CONTRIBUTION OF STOCKED LARGEMOUTH BASS FOLLOWING HURRICANE-INDUCED FISH KILLS IN TWO NORTH CAROLINA COASTAL RIVERS

FINAL REPORT

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SPORT FISH RESTORATION

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Abstract — Widespread fish kills occurred in North Carolina's coastal rivers following Hurricane Isabel in September 2003. An experimental, multi-phase largemouth bass stocking effort was launched in 2004 to determine whether localized population recovery could be achieved. Largemouth bass stockings included the release of 12,000 age-1 (mean TL = 167 mm) pellet-reared largemouth bass in February, 46,000 age-0 fingerling (mean TL = 44 mm) largemouth bass in June, and 8,000 age-0 advanced fingerlings (mean TL = 116 mm) in September. All fish were injected with magnetic wire tags, held in numbered batches, and scattered within 28 separate 1-km shoreline reaches in the Roanoke and Chowan rivers. Recapture electrofishing was conducted seasonally during spring and fall months of 2004–2007. Results indicated that stocking age-0 fingerling largemouth bass had no detectable effects. Similarly, the age-0 advanced fingerlings provided no significant contribution. Although we recovered 190 largemouth bass initially stocked at age 1, their relative abundance diminished with each recapture event. Recapture:capture ratios of largemouth bass stocked at age 1 were initially high (0.43 in the Chowan River and 0.14 in the Roanoke River), declined to 0.05 and 0.06 in the spring of 2005, and were <0.01 in 2006. Largemouth bass stocked at age 1 were often recaptured several km from their original stocking site, and harvest by anglers was observed as the tagged largemouth bass recruited to the fishery (356-mm length limit). However, supplemental stockings regardless of size were ultimately not necessary as we observed three successive strong year classes of native largemouth bass, and consistent increases in catch rates of native adult (> 200 mm) largemouth bass from both river systems.

As many hurricanes have made landfall in North Carolina during the past decade (1996–2006; N = 8) as have occurred over the 35-year period from 1961 to 1995 (Bales et al. 2000; Blake et al. 2007). Remnants of 13 other tropical cyclones have followed various tracks across the coastal region since 1996. This upswing in cyclonic frequency has had measurable impacts on fish community structure as fishes are often stressed, displaced, or killed following these events. Storm passage generally leads to inundation of forested wetlands and subsequent drainage (Bales and Walters 2004). Rapid flushing of hypoxic water and organic solids from backwater habitats into tributaries and rivers as the storm abates results in an increase in biological oxygen demand and a subsequent decrease in dissolved oxygen. This situation occurred in coastal North Carolina following Hurricane Isabel, which made landfall near Drum Inlet on 18 September 2003 before tracking across the northeastern part of the state. Hurricane Isabel made landfall as a Category-2 hurricane, and was considered one of the most significant tropical cyclones to affect portions of northeastern North Carolina since 1954 (Beven and Cobb 2004). Portions of several river basins experienced anoxic conditions following the storm, with fixed U.S. Geological Survey (USGS) gaging stations documenting oxygen diminution in the lower Roanoke River (Figures 1 and 2). Dissolved oxygen levels of 0.0 mg/L in the Roanoke River for approximately nine days resulted in over 30 km of extensive fish kills.

Following the 2003 fish kills in eastern North Carolina, angling groups offered time and financial resources to stock largemouth bass *Micropterus salmoides* and other sportfish (bluegill *Lepomis macrochirus* and channel catfish *Ictalurus punctatus*) to accelerate population recovery. Previous fish kill replacement procedures of the North Carolina Wildlife Resources Commission (NCWRC) generally involved stocking largemouth bass fingerlings (25–51 mm TL) raised from native brood fish. The fingerlings were typically stocked the summer following the kill events, and were afforded little, if any, formal evaluation for effectiveness. One exception was a study conducted by the NCWRC (unpublished data) from 2001–2003 on four coastal river systems that concluded that age-0 largemouth bass fingerlings stocked in June along shoreline areas at a rate of 1,000 largemouth bass/km made no significant contribution to existing populations.

Supplemental stockings of largemouth bass have been evaluated in a variety of lentic environments and their merits identified (Boxrucker 1986; Copeland and Noble 1994; Buynak and Mitchell 1999; Buckmeier and Betsill 2002; Heidinger and Brooks 2002; Hoxmeier and Wahl 2002; Buckmeier et al. 2003; Hoffman and Bettoli 2005). As Heitman et al. (2006) concluded, results of these studies are mixed, and little information is available regarding the stocking of largemouth bass in riverine systems. Information on natural recovery in terms of abundance and size structure of largemouth bass populations following hurricane-induced fish kills and displacement is also limited. The frequent perception of anglers, as well as biologists, is that stocking is needed following severe fish kills to promote recovery. However, for agencies to efficiently use their resources, the impacts of these storms on fish communities and the effectiveness of supplemental stockings need to be understood.

This project was undertaken to develop appropriate management strategies for largemouth bass enhancement following cyclonic events. Specific project objectives were to (1) determine the localized contribution of fingerlings (age-0, mean TL = 44 mm), advanced fingerlings (age-0, mean TL = 116 mm), and age-1 pellet-reared largemouth bass (mean TL = 167) stocked into two adjacent coastal river basins, and (2) monitor the natural recovery of largemouth bass populations in these rivers over a four-year period.

Methods

Study Area.—Stocking and recapture sampling was conducted in the Roanoke and Chowan rivers located in the Coastal Plain of northeastern North Carolina. Both rivers originate in Virginia before emptying into the western end of Albemarle Sound. The Roanoke River basin, with a drainage area of almost 16,000 km^2, contains numerous dams and reservoirs with three major impoundments located on the mainstem near the Virginia and North Carolina border. Variations in flow from these three reservoirs (Kerr, Gaston and Roanoke Rapids) influence the quality and quantity of water in the lower 200 km of Roanoke River. Low drainage density (defined as a small number of streams draining a large area of land) coupled with low base flows during the summer limits the ability of the system to maintain high dissolved oxygen levels. The floodplain in the lower Roanoke River is expansive, containing one of the least-impacted forested wetland communities in the southeastern United States (NCDWQ 2001).

Similarly, the Chowan River basin contains extensive areas of hardwood swamp forests with over 87% of the land cover in the basin dominated by forest and agriculture. The Blackwater and Nottoway rivers join at the Virginia and North Carolina border to form the Chowan River, which has a drainage area of almost 8,000 km^2 (NCDWQ 1997). Several major tributaries including the Meherrin River, Wiccacon River and Bennetts Creek are located in the study area. Dissolved oxygen levels are naturally low in the basin, with late summer daytime readings commonly near 3–4 mg/L. Localized fish kills have been common in the Chowan River basin in the late summer following the heavy winds and inundating rains associated with tropical systems; fish kills due to hypoxia were documented in the basin in the summers of 1996 and 1998 with more substantial die-offs observed following the passage of Hurricane Floyd in 1999 and Hurricane Isabel in 2003.

Sport fisheries in both river systems are abundant and diverse, supporting quality angling for largemouth bass and migratory species such as striped bass *Morone saxatilis* and hickory shad *Alosa mediocris*. While other anadromous fishes are present (American shad *A. sapadissima*, alewife *A. pseudoharengus* and blueback herring *A. aestivalis*), their populations are currently diminished and restoration efforts are underway. Substantial recreational angling effort for white perch *Morone Americana*, sunfish (primarily bluegill and redear sunfish *L. microlophus*), black crappie *Pomoxis nigromaculatus*, and catfish (white catfish *Ameiurus catus* and channel catfish) was observed during recent creel surveys on the Chowan River in 2002 (Dockendorf et al. 2004) and the Roanoke River in 2006 (McCargo et al. 2007). Anglers targeted largemouth bass on 44% of all fishing trips to the Chowan River from 1 July 2001 through 30 June 2002 (82,000 angler-hours). Catch of largemouth bass during this period was estimated at 46,955 largemouth bass (SE = 6,265) with over 73% of these fish released (Dockendorf et al. 2004). Reported angling effort over a 12-month period was lower in the Roanoke River (56,000 angler-hours) yet largemouth bass catch was higher (65,301 largemouth bass; SE = 13,375) and the harvest rate was only 1.8%. Directed effort for largemouth bass observed during the 2006 creel survey on the Roanoke River was thought to be an underestimate as methodologies during April and May were biased toward the collection of recreational harvest statistics for striped bass (McCargo et al. 2007). Largemouth bass regulations in both systems include a 356-mm (14-in) length limit and a daily creel limit of five fish.

Stocking.— Three separate largemouth bass stocking trials were conducted during 2004. Trial 1 involved stocking 12,000 age-1 (mean TL = 167 mm) largemouth bass into the Roanoke and Chowan rivers in February. These fish were cultured in Illinois in June 2003, then shipped and raised on pelletized feed at an aquaculture facility near South Mills, North Carolina. NCWRC purchased these northern strain largemouth bass from the facility at a cost of US$2 each and the fish were delivered to the Edenton National Fish Hatchery for tagging on 9 February 2004. Each largemouth bass was anesthetized and implanted in the right cheek musculature with a 1.1-mm magnetic, wire tag via a Mark IV© injector (Northwest Marine Technologies). In each river, six 1-km shoreline study sites were delineated prior to stocking, and a numbered batch of tagged largemouth bass was transported via boat to each site and distributed throughout the study reach. The stocking rates for each Trial-1 site were selected randomly as either 500 or 1,500 largemouth bass/km.

For Trial-2 stockings in June 2004, age-0 largemouth bass were cultured from native brood fish collected from several reservoirs in the Piedmont region of North Carolina. The brood fish (assumed to be intergrades between northern and Florida strains) were transported to the NCWRC Watha State Fish Hatchery in March 2004 and placed into rearing ponds. Once fingerlings reached a mean total length of 44 mm, they were seined from hatchery ponds and transported to on-site raceways. After a settling period of 6–24 h, all fish (N = 46,000) were implanted with 0.5-mm magnetic wire tags in the right cheek musculature using methods as described above. Tagged bass were held overnight, any mortalities were counted and replaced, and fish were transported in numbered batches to boating access areas on the Roanoke and Chowan rivers. Largemouth bass were then distributed via boat into four 1-km study areas within each river. Stocking rates for Trial-2 stockings were randomly selected as either 1,500 or 10,000 largemouth bass/km. This higher rate was selected based on recommendations in Buckmeier et al. (2003) where stocking rates of 10,000 bass released at a central location within a 2-km site represented a successful, cost-effective strategy for influencing genetic composition in Toledo Bend Reservoir.

Approximately 20,000 surplus fingerlings (range 31–72 mm) were retained at the Watha State Fish Hatchery in June 2004, and fed live fish forage through the summer. By September 2004, 8,000 age-0 advanced fingerlings (mean TL = 116 mm; range 67–187 mm) were available for the third stocking trial (Trial 3). All fish stocked during Trial 3 were implanted with 1.1-mm magnetic wire tags in the left cheek. In each river system, four 1-km sites received age-0 advanced fingerlings via boat stocking at a randomly-selected rate of either 500 or 1,500 largemouth bass/km.

A subsample of tagged largemouth bass from each of the three stocking trials was evaluated for 24-h tag retention and mean total length was calculated. After the stockings for all three trials were completed, the Chowan River (Figure 3) and the Roanoke River (Figure 4) each contained 14 discrete stocking sites. The sites were located within mainstem and tributary locations of varying habitat types and separated by a minimum of 2 km.

Recapture.— Boat-mounted electrofishing gear (Smith-Root 7.5 GPP; 1000 V, 2–4 A) was operated to collect tagged and native largemouth bass during the study. Each recapture site was defined as a 2-km unit which consisted of the 1-km section of stocked shoreline and a parallel 1-km transect of shoreline directly across the river or tributary. Average stream width was variable and ranged from 50 m to approximately 1 km. Recapture sampling began in April 2004 and continued each spring and fall through May 2007 for a total of seven seasonal sampling periods. Frequency of seasonal sampling events for each stocking trial was variable depending upon the timing of stocking (Trial 1, N = 7; Trial 2, N = 5; and Trial 3, N = 4). Trial 2 and Trial 3 locations were not sampled in 2007 as preliminary results indicated low probability of recapture. Shoreline areas adjacent to Trial-1 sites were sampled during the spring and fall of 2004 to document emigration. All largemouth bass collected from each site were measured for total length (TL mm) and weight (g) and scanned with a hand-held detector for the presence of a magnetic wire tag. The original stocking trial (1, 2 or 3) for each fish was also noted; differences in cheek tag location coupled with mean length at stocking data allowed for effective partitioning of fish between the three separate stocking trials throughout the study period. Morphological differences (primarily body color) between the Trial-1 largemouth bass and all other largemouth bass assisted with this distinction. Fish were released along the shoreline in the middle of each transect after processing.

During fall 2005 and spring 2006, largemouth bass collected by anglers during six organized tournaments were scanned for the presence of a magnetic cheek tag. Total length was recorded for each tagged largemouth bass, and the percent contribution of tagged largemouth bass from each tournament was calculated.

Analytical Procedures.— The ratio of recaptured tagged largemouth bass to the total number of largemouth bass captured (native largemouth bass plus tagged largemouth bass) was calculated for each stocking trial over time to evaluate the contribution of stocked largemouth bass to the localized population (Copeland and Noble 1994). If tagged fish were recovered, then Poisson confidence intervals for Λ were constructed where Λ is the mean number of tagged fish caught per 2-km recapture site. In addition to a comparison of abundance between tagged and native largemouth bass of all sizes, the data were sorted by length group (<200, 200–299, 300–355 and >355 mm) to observe the growth and movement of tagged fish within the population over time. This same analysis was implemented to quantify the recovery of native largemouth bass. To determine the effect of stocking rate (500 tagged largemouth bass per site vs. 1,500 tagged largemouth bass per site) on the abundance of Trial-1 largemouth bass, Poisson confidence intervals for Λ were compared within each river. Mean relative weights (W_r) of similar sized Trial-1 largemouth bass and native largemouth bass from fall 2004 and spring 2005 samples from the Chowan and Roanoke rivers were compared using Student's *t*-tests assuming unequal variances with significance declared at $P < 0.05$ (Zar 1999).

One-way analysis of variance (ANOVA) was calculated to determine differences in mean abundance of native largemouth bass greater than or equal to stock size (200 mm) per 2-km site by seasonal sampling period for each river. Because the variance was proportional to the mean, a square root transformation was applied to the data prior to analysis. Fisher's Least-Significant-Difference test was used to determine which years differed within each river system. Statistical tests were declared significant when P-values were ≤0.05. A comparison of trends in native largemouth bass abundance from 2004–2007 with historical NCWRC survey data was performed by plotting CPUE as a measure of the number of adult largemouth bass (>200 mm) captured per hour spent electrofishing.

Results

Trial 1 recapture sampling

During the study period, 120 Trial-1 largemouth bass (initially stocked at age 1 with mean TL = 167 mm) were recovered from the Chowan River; 92 within their original release sites and 28 from other locations. Tag loss was not a likely contributor to the low returns given the high tag retention rates observed (Table 1). In addition, differences in appearance (body coloration primarily) between stocked Trial-1 largemouth bass and native fish throughout the study period were distinct, to the point that successful individual identifications could frequently be made prior to scanning for a wire tag. On the Roanoke River, 70 tagged Trial-1 largemouth bass were captured with 47 of those fish collected within the defined 2-km study sites. Recapture:capture (R:C) ratios for Trial-1 largemouth bass were highest for both rivers during the first sampling period approximately six weeks post-stocking (Table 2). The R:C ratio for the Chowan River during the first recapture event (spring 2004) was the highest observed during the study (0.432) before declining markedly by spring 2005. A similar trend was noted in the Roanoke River as R:C ratios decreased after the initial recapture sample. By the fall of 2005 and continuing through 2007, R:C values for tagged Trial-1 largemouth bass in both the Chowan and Roanoke rivers remained < 0.01.

Analysis of mean CPUE of tagged Trial-1 largemouth bass exhibited a similar pattern (Figure 5). Initial CPUE in the Chowan River was 11.7 tagged largemouth bass/site (9.1–14.7 Poisson 95% CIs) before declining to less than 2.0 by fall 2004. Spring 2004 CPUE of Trial-1 largemouth bass was lower in the Roanoke River ($\Lambda = 3.2$; 1.9–4.9 Poisson 95% CIs). Mean CPUE values for the Chowan and Roanoke rivers decreased to near 0.0 tagged largemouth bass per 2-km study site by fall 2005, with Poisson confidence intervals including 0.0 throughout 2006 and 2007. Recovery of Trial-1 largemouth bass was influenced significantly by stocking rate. Mean CPUE for the entire sampling period from sites stocked with 1,500 Trial-1 largemouth bass/km was higher in both river systems than those observed at the lower stocking rate (Figure 6).

Because fish were marked with batch tags, original stocking locations could not be determined for individual largemouth bass recovered outside of a site. However, analysis of Trial-1 relocations suggested movement of at least 4 km from sites within both rivers (Figures 7 and 8). In the Chowan River, several Trial-1 largemouth bass were recaptured in Trial-2 and Trial-3 sites with the closest release point 4 km away in one instance (Figure 7). Similarly, in the lower Roanoke River Trial-1 largemouth bass were recaptured consistently in a Trial-2 site located 4 km upstream of their original stocking location (Figure 8). The highest numbers of relocated Trial-1 largemouth bass were collected adjacent to or in proximity to sites stocked at the higher rate with no apparent trend in emigration direction (upstream vs. downstream) noted.

Over 71% of all largemouth bass <200 mm collected in spring 2004 recapture samples in the Chowan River were tagged Trial-1 fish (Figure 9). Although tagged largemouth bass were found in the 200–299 and 300–355 mm size groups in the fall of 2004 and again in the 300–355 mm group during spring of 2005, contribution by size group declined progressively as seasonal sampling continued. A similar pattern was observed in the Roanoke River as tagged largemouth bass moved into the 200–299 and 300–355 mm size groups through the spring of 2005 before their contribution became indiscernible within the size distribution series (Figure 10). The initial contribution of tagged largemouth bass to the <200 mm size group in the Roanoke River was much lower than in the Chowan River at only 17%; CPUE of native largemouth bass at this size group was 12.8 largemouth bass/2 km (SE = 5.1).

The growth increment between spring and fall recapture periods in 2004 suggested age-1 growth was approximately 38 mm faster for tagged largemouth bass in the Chowan River than from the Roanoke River (Table 3). This trend did not persist as mean length at capture for both river systems was similar (304 and 310 mm) by the third sampling period (spring 2005, age-2 largemouth bass). Six age-3 largemouth bass and two age-4 largemouth bass from the initial Trial-1 stockings were eventually recovered in our samples. Tagged Trial-1 largemouth bass first reached harvestable size (>355 mm) at age 2 in both systems by the fall of 2005. The maximum size Trial-1 largemouth bass recaptured during electrofishing sampling was 418 mm (age 3) and was collected from the Chowan River.

Body condition of Trial-1 largemouth bass was good as evidenced by W_r values ≥ 92 for both systems during the fall of 2004 and spring of 2005 (Table 4). Mean W_r values between Trial-1 largemouth bass and native largemouth bass of similar length did not differ significantly with the exception of the spring 2005 sample for the Roanoke River (stocked mean $W_r = 92$, native mean $W_r = 100$; $P < 0.001$).

To evaluate recruitment to the recreational fishery, 247 largemouth bass weighed-in at six largemouth bass tournaments were scanned for the presence of magnetic tags with 19 Trial-1 tagged largemouth bass (7.7%) identified (Table 5). Unadjusted return rates varied from 0 to 14.3% with the largest fish recovered measuring 420 mm from a spring tournament held on the Chowan River in March 2006.

Trial 2 and Trial 3 recapture sampling

Few tagged largemouth bass were recovered from Trial-2 (N = 7) and Trial-3 (N = 9) stockings regardless of stocking rate or location. Only two tagged largemouth bass from the original Trial-2 fingerling stockings were recovered on the Chowan River, with one of those fish (73 mm) collected 3 km from the nearest Trial-2 site. Results were similar on the Roanoke River as only five Trial-2 largemouth bass were recaptured. R:C ratios for Trial-2 largemouth bass were highest on the Roanoke during spring 2005 (0.031) but were 0.0 for seven of the ten seasonal recapture events (Table 6). The three largemouth bass recovered during the spring 2005 sample on the Roanoke River were all from one site stocked at the 10,000 largemouth bass/km rate, with total length ranging from 114–143 mm. In the fall of 2004, a Trial-2 largemouth bass (108 mm) was collected 3 km down river of this same site. No largemouth bass from the Trial-2 stockings were found after the fall 2005 sampling period; maximum length during fall 2005 was 257 mm in the Chowan River and 247 mm in the Roanoke River.

The advanced age-0 fingerlings stocked during Trial 3 were also rare in our collections, with only five fish recovered in the Chowan River and four fish found in the Roanoke River. R:C ratios within the Trial-3 sites remained ≤ 0.010 between spring 2005 and fall 2006 (Table 7). In the Chowan River, three of the five Trial-3 largemouth bass recaptured were collected outside of their original stocking sites. In fall 2004, one largemouth bass (147 mm) was collected within a tributary approximately 7 km down river from the nearest Trial-3 release point. Another fish (282 mm) apparently from this same original stocking site was found in a different tributary 4 km downstream and across the river. Maximum sizes of Trial-3 largemouth bass recaptured within Chowan River sites included a 345 mm fish in fall 2005, and a 365 mm specimen in fall 2006. A 272 mm largemouth bass collected during fall 2006 from the Roanoke River represented the largest Trial-3 fish recaptured from this system. No Trial-2 or Trial-3 fish were recovered from largemouth bass tournaments.

Abundance and recovery of native largemouth bass

As the ratios and catch rates of tagged largemouth bass decreased over time, abundance of native largemouth bass from both river systems improved markedly. ANOVA comparisons of native adult ($\geq$200 mm) abundance from spring and fall sampling periods indicated significant improvements on the Chowan River (Table 8). Mean CPUE of native Chowan River largemouth bass was 10.8 largemouth bass/2 km during spring 2004 and peaked at 34.7 largemouth bass/2 km during spring 2006. Similar increases in annual spring abundance estimates were observed on the Roanoke River through 2006, although CPUE estimates were not significantly different ($P = 0.105$; Table 8). Spring 2007 CPUE values for both rivers were lower than the peak observed in

2006. A noticeable exception to increasing CPUE values over time was observed during fall collections on the Roanoke River. Initial fall 2004 abundance values for largemouth bass on the Roanoke River were highest, with fall CPUE values ranging from 20.8 to 25.0 between 2004 and 2006 (ANOVA, $F = 0.09$, $P = 0.920$).

Mean CPUE by size class indicated native adult largemouth bass were present in both rivers, albeit at low levels, during the first spring recapture period (Figures 9 & 10). Fall size distributions indicated relatively strong numbers of native young-of-year largemouth bass, especially in 2004. During the 2006 and 2007 spring sampling periods, the pattern of mean CPUE by size class was similar among and within river systems, with the peak in abundance represented by the 200–299 mm size group.

Analysis of CPUE as defined as number of largemouth bass ≥200 mm per hour spent electrofishing confirmed native abundance had recovered by the spring of 2006 to levels observed during routine NCWRC surveys in both the Chowan and Roanoke rivers prior to Hurricane Isabel (Figure 11). Lowest spring CPUE values (approximately 4–6 largemouth bass/h) occurred in 2004 before returning to approximately 25 largemouth bass/h two years later.

Discussion

The apparent absence of tagged age-0 fingerlings (mean TL = 44 mm) and advanced age-0 fingerlings (mean TL = 116 mm) from our largemouth bass recapture sampling regardless of river, site location or stocking rate suggests no value in their use as a recovery strategy following fish kill events in the Coastal Plain of North Carolina. Mechanisms responsible for poor survival of stocked age-0 fingerlings and advanced fingerlings in the Roanoke and Chowan rivers were not formally evaluated. However, a combination of possible factors including predation, inadequate forage and competitive interactions are well documented in the existing literature (Wahl et. al. 1995; Hoxmeier and Wahl 2002). Post-hurricane electrofishing in fall 2003 of the fish community from two sites in the lower Roanoke River revealed native adult largemouth bass were absent or represented by only one individual; species composition decreased by 55% (18 of 33 species absent) and 52% (12 of 23 species absent) from sample locations and consisted primarily of minnows and emigrating alosines (McCargo et al. 2008). Our assumption that the disequilibrium in fish community structure and associated decline in predator abundance would have increased the probability of stocked age-0 largemouth bass survival especially at an advanced size, was apparently incorrect. Despite widespread anoxic conditions observed six months earlier in both systems due to Hurricane Isabel, native juvenile and adult largemouth bass were present during each recapture event with abundances increasing over time.

Predation during the nearly four-month period between stocking and the first recapture event would offer the most likely explanation for the lack of age-0 stocking success. Buckmeier and Betsill (2002) found that dispersal of stocked largemouth bass fingerlings in a Texas reservoir stabilized within one month of stocking, but found that few stocked fish remained 150 days post stocking. Disorientation of stocked largemouth bass after release may limit their ability to avoid predation (Hoffman and Bettoli 2005) even if stocked fish are scattered along high-quality shoreline habitats. In June 2003, the NCWRC conducted a pilot study assessing short-term predation on fingerlings (approximately 51 mm TL) stocked with magnetic cheek tags at a rate of 1,000 largemouth bass/km from two sites on the Perquimans River. Electrofishing conducted less than 24 h after release found only four tagged largemouth bass within the shoreline sites, with four more found in the stomachs of two largemouth bass (mean TL = 232 mm) and a warmouth (176 mm). A more comprehensive study conducted on four Illinois lakes found that the proportion of adult largemouth bass that had consumed stocked largemouth bass averaged 10% across all stockings, and was as high as 26% for one lake (Hoxmeier and Wahl 2002). Similarly, predation was cited as the most important factor contributing to survival of age-0 largemouth bass stocked in Chickamauga Lake, TN (Hoffman and Bettoli 2005).

In contrast to age-0 fingerling and advanced fingerling stockings, age-1 largemouth bass stocked during Trial 1 contributed noticeably to localized populations through the third sampling period, more than one year after stocking. Higher survival of larger stocked fish was expected, and has been attributed in other systems to lower vulnerability to predation and higher forage availability than fingerlings (Wahl et al. 1995; Porak et al. 2002). The R:C ratios of tagged Trial-1 largemouth bass declined noticeably after the first period, suggesting emigration from our sites may have occurred. Percent composition of tagged age-1 largemouth bass in the first recapture period (spring 2004) was likely biased in both systems as native largemouth bass densities were low following the fish kills. Hoxmeier and Wahl (2002) reported that survival rates of largemouth bass stocked in lakes would be higher in systems with low densities of native largemouth bass, and cautioned against using percent contribution to define stocking success. The authors applied relative abundance estimates to conclude that recruitment of native largemouth bass had no influence on survival of stocked fish. Mean CPUE of tagged largemouth bass <200 mm in the Chowan River during spring 2004 was as high or higher than any estimate of spring abundance of native largemouth bass for that size group. After the first sampling period, CPUE of tagged largemouth bass remained approximately 2 largemouth bass/2 km (or nearly 1 largemouth bass/h) through the spring of 2005 in both systems suggesting consistent contribution, albeit low, following initial dispersal. Although emigration was the most likely cause for declining numbers of largemouth bass stocked at age-1, differential predation avoidance between stocked, northern-strain largemouth bass and native fish was not investigated and may have contributed to their absence.

Dispersal was directly observed as evidenced by the number of tagged fish found outside defined Trial-1 stocking sites in spring 2004. The majority of these movements were linear with fish found within 500 m on either side of the original stocking site. However, beginning with the first recapture period, age-1 tagged fish were also found directly across from stocked shorelines at distances exceeding 1 km. For this reason, the decision was made to expand the recapture sites to include largemouth bass collected across the river or tributary and parallel to the original 1 km stocked shoreline. Movement of age-1 tagged largemouth bass across wide, open water sections may have been a function of rearing to an advanced size in a pond environment devoid of structure. Possible adaptive mechanisms favoring competition in hatchery ponds may be disadvantageous in a riverine environment. For example, higher mobility, especially in open-water environments might increase predation risk and elevate mortality rates of stocked fish. Heidinger and Brooks (2002) noted stocked fish with no established home range may move more than native largemouth bass, especially if stocked in poor quality habitat or if forage is limited, and concluded that reduced contribution of stocked largemouth bass was a result of movement into areas not sampled. We noted movement of age-1 stocked largemouth bass of at least 4 km from their original stocking locations. For most of the seasonal recapture events, 28 km of shoreline habitats within each river were sampled by electrofishing; any movement outside of these sites would have been undetected. As fish reached harvestable size (356 mm; 14 inches) they were also subject to be moved by anglers as tournament activity increased steadily during the recapture period. Documentation of Trial-1 tagged fish captured by tournament anglers from both systems provided evidence of contribution to areas outside our sampling locations.

Associations between stocked and native largemouth bass in our study were confounded by the disequilibrium that existed within the native fish communities following the fish kills. Although interactions with native largemouth bass likely occurred with the age-1 stockings (Trial 1), tagged largemouth bass did not appear to displace native largemouth bass. Conversely, native largemouth bass abundance increased over time as a result of natural recovery. These findings were consistent with other authors who concluded that sub-adult largemouth bass stockings did not have a negative effect on native largemouth bass abundance (Buynak and Mitchell 1999; Heidinger and Brooks 2002). Minor differences in condition factors at selected size ranges between recovered non-native, northern strain largemouth bass stocked at age 1 and native largemouth bass suggests that these initially pellet-reared bass experienced no noticeable disadvantage in foraging behavior. While foraging efficiency, catchability, and condition discrepancies between pellet-reared largemouth bass and native fish have been noted in several recent studies (Porak e al. 2002; Hoffman and Bettoli 2005) we did not observe this situation on the Roanoke and Chowan rivers. During the initial spring 2004 recapture period, forage was noticeably low or absent from most of our recapture sites. Post-hurricane abundance of adult bluegill in the lower Roanoke was significantly lower during a survey of the fish community in fall 2004; however, age-0 bluegill abundance was relatively high (McCargo et al. 2008). Age-0 bluegill abundance correlated closely with survival of largemouth bass stocked in Illinois lakes (Hoxmeier and Wahl 2002), and would suggest that timing of release later in the year to allow for immigration of forage into affected sites may have improved initial growth and survival of age-1 tagged largemouth bass while promoting higher site fidelity. The timing of age-1 bass stockings (February) in the Roanoke and Chowan rivers was a function of their availability coupled with production constraints at state and commercial fish hatcheries.

Immigration of native largemouth bass into our recapture sites was consistent in both river systems throughout the study period. While densities of adult largemouth bass were low in spring 2004, they were still higher than we expected given the severity of the fish kills and extent of anoxic shoreline habitats following hurricane passage. Native adult largemouth bass, even though low in abundance, were able to effectively spawn during spring 2004 as evidenced by age-0 largemouth bass abundance in fall samples. In the absence of hypoxic conditions, this pattern of improvement continued and by 2006, culminated with spring catch rates of adult largemouth bass that were comparable to pre-hurricane electrofishing surveys. Diversity and abundance of resident fishes in the Roanoke River followed a similar pattern of recovery following the 2003 fish kills in this system (McCargo et al. 2008). A similar upturn in largemouth bass population abundance was observed in the Chowan River in the early 2000s as CPUE increased annually following widespread fish kills associated with Hurricane Floyd in 1999 (unpublished NCWRC survey data). Regardless of localized contribution by stocked age-1 largemouth bass, stockings of any size were ultimately unnecessary for population recovery in either river system. Although age distribution and size structure have not fully recovered, abundance of native largemouth bass populations in both systems had returned to pre-existing conditions within a three-year period.

Management Applications

The resiliency of coastal river largemouth bass populations documented in our study strongly suggests delaying supplemental stockings of fish at any size, regardless of the severity of fish kills, pending an evaluation of native resource recovery. Post-hurricane sampling that finds native spawning populations and evidence of fall age-0 recruitment would justify a "no stocking" policy pending further assessment. If spring adult densities and subsequent young-of-year recruitment are non-existent or severely reduced, then localized stocking of pellet-reared age-1 largemouth bass (TL range = 143–196 mm) may be justified. Stocking rates of 1,500 age-1 largemouth bass/km provided measurable results in our study and would be best utilized in discrete tributary habitats. Timing of age-1 stockings to coincide with improvement of the forage base may reduce largemouth bass movement and increase survival. Another recovery option would be to collect pre-spawn adults from healthy systems and transplant small concentrations into tributary habitats where population improvement continues to be impeded. This strategy would be supported by our findings of successful native spawning in spite of low adult densities coupled with the poor survival of stocked age-0 fingerlings. Further research on largemouth bass survival and movement in response to periodic episodes of hypoxia, as well as salinity intrusion, is warranted for understanding of mechanisms influencing coastal riverine largemouth bass populations.

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TABLE 1.—Mean total length (TL mm) and tag retention of a subsample of microtagged largemouth bass from three separate stocking trials conducted within the Roanoke and Chowan rivers during 2004. Standard deviations are in parentheses. Differences in stocking rate for Trial 3 in the Chowan River refer to sites stocked with either 500 or 1,500 largemouth bass per km.

Stocking Trial	River	Stocking Date	Stocking Rate	Mean TL	Range	Tag Retention
Trial 1	Both	25 Feb 2004	All	167.4 (12.2)	143–196	100%
Trial 2	Roanoke	17 Jun 2004	All	40.4 (5.9)	31–72	94%
Trial 2	Chowan	23 Jun 2004	All	48.6 (5.7)	37–62	99%
Trial 3	Roanoke	14 Sep 2004	All	92.2 (8.8)	68–118	100%
Trial 3	Chowan	15 Sep 2004	500	147.2 (20.7)	112–187	100%
Trial 3	Chowan	15 Sep 2004	1500	107.9 (23.6)	67–175	100%

TABLE 2.—Number of microtagged Trial-1 (age-1, mean TL at stocking = 167 mm) largemouth bass recaptured within and outside their stocking sites by sampling period from the Roanoke and Chowan rivers, 2004–2007. Number recaptured outside of sites included all tagged largemouth bass collected during sampling adjacent to Trial-1 sites and within Trial-2 and Trial-3 study sites. All electrofishing in spring 2007 occurred within Trial-1 sites only. A size breakdown of native (non-tagged) largemouth bass collected from Trial-1 sites is also provided. Recapture:capture (R:C) ratios are for directed sampling within Trial-1 sites.

Period	Number Recaptured Within Sites	Number Recaptured Outside of Sites	Native <200	Native ≥200	Native Total	R:C Ratio
			Chowan River			
Spring 2004	70	18	27	65	92	0.432
Fall 2004	8	5	204	43	247	0.031
Spring 2005	9	4	65	105	170	0.050
Fall 2005	1	0	116	83	199	0.005
Spring 2006	1	1	46	208	254	0.004
Fall 2006	1	0	77	146	223	0.004
Spring 2007	2	–	39	168	207	0.010
			Roanoke River			
Spring 2004	19	8	77	38	115	0.142
Fall 2004	11	8	150	150	300	0.035
Spring 2005	12	4	56	117	173	0.065
Fall 2005	3	2	89	125	214	0.014
Spring 2006	2	1	38	168	206	0.010
Fall 2006	0	0	127	139	266	0.000
Spring 2007	0	–	31	139	170	0.000

TABLE 3.— Mean total length (mm) by sampling period of tagged Trial-1 largemouth bass recaptured from all locations in the Chowan and Roanoke rivers, 2004–2007. Standard errors are in parentheses.

Period	Known Age	N	Mean TL (SE)	Range
Chowan River				
Spring 2004	1	86	172.8 (1.4)	142–204
Fall 2004	1	13	301.2 (5.4)	253–326
Spring 2005	2	13	309.5 (4.2)	281–338
Fall 2005	2	1	372	–
Spring 2006	3	2	316.5 (6.5)	310–323
Fall 2006	3	1	418	–
Spring 2007	4	2	366 (7.0)	359–373
Roanoke River				
Spring 2004	1	27	186.7 (2.9)	146–216
Fall 2004	1	19	277.6 (6.2)	230–318
Spring 2005	2	16	304.1 (3.8)	264–323
Fall 2005	2	5	348.4 (14.2)	298–380
Spring 2006	3	3	363.0 (21.0)	332–403
Fall 2006	3	–	–	–
Spring 2007	4	–	–	–

TABLE 4.— Comparison of mean W_r with standard deviations (SD) between tagged, Trial-1 largemouth bass and native largemouth bass from fall 2004 and spring 2005 sampling events on the Chowan and Roanoke rivers. Results of Student's *t*-tests assuming unequal variances with significance declared at $P < 0.05$.

Sampling events	Size range (TL mm)	Tagged			Native			
		N	W_r	SD	N	W_r	SD	*P*
Roanoke								
Fall 2004	230–318	19	94	8	86	94	8	0.479
Spring 2005	264–323	16	92	6	42	100	10	0.000
Chowan								
Fall 2004	253–326	13	95	6	16	89	14	0.063
Spring 2005	281–338	13	94	7	31	95	7	0.289

TABLE 5.— Number of tagged Trial-1 largemouth bass recovered during tournament weigh-ins conducted on the Roanoke and Chowan rivers from October 7, 2005 through April 15, 2006. Total length (TL mm) data is for tagged largemouth bass only. Legal harvestable size was 356 mm.

Date	Location	# Bass Caught	# Bass Scanned	# Bass Tagged	TL Min	TL Max
Oct 7, 2005	Albemarle Sound tributaries	138	44	5	356	413
Oct 8, 2005	Albemarle Sound tributaries	53	41	0	-	-
Oct 16, 2005	Roanoke River	14	14	2	369	380
Oct 22,2005	Chowan River	24	24	2	371	373
Oct 22, 2005	Chowan River	11	7	0	-	-
Oct 22, 2005	Chowan River	23	20	1	-	357
Mar 11, 2006	Chowan River	22	22	2	393	420
Apr 15, 2006	Roanoke River	75	75	7	359	386

TABLE 6.—Number of microtagged Trial-2 (age-0, initial mean TL = 49 mm for Chowan River and 40 mm for Roanoke River) largemouth bass recaptured within and outside their stocking sites by sampling period from the Roanoke and Chowan rivers, 2004–2007. Number recaptured outside of sites included all tagged Trial-2 largemouth bass collected from Trial-1 and Trial-3 study sites. A size breakdown of native (non-tagged) largemouth bass collected from Trial-2 sites is also provided. Recapture:capture (R:C) ratios are for directed sampling within Trial-2 sites only.

Period	Number Recaptured Within Sites	Number Recaptured Outside of Sites	Native <200	Native ≥200	Native Total	R:C Ratio
Chowan River						
Fall 2004	0	1	153	37	190	0.000
Spring 2005	0	0	52	68	120	0.000
Fall 2005	1	0	85	76	161	0.006
Spring 2006	0	0	38	134	172	0.000
Fall 2006	0	0	33	80	113	0.000
Roanoke River						
Fall 2004	0	1	60	27	87	0.000
Spring 2005	3	0	40	53	93	0.031
Fall 2005	1	0	50	79	129	0.008
Spring 2006	0	0	26	71	97	0.000
Fall 2006	0	0	77	79	156	0.000

TABLE 7.—Number of microtagged Trial-3 advanced fingerlings (age-0, initial mean TL at stocking = 116 mm) recaptured within and outside their stocking sites by sampling period from the Roanoke and Chowan rivers, 2004–2007. Number recaptured outside of sites included all tagged Trial-3 largemouth bass collected from Trial-1 and Trial-2 study sites. A size breakdown of native (non-tagged) largemouth bass collected from Trial-3 sites is also provided. Recapture:capture (R:C) ratios are for directed sampling within Trial-3 sites only.

Period	Number Recaptured Within Sites	Number Recaptured Outside of Sites	Native <200	Native $\geq$200	Native Total	R:C Ratio
Chowan River						
Fall 2004*	-	1	-	-	-	-
Spring 2005	0	0	34	57	91	0.000
Fall 2005	1	2	96	38	134	0.007
Spring 2006	0	0	14	73	87	0.000
Fall 2006	1	0	50	64	114	0.009
Roanoke River						
Spring 2005	0	0	44	91	135	0.000
Fall 2005	1	0	31	90	121	0.008
Spring 2006	1	0	20	94	114	0.009
Fall 2006	2	0	115	81	196	0.010

* No directed recapture sampling was conducted in Trial-3 sites during fall 2004.

TABLE 8.— Comparison of native adult largemouth bass abundance (mean number of largemouth bass ≥200 mm per 2-km study site) from spring and fall sampling periods on the Chowan and Roanoke rivers. Results of ANOVA test of the hypothesis that mean CPUE was the same among annual sampling periods. For periods where results of the ANOVA were significant ($P < 0.05$), means among sampling periods followed by a common letter are not significantly different (Fisher's Least-Significant-Difference test, $P < 0.05$).

Period	Mean CPUE	SE	*F*	*P*
		Chowan River		
Spring 2004	10.83 x	3.32	3.90	0.024
Spring 2005	17.50 xy	5.32		
Spring 2006	34.67 z	8.23		
Spring 2007	28.00 yz	5.39		
Fall 2004	7.17 x	1.62	15.64	0.000
Fall 2005	13.83 y	2.06		
Fall 2006	24.33 z	2.60		
		Roanoke River		
Spring 2004	6.33	3.57	2.33	0.105
Spring 2005	19.50	7.74		
Spring 2006	28.00	8.82		
Spring 2007	23.17	7.67		
Fall 2004	25.00	14.44	0.09	0.920
Fall 2005	20.83	4.30		
Fall 2006	23.17	4.66		

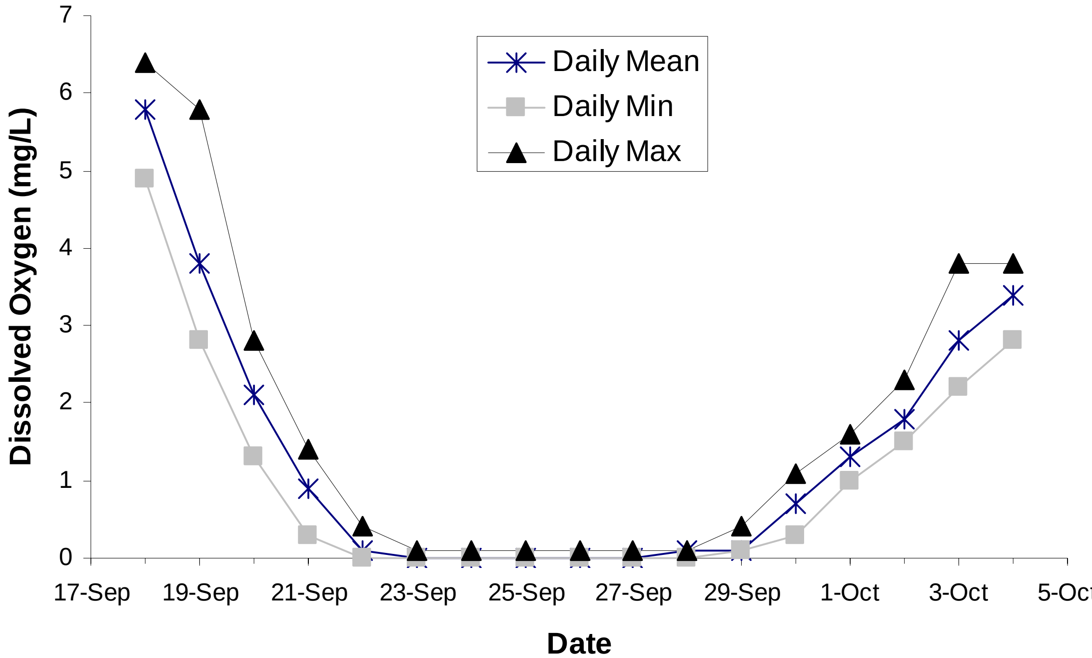

FIGURE 1.— Dissolved oxygen concentrations in the Roanoke River at Jamesville, September 18 – October 4, 2003. Data collected from USGS permanent gaging station with identification number 02081094.

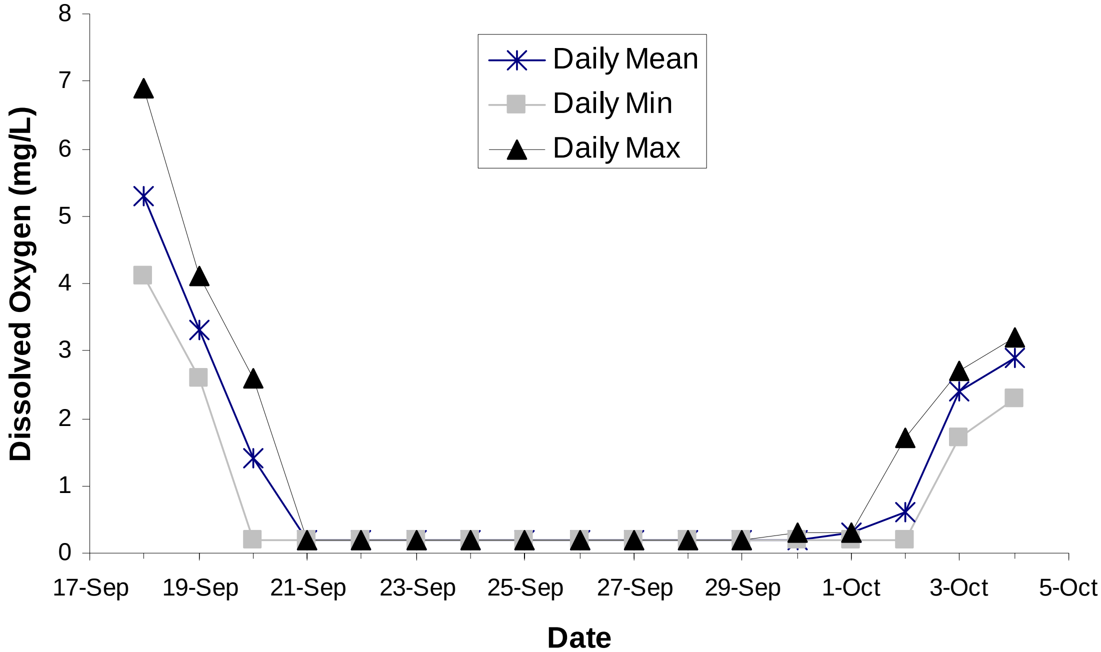

FIGURE 2.— Dissolved oxygen concentrations in the Roanoke River at Westover (NC 45 Bridge), September 18 – October 4, 2003. Data collected from USGS permanent gaging station with identification number 0208114150.

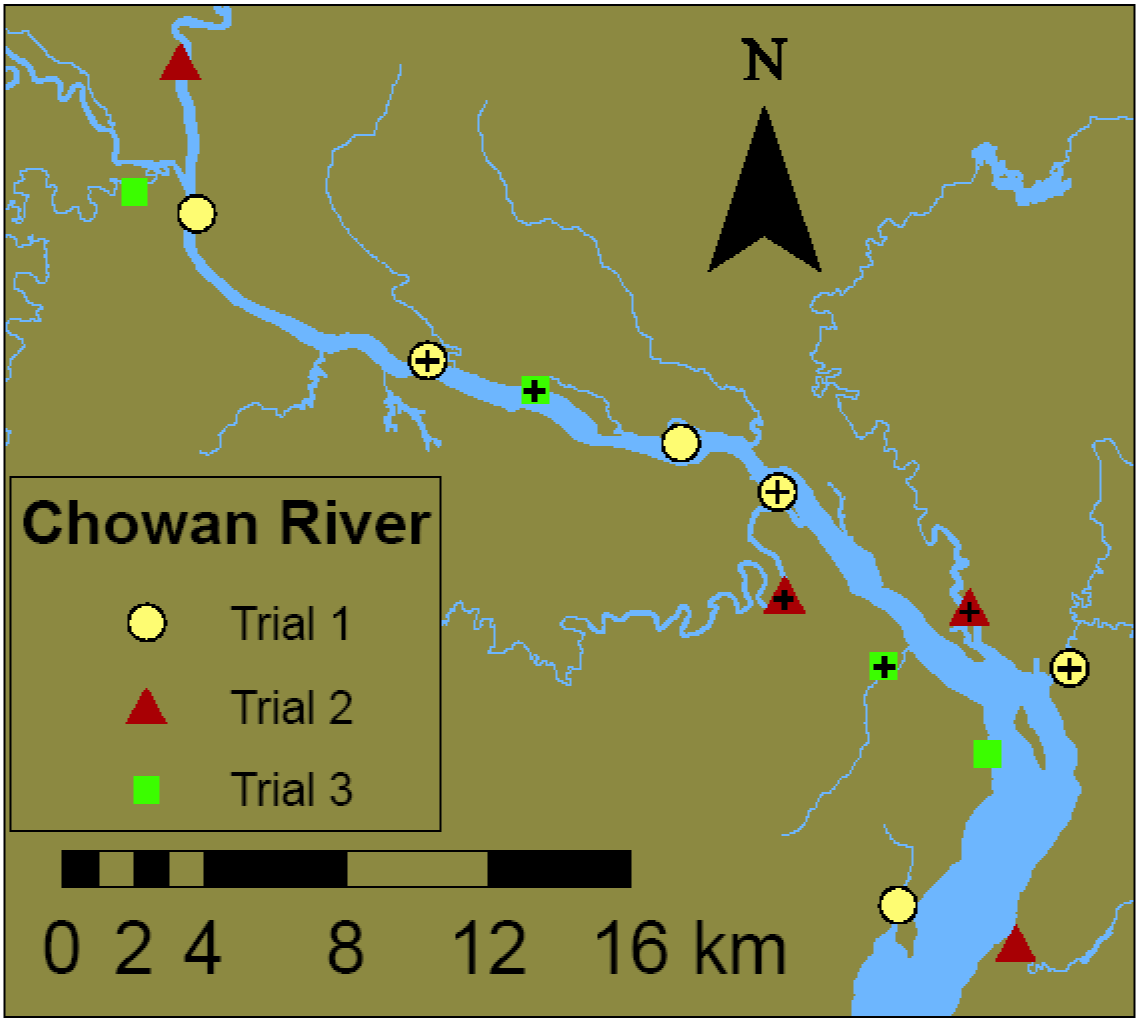

FIGURE 3.— Study locations on the Chowan River for stocking and recapture sampling conducted during an assessment of three separate stocking trials of largemouth bass from spring 2004 through spring 2007. The plus sign within selected symbols denotes the higher stocking rate.

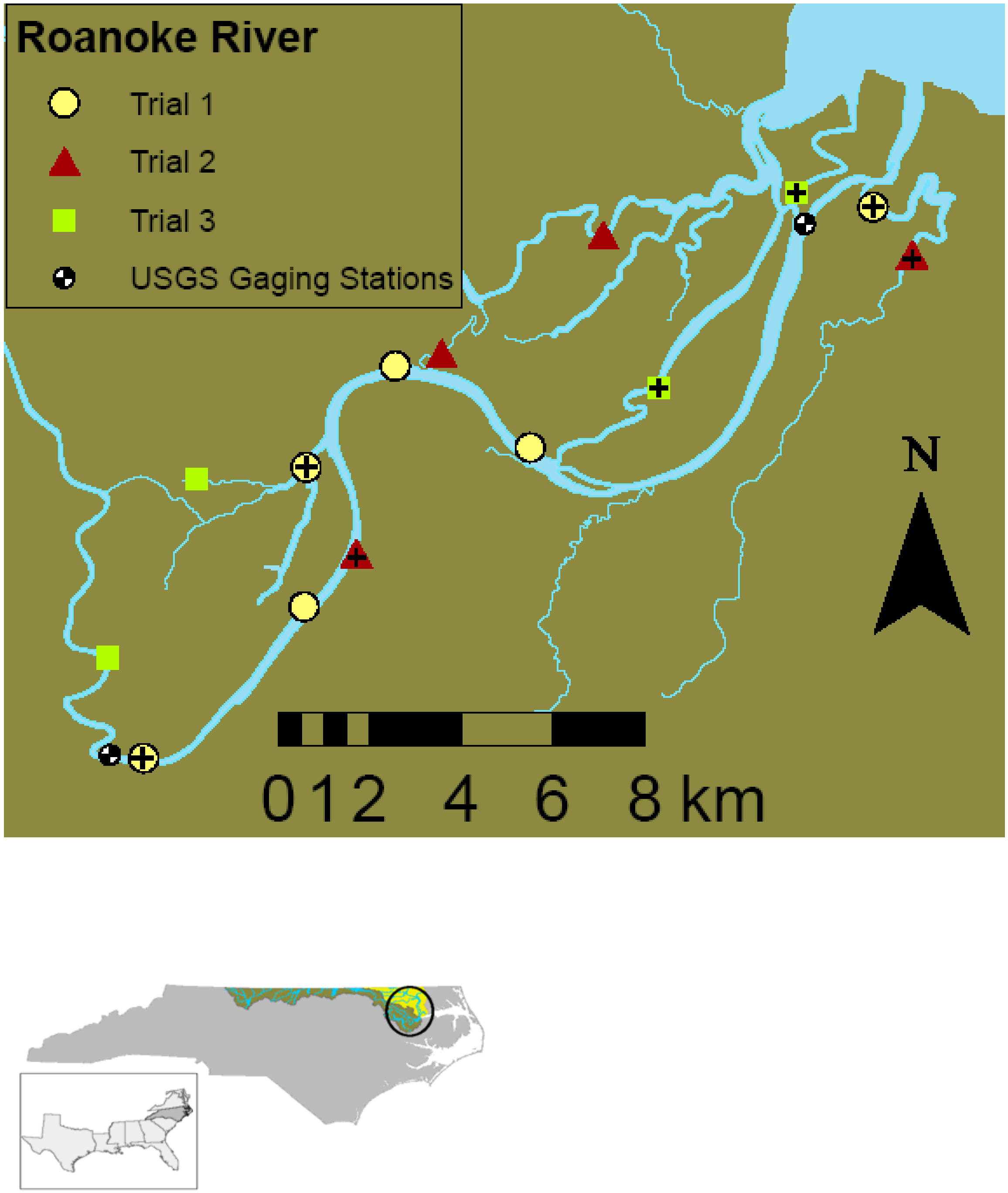

FIGURE 4.— Study locations on the Roanoke River for stocking and recapture sampling conducted during an assessment of three separate stocking trials of largemouth bass from spring 2004 through spring 2007. The plus sign within selected symbols denotes the higher stocking rate. USGS permanent gaging stations are also identified.

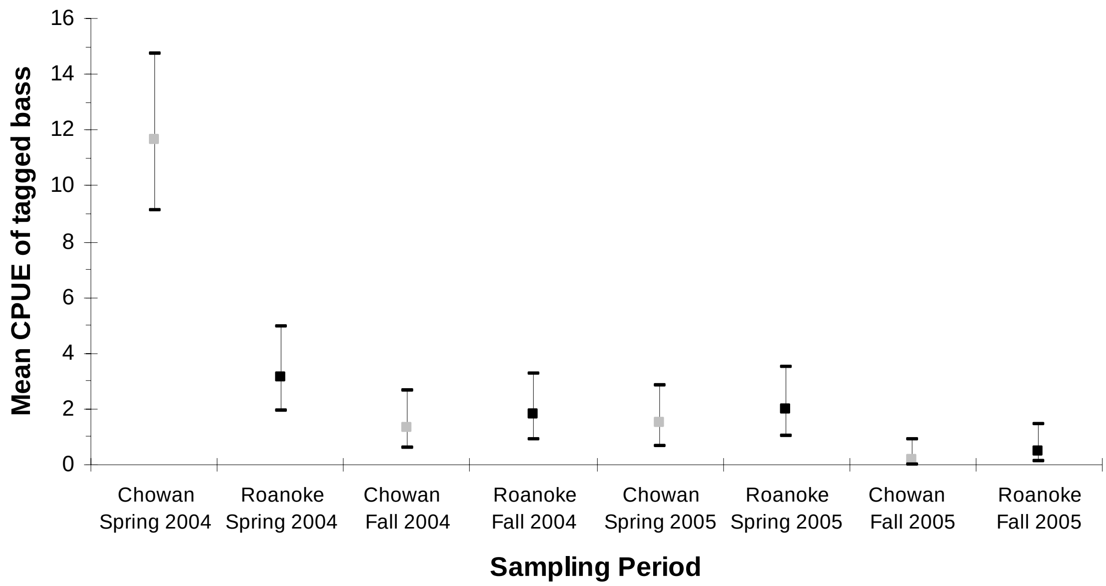

FIGURE 5.—Mean electrofishing CPUE (number of tagged largemouth bass per 2-km) of recaptured Trial-1 largemouth bass (stocked at age 1, mean TL = 167 mm) collected from the Chowan and Roanoke Rivers during 2004 and 2005. Bars represent Poisson 95% confidence intervals.

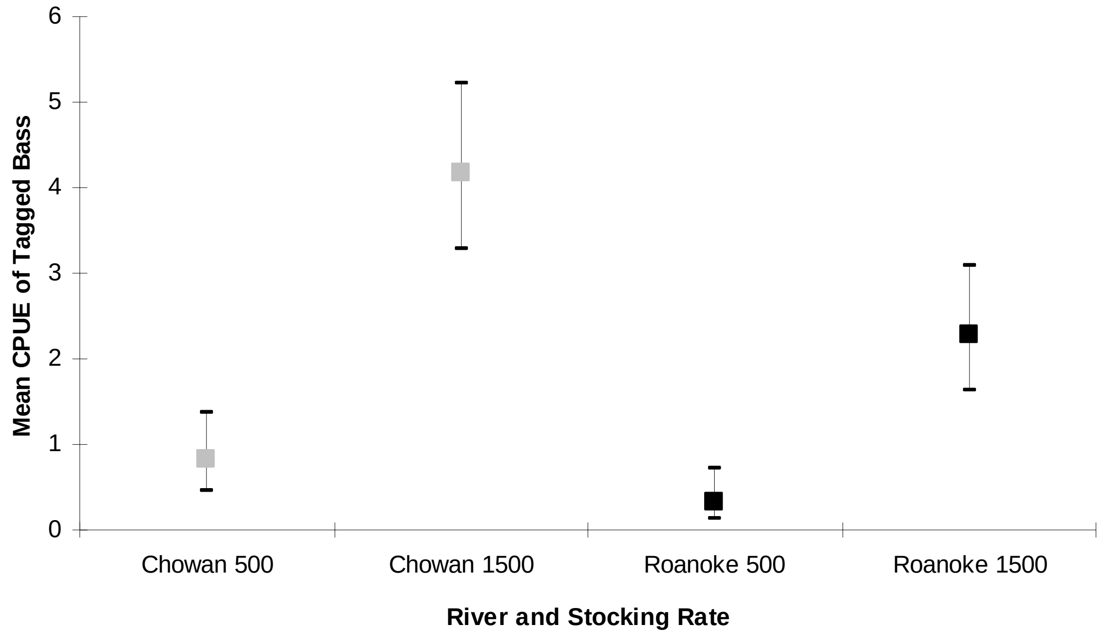

FIGURE 6.—Mean electrofishing CPUE (number of tagged largemouth bass per 2-km) of Trial-1 largemouth bass (stocked at age 1, mean TL = 167 mm) from sites stocked with either 500 or 1,500 microtagged largemouth bass per site. Data included recapture sampling from all Trial-1 sites in the Chowan and Roanoke Rivers, 2004–2006. Bars represent Poisson 95% confidence intervals.

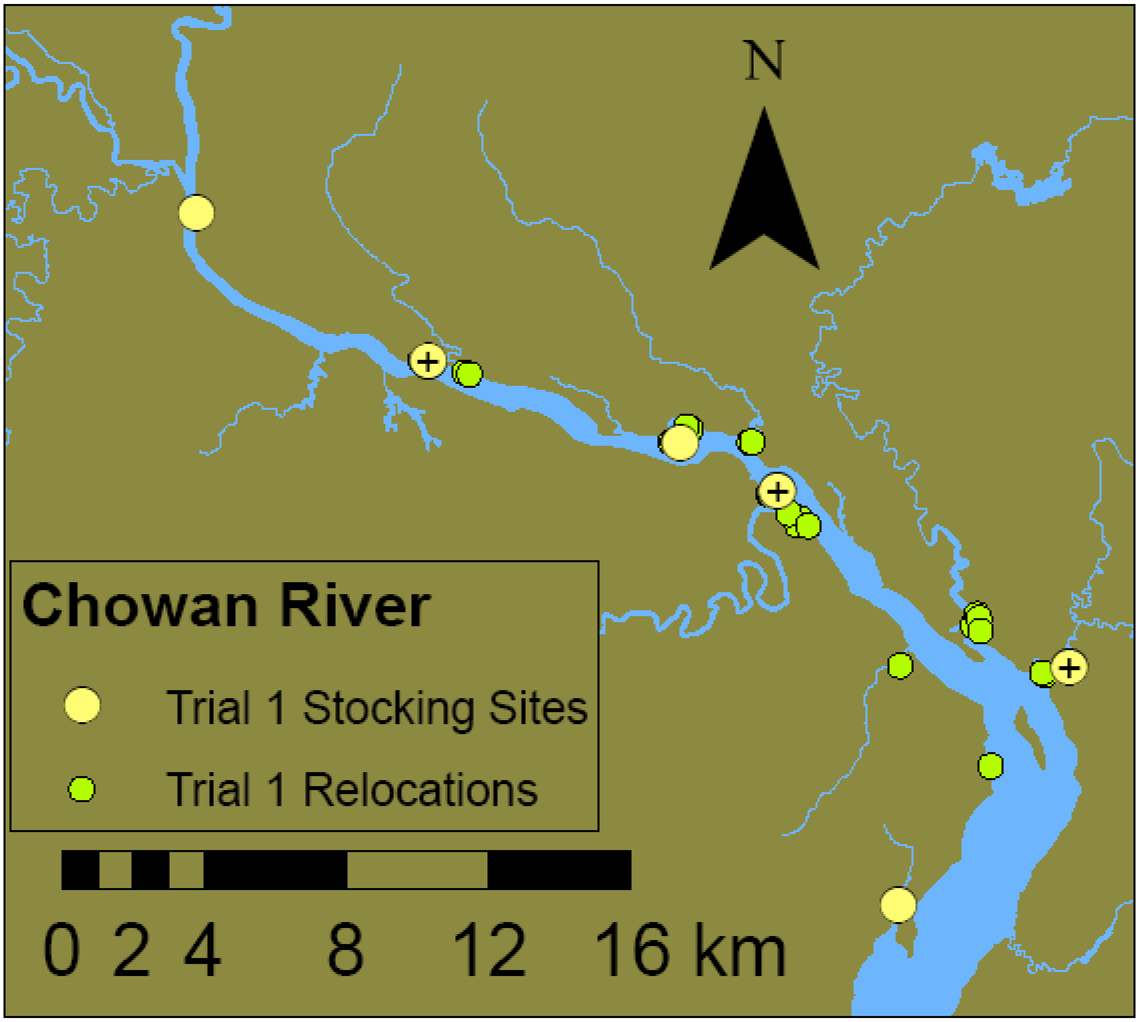

FIGURE 7.— Relocations of Trial-1 largemouth bass (stocked at age 1, mean TL at stocking = 167 mm) outside the 2-km sampling sites on the Chowan River. The plus sign within selected symbols denotes sites given the higher stocking rate.

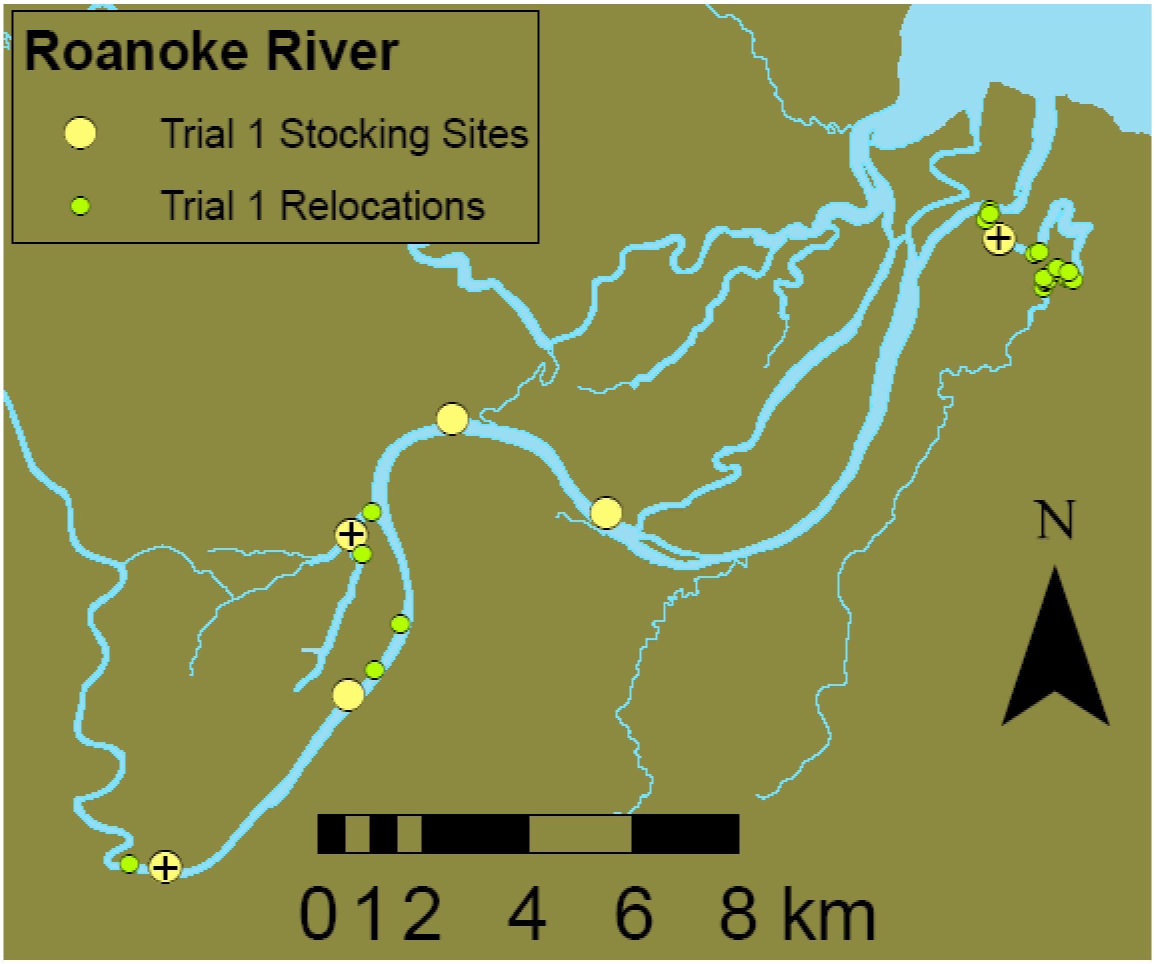

FIGURE 8.— Relocations of Trial-1 largemouth bass (stocked at age 1, mean TL at stocking = 167 mm) outside the 2-km sampling sites on the Roanoke River. The plus sign within selected symbols denotes sites given the higher stocking rate.

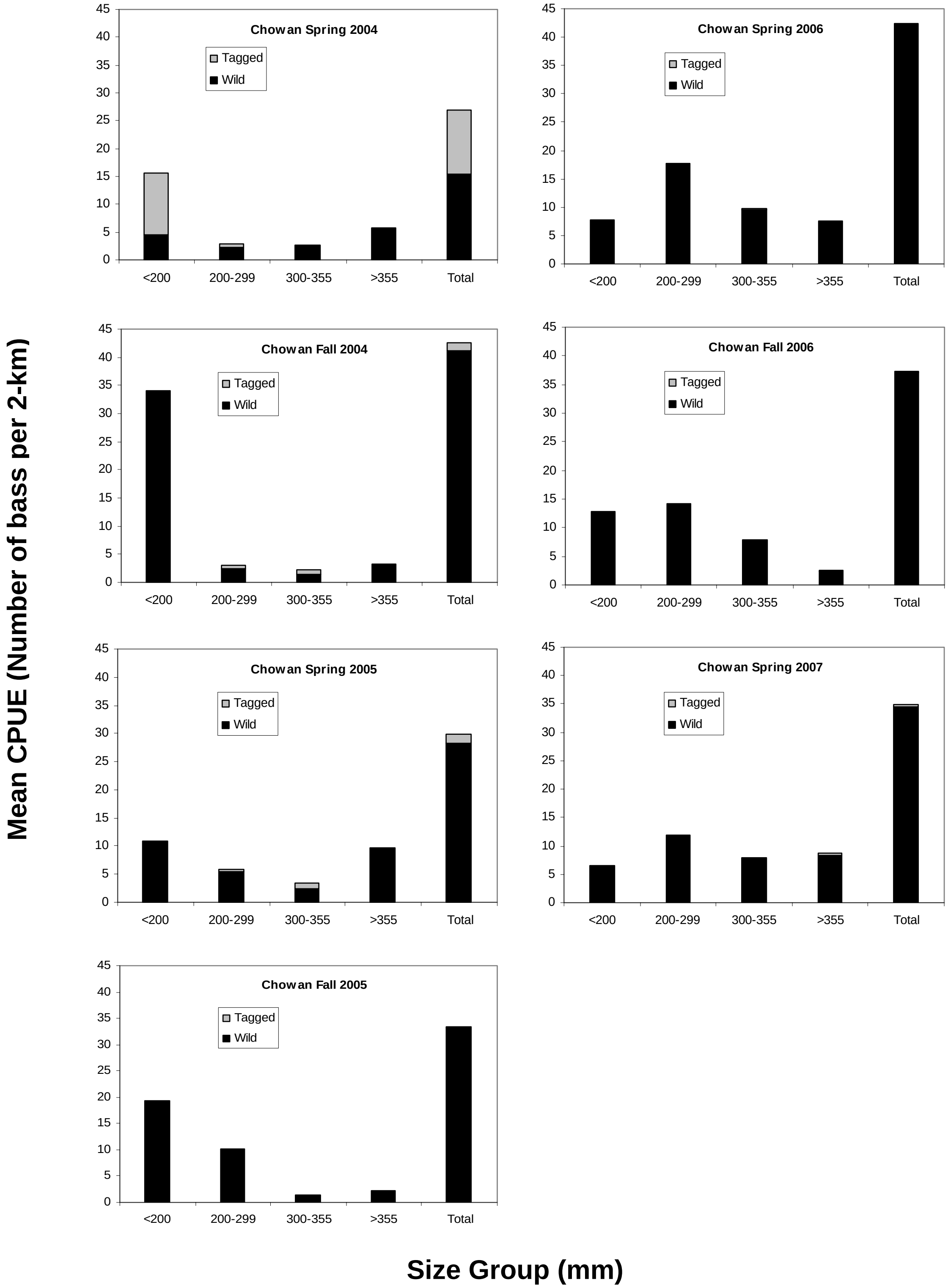

FIGURE 9.—Mean electrofishing CPUE (number of largemouth bass per 2-km) of native (wild) and tagged largemouth bass from selected size groups from the Chowan River, 2004–2007. Data from sites stocked initially with Trial-1 largemouth bass.

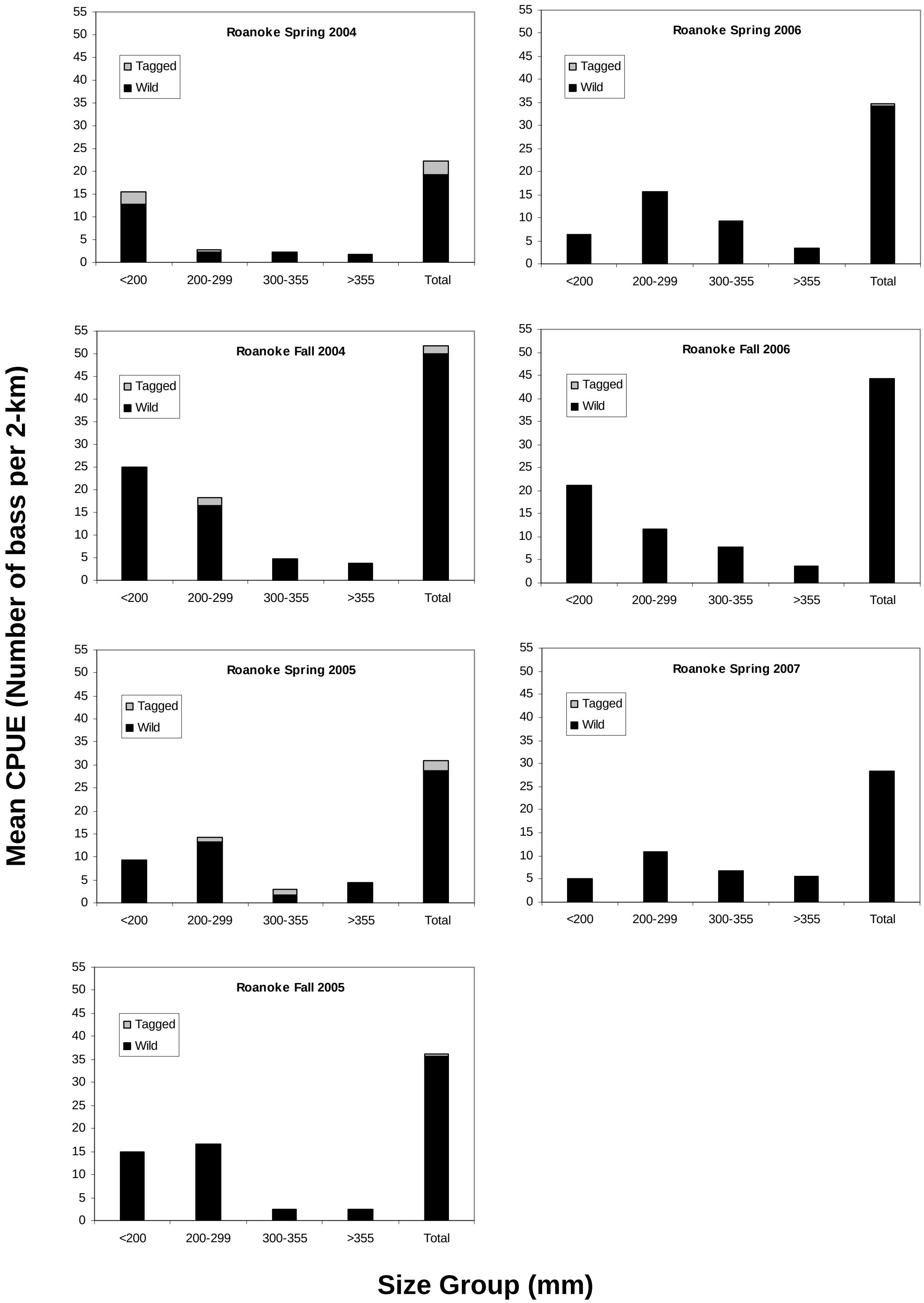

FIGURE 10.—Mean electrofishing CPUE (number of largemouth bass per 2-km) of native (wild) and tagged largemouth bass from selected size groups from the Roanoke River, 2004–2007. Data from sites stocked initially with Trial-1 largemouth bass.

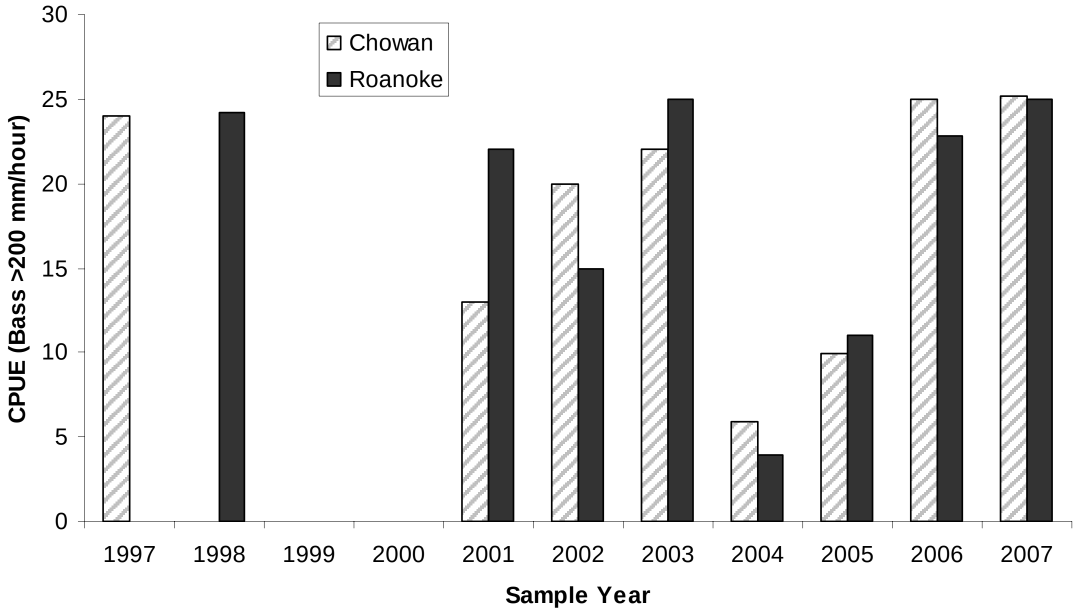

FIGURE 11.—CPUE (number ≥200 mm per h) of native largemouth bass collected during spring electrofishing on the Chowan and Roanoke rivers. Values from 1997–2003 are from NCWRC agency reports or unpublished survey data; 2004–2007 values are from the present study. Values represent total catch/total effort for all sites each year. Significant fish kills were observed in the Chowan River following Hurricane Floyd in the summer of 1999, and in both rivers following Hurricane Isabel in the summer of 2003.