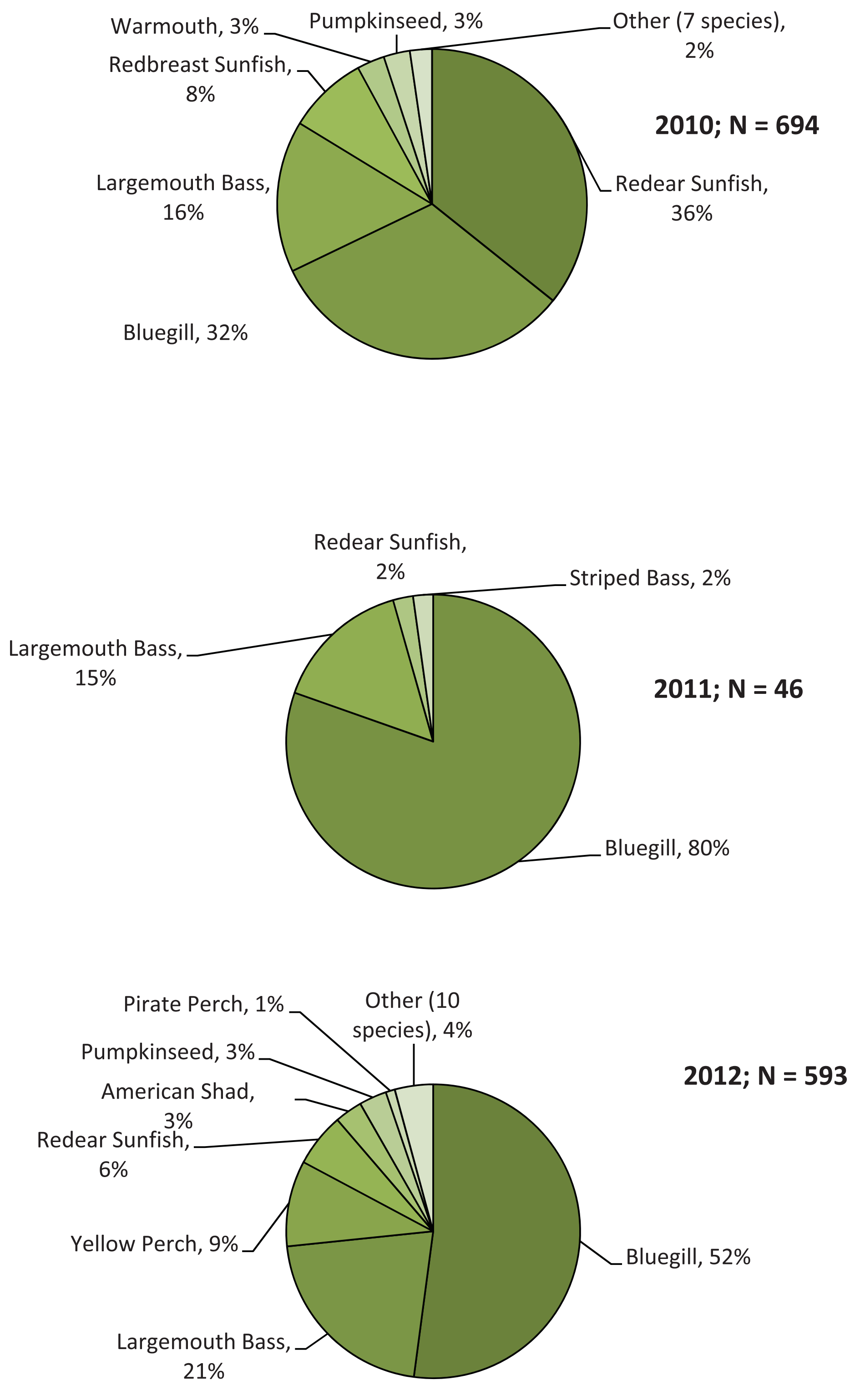


FIGURE 4.—Species composition of Neuse River electrofishing sample before (2010), immediately after (2011), and one year after (2012) Hurricane Irene.

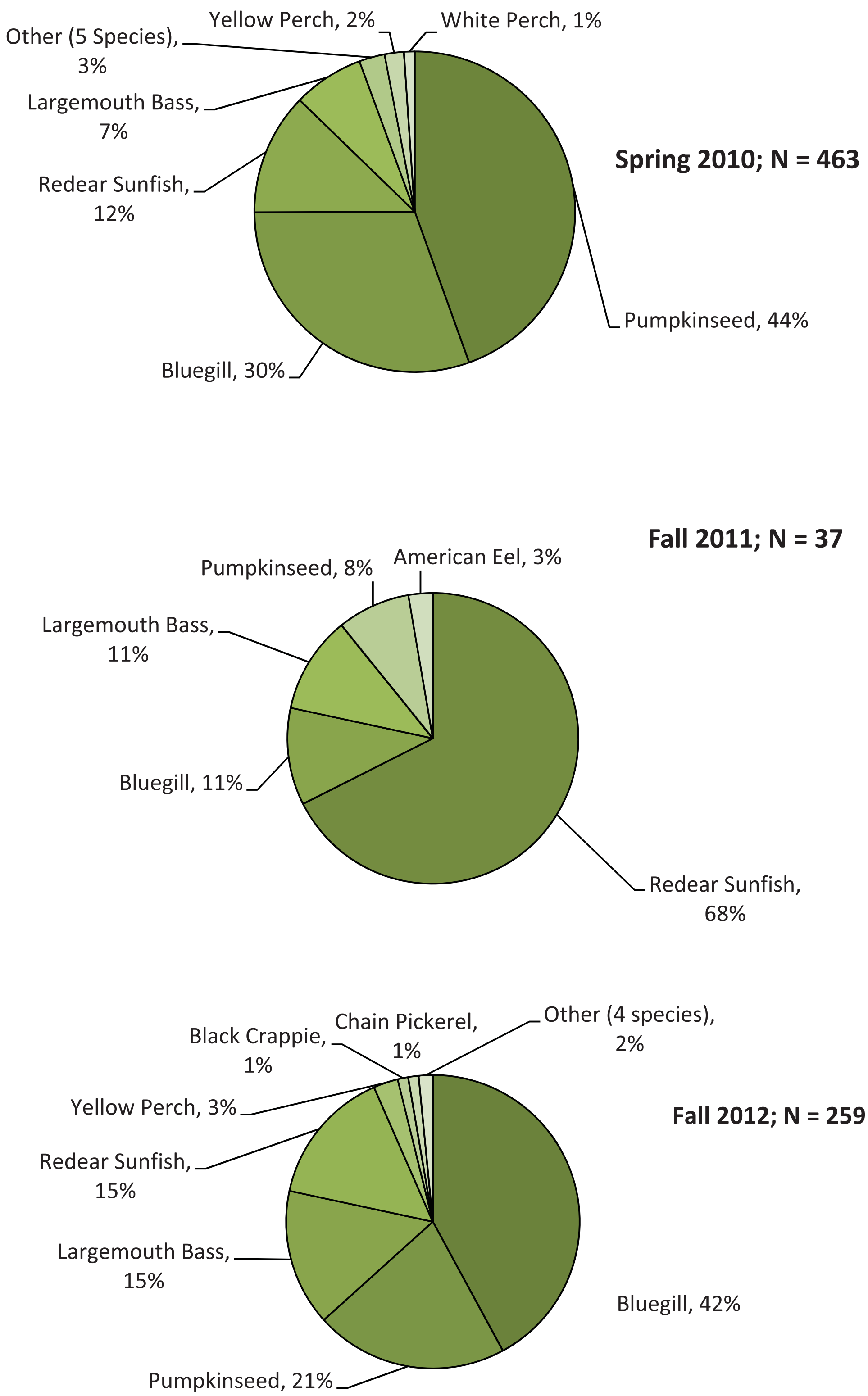


FIGURE 5.—Species composition of Trent River electrofishing sample before (2010), immediately after (2011), and one year after (2012) Hurricane Irene.

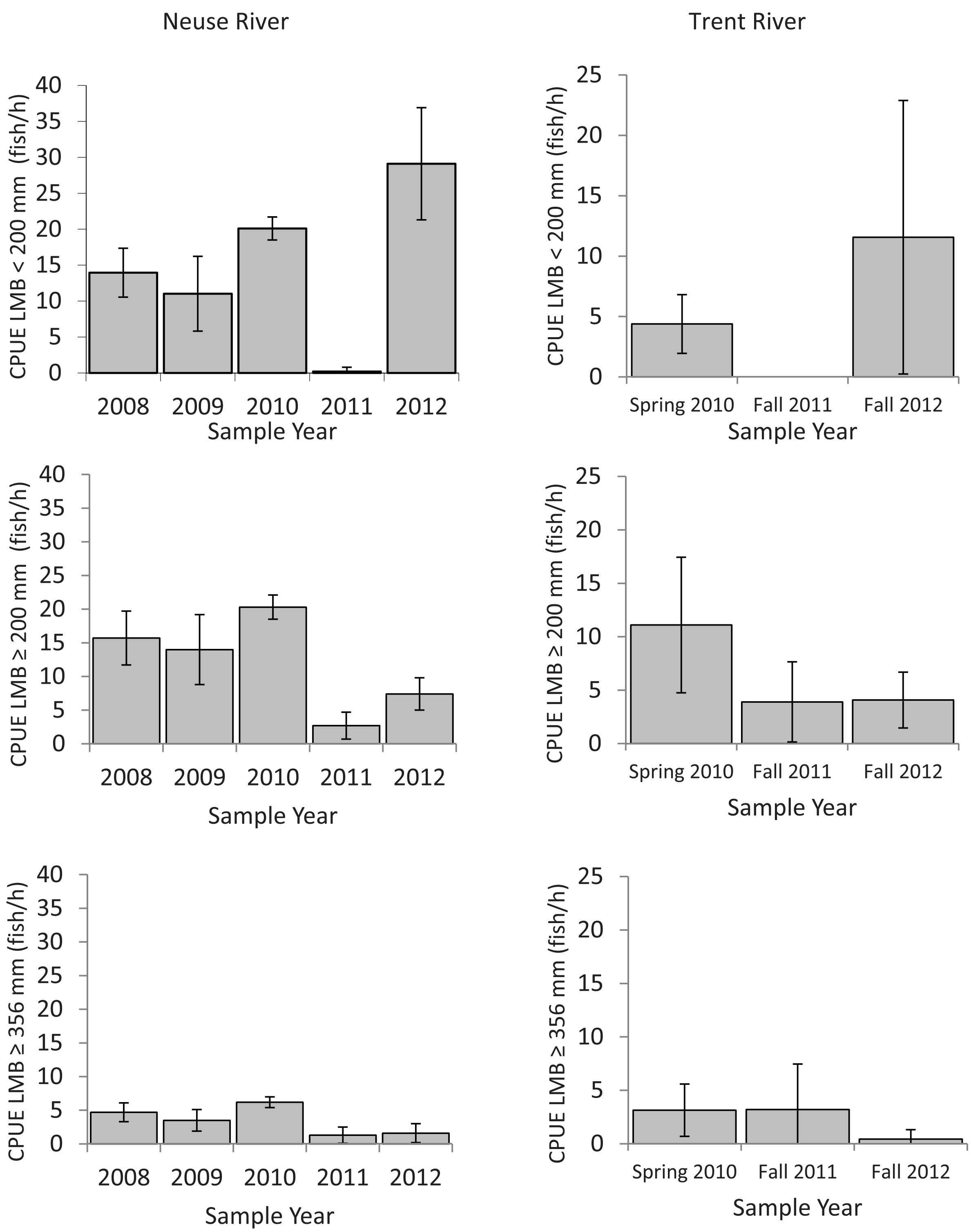
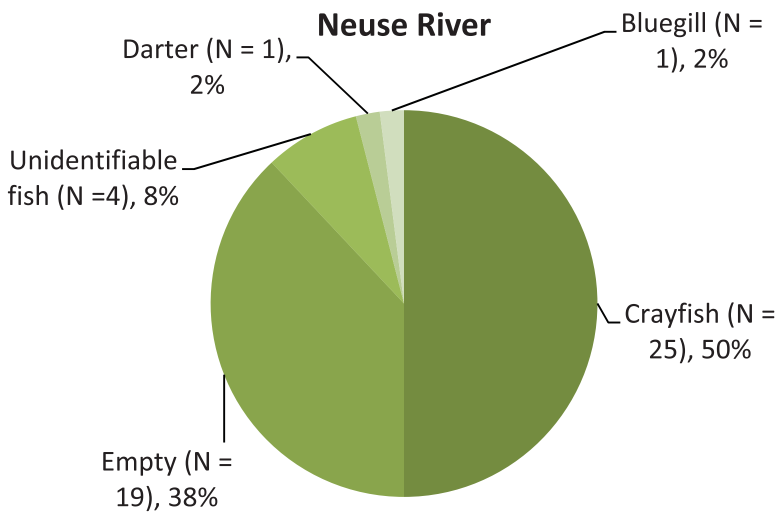


FIGURE 6.—Catch-per-unit-effort of Largemouth Bass < 200 mm (top charts), ≥ 200 mm (middle charts), and ≥ 356 mm (bottom charts) during fall 2008–2012 on the Neuse River and 2010–2012 on the Trent River. Error bars are ± 2 SE.



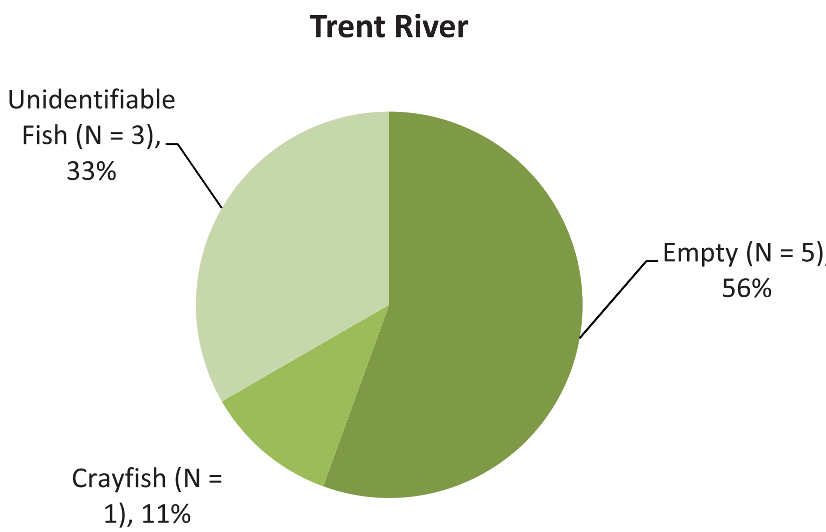


FIGURE 7.—Diet composition of Largemouth Bass ≥ 200 mm collected by electrofishing in the Neuse and Trent rivers fall 2012.

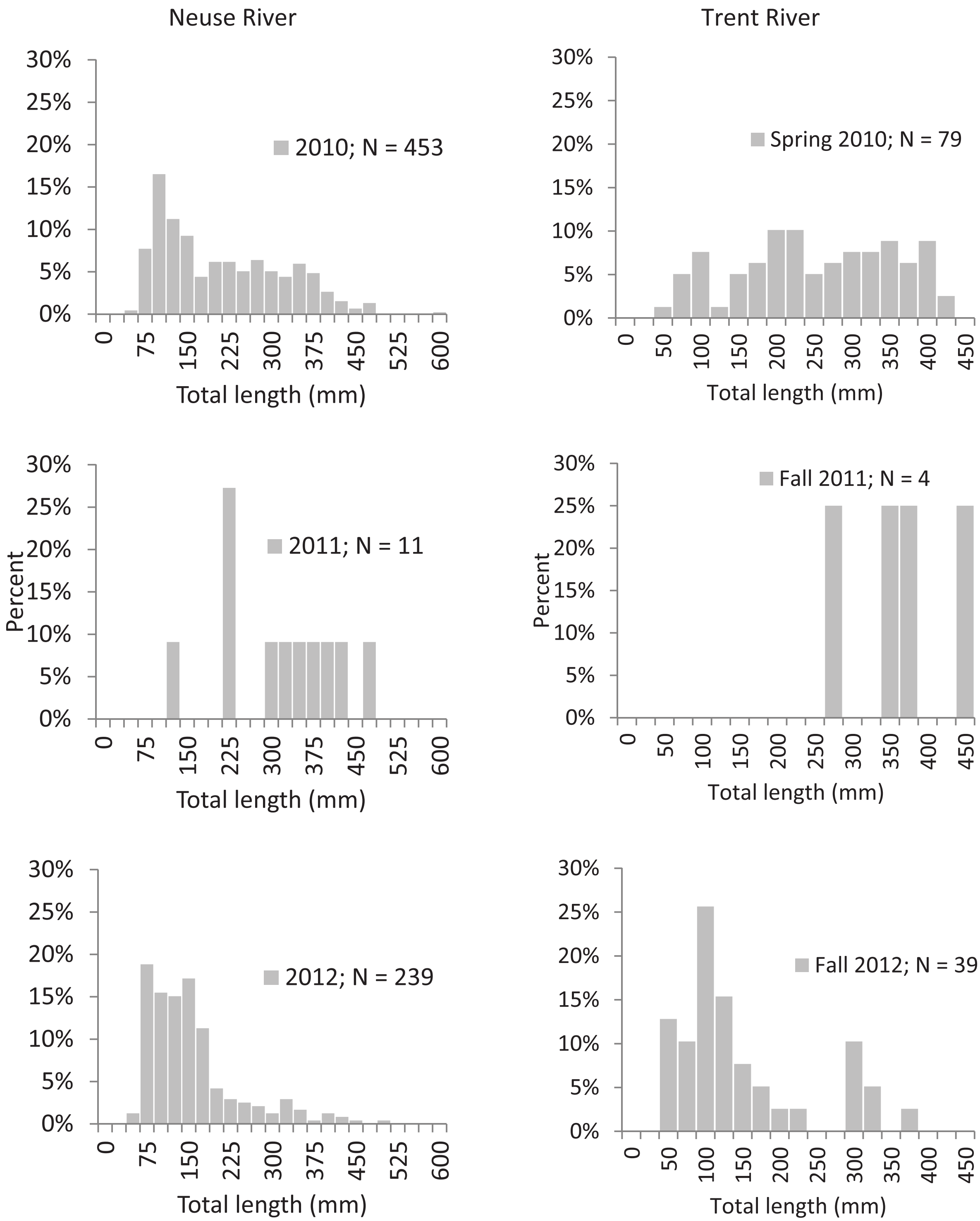


FIGURE 8.—Length-frequency distribution of Largemouth Bass collected by electrofishing on the Neuse and Trent rivers before (top charts, 2010), immediately after (middle charts, 2011), and one year after (bottom charts, 2012) Hurricane Irene.

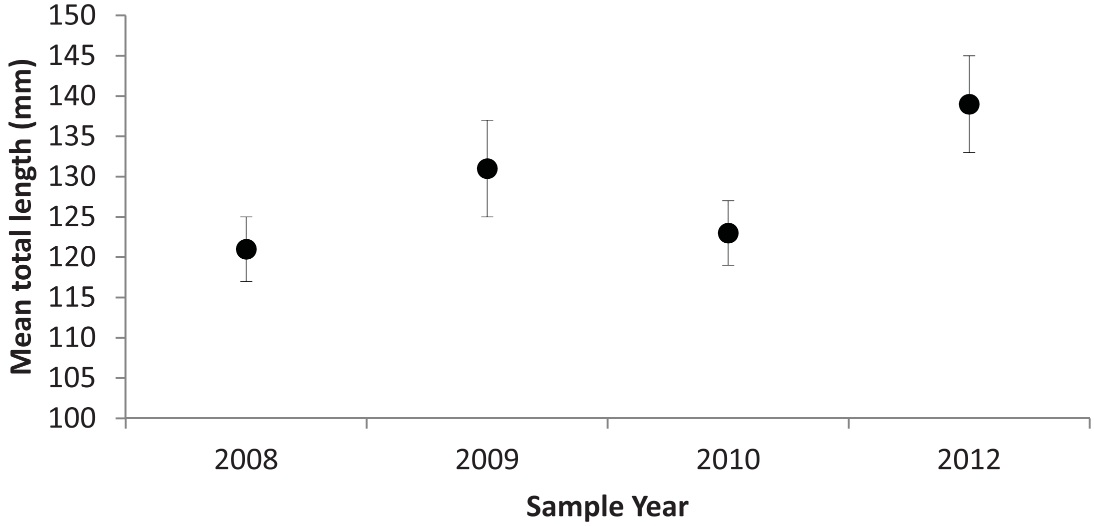


FIGURE 9.—Mean length-at-age of age-0 Largemouth Bass from the Neuse River 2008–2010 and 2012. Error bars are ± 2 SE.

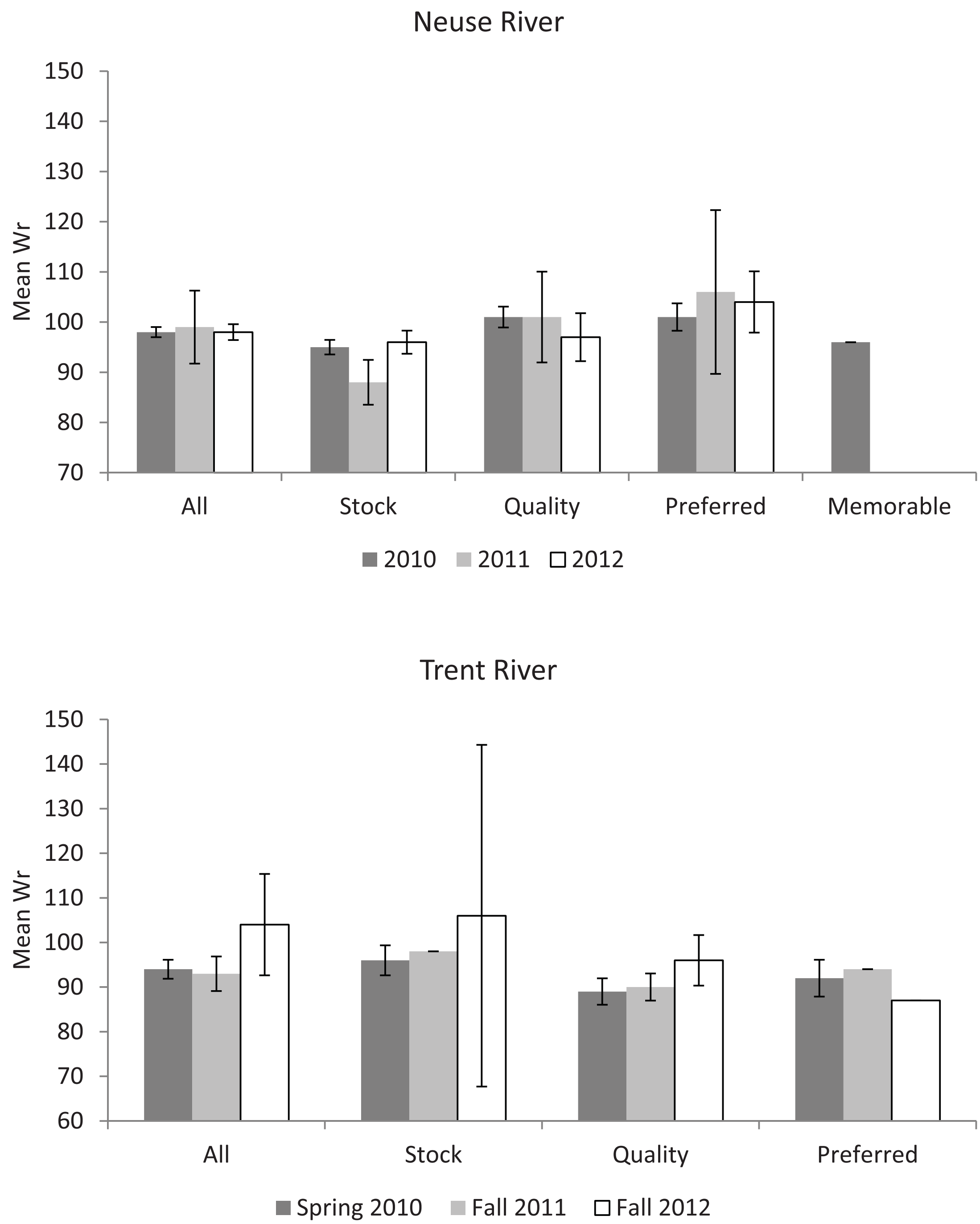
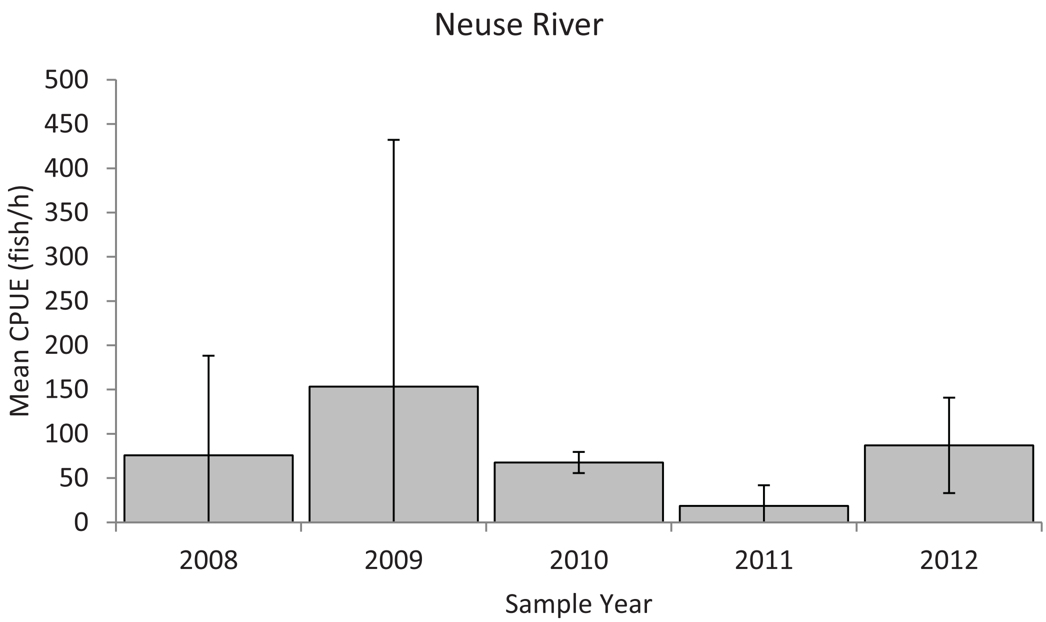


FIGURE 10.—Mean Wr of all Largemouth Bass and stock, quality, preferred, and memorable size Largemouth Bass from the Neuse and Trent rivers before (2010), immediately after (2011), and one year after (2012) Hurricane Irene. Error bars are ± 2 SE.



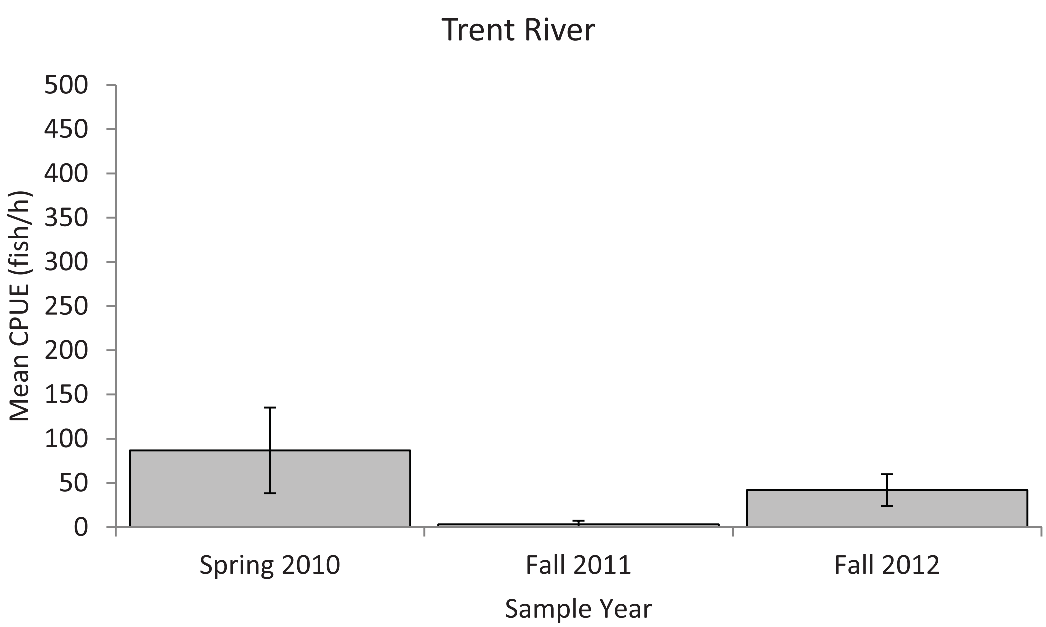


FIGURE 11.—Mean CPUE of Bluegill collected by electrofishing in Neuse River in fall 2008–2012 and Trent River 2010–2012. Error bars are ± 2 SE.

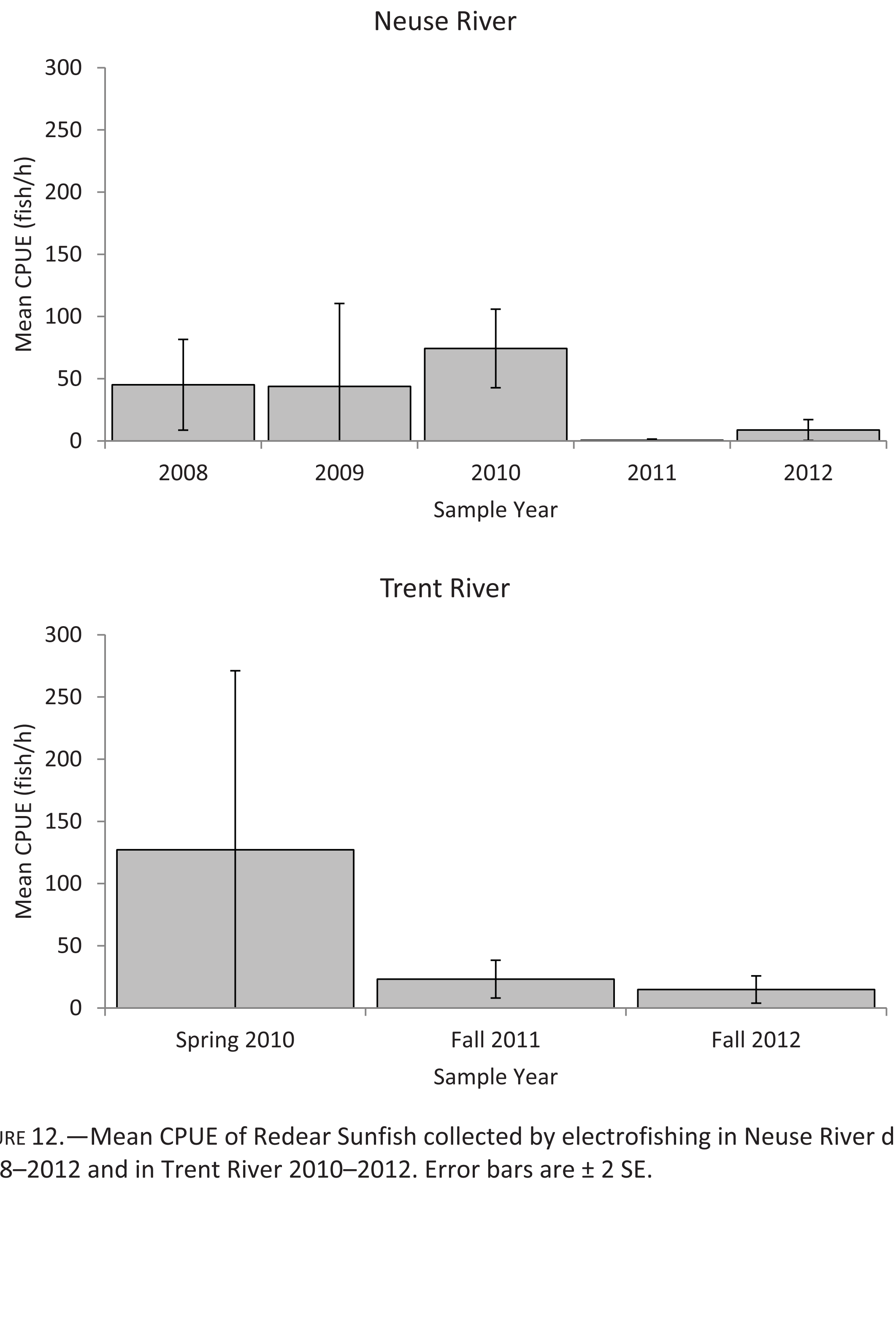
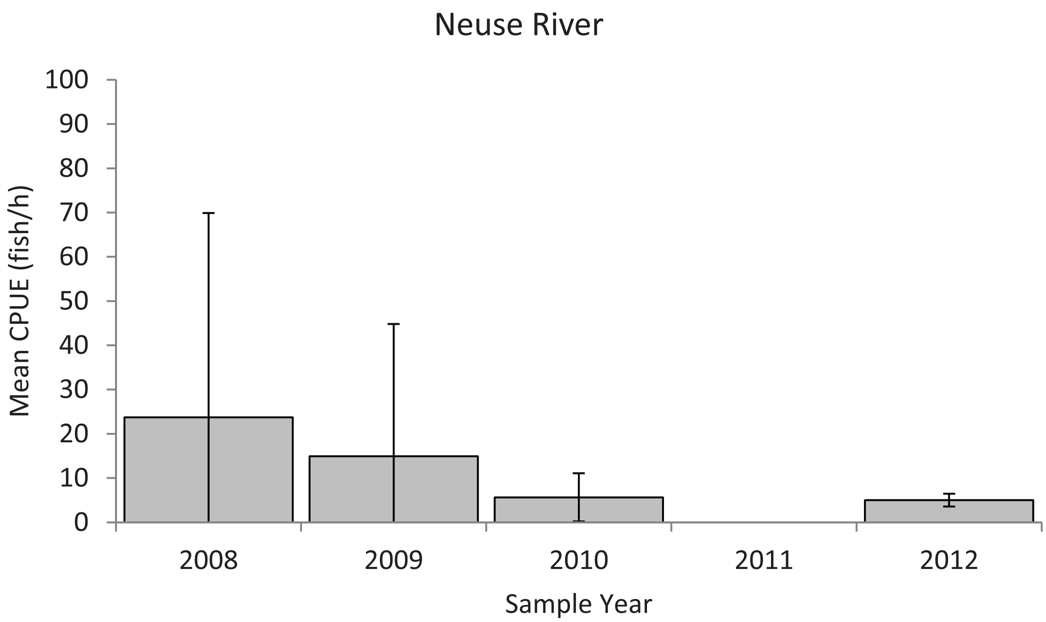


FIGURE 12.—Mean CPUE of Redear Sunfish collected by electrofishing in Neuse River during fall 2008–2012 and in Trent River 2010–2012. Error bars are ± 2 SE.



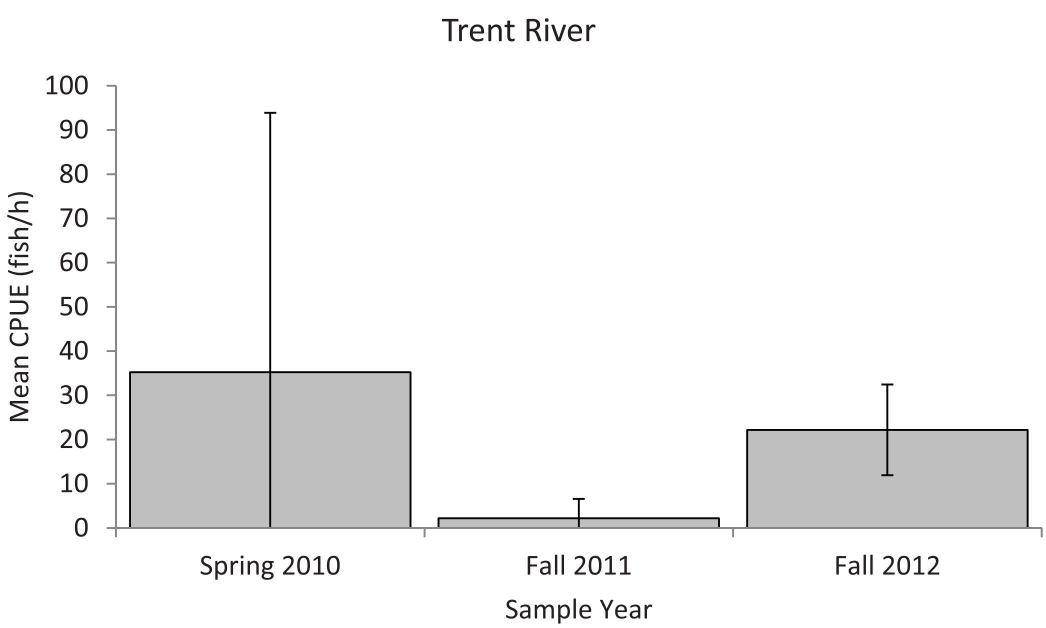


FIGURE 13.—Mean CPUE of Pumpkinseed collected by electrofishing in Neuse River during fall 2008–2012 and in Trent River 2010–2012. Error bars are ± 2 SE.

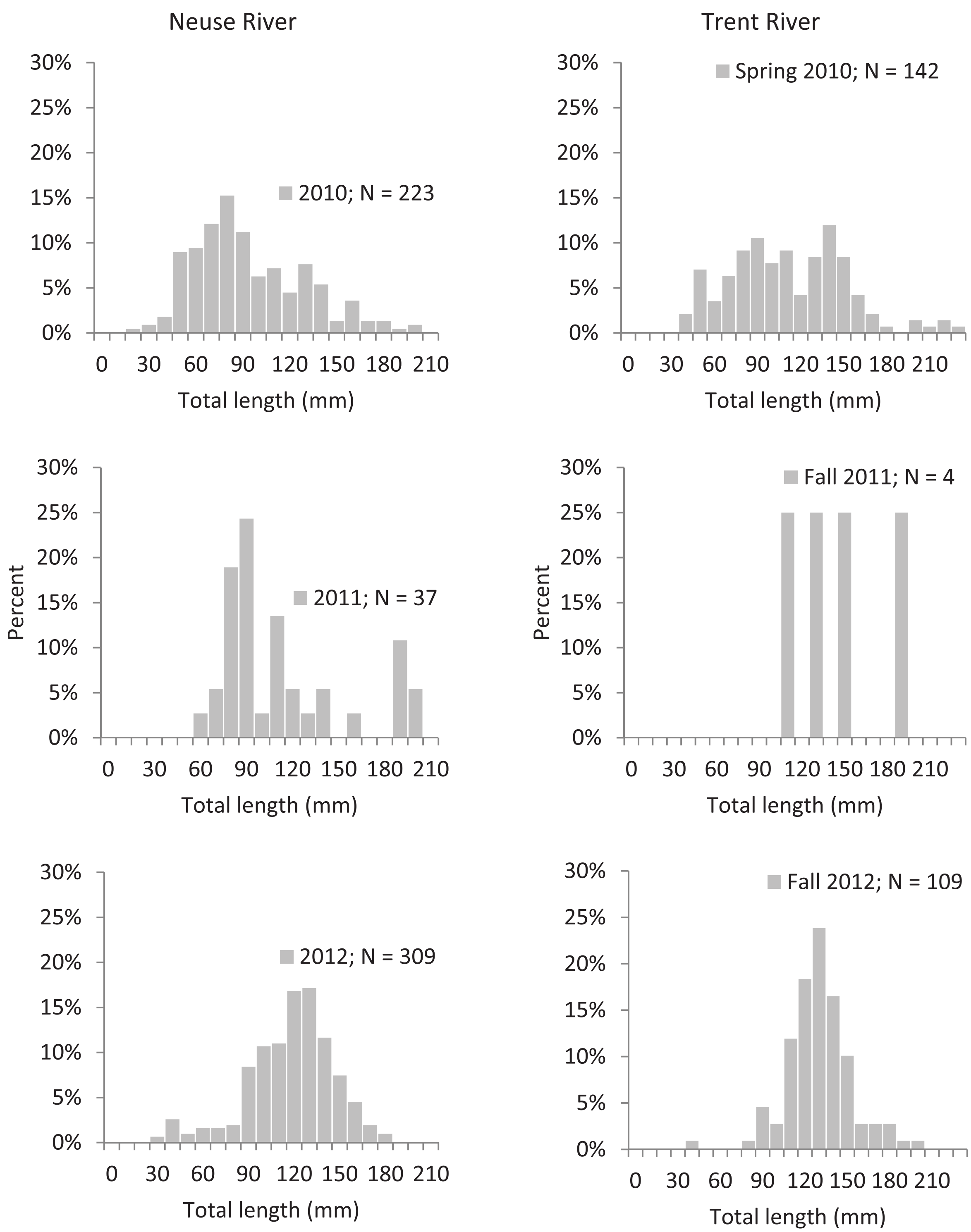


FIGURE 14.—Length-frequency distribution of Bluegill collected by electrofishing before (top chart, 2010), immediately after (middle chart, 2011), and one year after (bottom chart, 2012) Hurricane Irene on the Neuse and Trent rivers.

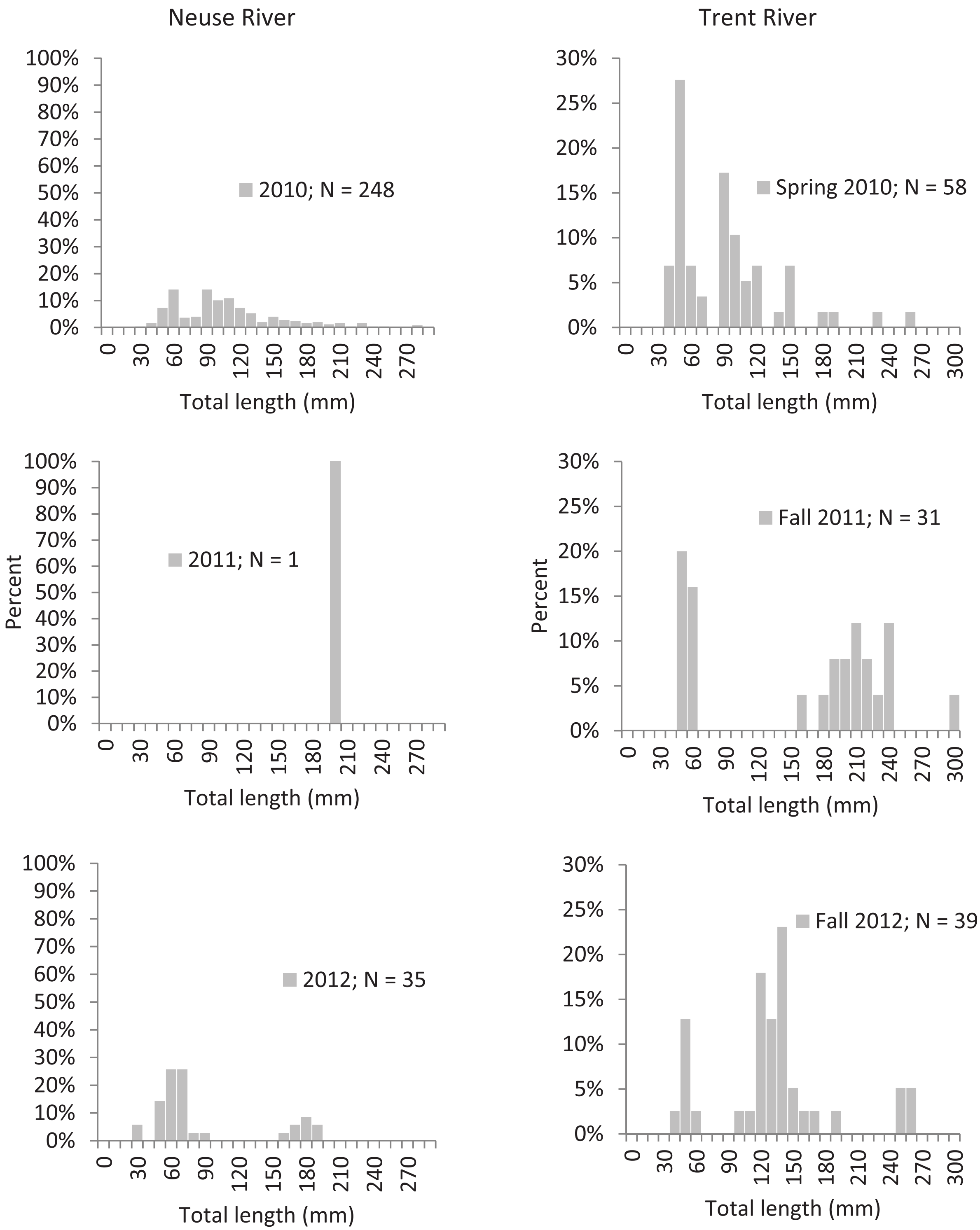


FIGURE 15.—Length-frequency distribution of Redear Sunfish collected by electrofishing before (top chart, 2010), immediately after (middle chart, 2011), and one year after (bottom chart, 2012) Hurricane Irene on the Neuse and Trent rivers.

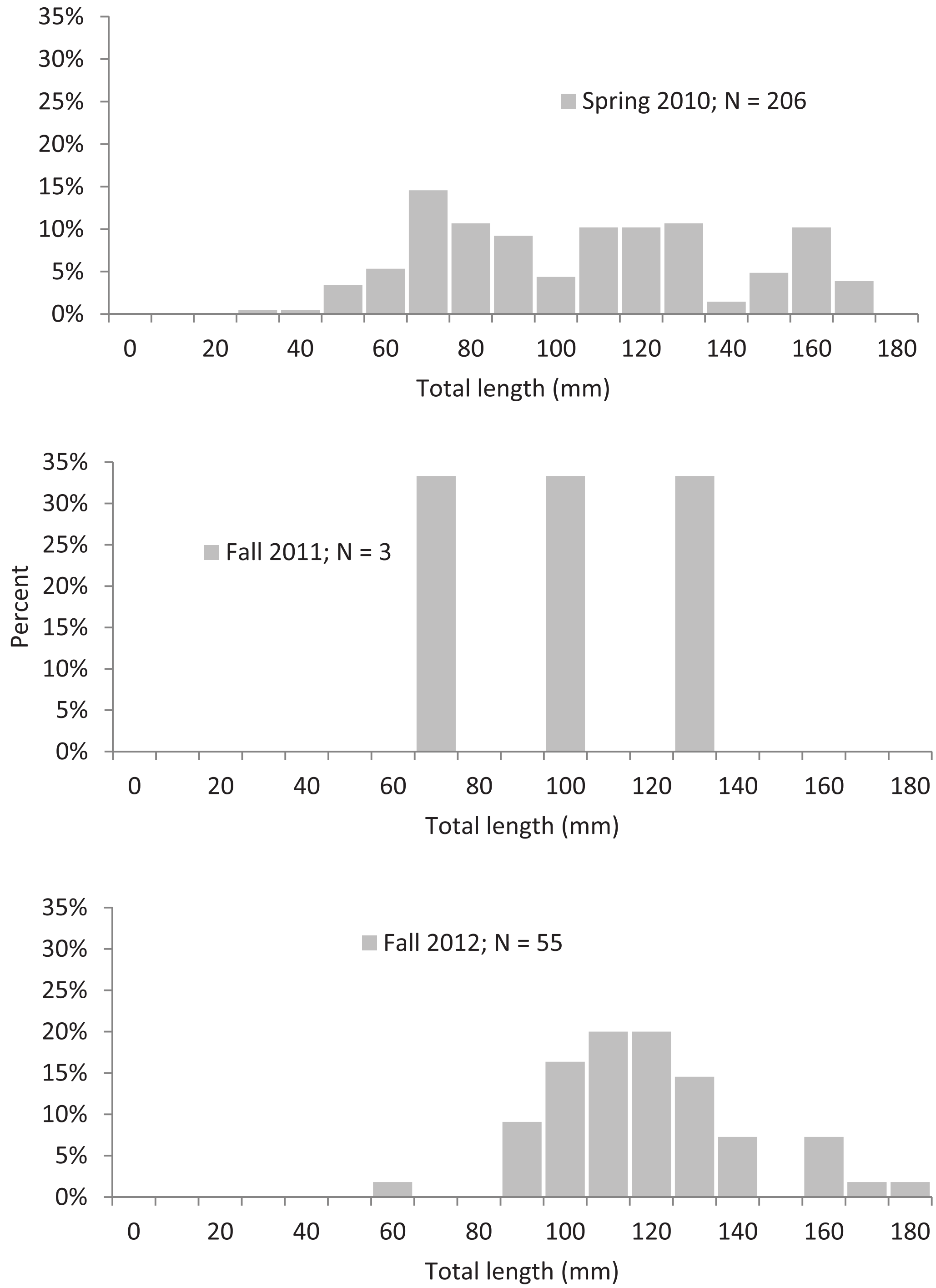


FIGURE 16.—Length-frequency distribution of Pumpkinseed collected by electrofishing before (top chart, 2010), immediately after (middle chart, 2011), and one year after (bottom chart, 2012) Hurricane Irene on the Trent River.