North American Journal of Fisheries Management 35:431–439, 2015

ISSN: 0275-5947 print / 1548-8675 online
DOI: 10.1080/02755947.2015.1009660

ARTICLE

Dispersal Patterns of Coastal Largemouth Bass in Response to Tournament Displacement

Daniel T. Brown* and James A. Rice
Department of Applied Ecology, College of Agriculture and Life Sciences, North Carolina State University, 127 David Clark Labs, Raleigh, North Carolina 27695, USA

Cory D. Suski
Department of Natural Resources and Environmental Sciences, University of Illinois, 1102 South Goodwin Avenue, Urbana, Illinois 61801, USA

D. Derek Aday
Department of Applied Ecology, College of Agriculture and Life Sciences, North Carolina State University, 127 David Clark Labs, Raleigh, North Carolina 27695, USA

Abstract
Tournament displacement, stockpiling near release points, and handling stress are major concerns for managers of sport fisheries in the southeastern USA. We examined the effects of transport distance and tournament handling stress on dispersal of 40 Largemouth Bass *Micropterus salmoides* via telemetry from May 2012 to September 2013 in the Albemarle Sound system of eastern North Carolina. Largemouth Bass were captured from four tributaries of Albemarle Sound and transported 16.5–45 km to a central release point before being acoustically tagged and released. Movement data from an array of passive receivers was used to calculate rates of dispersal from the release point, emigration from the study area and return to capture location over time. Blood cortisol concentration, collected from our tagged Largemouth Bass and those captured in an actual tournament, was used to determine the effect of stress on potential postrelease movement and survival. Our findings indicate little evidence of long-term stockpiling (i.e., fish remaining close to release point; Richardson-Heft et al. 2000); 57% of displaced Largemouth Bass dispersed more than 500 m from the release point within 7 d and 87% within 21 d postrelease. Half of those that emigrated from Edenton Bay returned to their capture location. However, no Largemouth Bass displaced 35–45 km returned to their capture locations, suggesting that long-distance displacement inhibits return. Fishing (2.8%) and nonharvest mortality (0.5%) were low throughout this study except for peaks observed during late spring (42.9%) and early summer (25.1%) of 2013. Mean cortisol concentrations were similar in Largemouth Bass collected during our simulated tournament (126.7 ng/mL) and an actual tournament (118.4 ng/mL). However, cortisol concentrations were unrelated to survival, postrelease dispersal, or return of tagged individuals to their capture location. Largemouth Bass appear to be able to cope with current tournament practices; however, restrictions on displacement distance may increase return rates.

Displacement of fish during angling tournaments can have a significant effect on the distribution of target species (Lantz and Carver 1976; Fewlass and Groves 1991; Richardson-Heft et al. 2000; Wilde 2003), and the increasing popularity of competitive fishing (Duttweiler 1985; Kerr and Kamke 2003; Schramm and Hunt 2007; Driscoll et al. 2012) may exacerbate this effect. The increasing number of competitive fishing tournaments has led to concerns about potential stockpiling of captured fish near weigh-in locations, detrimental effects of tournament stress on fish health, and postrelease mortality

*Corresponding author: brown.daniel@deq.state.or.us
Received August 26, 2014; accepted January 14, 2015

(Gilliland 1999; Richardson-Heft et al. 2000; Kerr and Kamke 2003; Schramm and Hunt 2007). An estimated 25,000 competitive fishing tournaments occur annually in North America; a significant portion of these tournaments target black basses (*Micropterus*) and in particular Largemouth Bass *Micropterus salmoides* (Duttweiler 1985; Schramm et al. 1991b; Kerr and Kamke 2003). For example, Driscoll et al. (2012) estimated that Largemouth Bass were the focal species of more than 90% of fishing tournaments held between 2009 and 2011 in the southeastern USA. While much of this tournament angling occurs in inland systems, many competitive tournaments targeting Largemouth Bass take place in coastal river systems in North Carolina (Dockendorf et al. 2004; McCargo et al. 2007; Ricks and McCargo 2013) as well as New York, Maryland, and Alabama (Nack et al. 1993; Richardson-Heft et al. 2000; Norris et al. 2005).

Studies examining the effect of tournament displacement on Largemouth Bass have focused primarily on inland lakes and impoundments. Results from these studies are equivocal concerning postrelease dispersal, with support for both substantial (>1.6 km; Healy 1990; Fewlass and Groves 1991) and restricted (<1.6 km; Lantz and Carver 1976; Gilliland 1999) distance traveled from the release point. In contrast, studies focused on tournament displacement of Largemouth Bass in coastal systems have yielded results that are more consistent. For example, Richardson-Heft et al. (2000) found that 64% of Largemouth Bass displaced in Chesapeake Bay dispersed more than 500 m within 7 d, and Norris et al. (2005) reported 58% dispersal beyond 500 m within a week of release in the Mobile–Tensaw delta, Alabama.

Despite evidence for rapid postrelease dispersal of Largemouth Bass caught during tournaments in coastal systems, frequent tournaments (e. g., weekly; Gilliland 1999) can create short-term accumulations (Ricks and Maceina 2008) near popular release points. At one such release point in the Chowan River, a tributary of Albemarle Sound, North Carolina, (up to five tournaments occur monthly in the sound) sampling conducted by the North Carolina Wildlife Resources Commission found much higher catch rates (111 fish/h) than at sampling locations (35–78 fish/h; Jeremy McCargo, personal communication). In addition, known tournament release locations often attract tournament and nontournament anglers (Gilliland 1999). This can lead to increases in mortality (Gilliland 1999) due to additive stress from multiple captures, an outcome that fishery managers and angling organizations strive to minimize.

Concerns over the fate of angled fish extend to the final distribution of those individuals, including the availability of these fish for further angling (Schramm et al. 1991a), metapopulation structure, and potential overharvest. Although there is some agreement that Largemouth Bass have the ability to return to capture sites following displacement (Stang et al. 1996; Pearson 2002), questions remain regarding how displacement distance, or the distance from capture site to release point, influences the rate of return. In Rideau Lake, Ontario, Ridgway (2002) reported a 47% rate of return for Largemouth Bass displaced less than 8.0 km; however, 0% of the fish displaced more than 8 km returned to their capture location. In contrast, Richardson-Heft et al. (2000) found substantial rates of return for Largemouth Bass displaced 15 km (33%) or 21 km (43%) in the tidal Chesapeake Bay. However, variations in salinity and dissolved oxygen can potentially influence the movement of Largemouth Bass in coastal systems (Heft and Richardson-Heft 2002; Brown 2014; Norris et al. 2005).

In addition to tournament displacement, handling stress associated with angling activities (e.g., hooking, air exposure, livewell confinement, weigh-in) can cause substantial physiological disturbances. Stress is commonly evaluated from cortisol levels, which rise rapidly following a stress event, and because samples are easily collected and measured from blood plasma (Wendelaar Bonga 1997; Mommsen et al. 1999). For example, cortisol concentrations from Largemouth Bass caught during large, 2-d tournaments were 140 times the cortisol concentrations of control fish (Suski et al. 2003). These authors later confirmed that angling-associated activities, specifically air exposure during weigh-in, could further exacerbate the physiological disturbance associated with tournament angling (Suski et al. 2004). Sublethal effects of angling stress on Largemouth Bass include depressed growth rates (Wendelaar Bonga 1997; O'Connor et al. 2010), decreased locomotory activity, and reduced reproductive success (Cooke et al. 2000). Although the physiological effects of angling stress have been well documented, the effect of angling stress on postrelease movement and survival of displaced Largemouth Bass remains unclear.

The goal of this study was to quantify the effects of displacement on the survival, postrelease dispersal, and rate of return to capture location of Largemouth Bass in an open coastal system. Anglers traverse great distances across Albemarle Sound during tournaments; thus, we tested the effect of a wider range of displacement distances on these variables than has previously been evaluated. We simulated a fishing tournament by collecting Largemouth Bass from four tributaries of the Albemarle Sound often fished by anglers during tournaments; captured bass were transported to a central release point frequently used for tournaments. The orientation of these tributaries allowed us to quantify the effect of open-water crossing on the ability of displaced Largemouth Bass to return to their capture locations. We used acoustic telemetry to monitor postrelease movement and detection data to estimate fishing and nonharvest mortality. These estimates of mortality were used to determine the effect of frequent tournament releases and potentially increased fishing pressure on the survival of displaced Largemouth Bass near the release point. A second goal was to measure cortisol concentrations as an indicator of handling stress effects on rates of dispersal, emigration, return to initial capture location, and mortality of Largemouth Bass displaced during our simulated tournament. Results from this study will help managers ensure the health and distribution of fish captured during tournaments.

STUDY AREA

We selected a release point located at Bayside Marina on Pembroke Creek, a small creek that flows into Edenton Bay, which opens onto Albemarle Sound (Figure 1). Albemarle Sound is located in northeastern North Carolina and extends nearly 90 km inland. Our release point provided easy access to Albemarle Sound, as well as its tributaries, and was a popular starting point for many fishing tournaments throughout the year. Largemouth Bass were collected from four tributaries frequently used during tournaments originating at our release point (Figure 1). Two tributaries approximately 16.5 km from the release point (Roanoke River and Rockyhock Creek, a small tributary of the Chowan River) and two tributaries 35–45 km from the release point (Perquimans River and Scuppernong River) were selected to evaluate the ability of displaced Largemouth Bass to return to their original capture location across the wide range of distances typically traversed during tournaments in the Albemarle Sound system. In addition, two of these tributaries (Rockyhock Creek and Perquimans River) are located on the same (north) side of Albemarle Sound as the release point, and two are located on the south side of the sound. Largemouth Bass collected from the north-side tributaries could return to their capture location by traveling along a continuous shoreline, while those captured in south side tributaries would have to cross the open waters of Albemarle Sound to return.

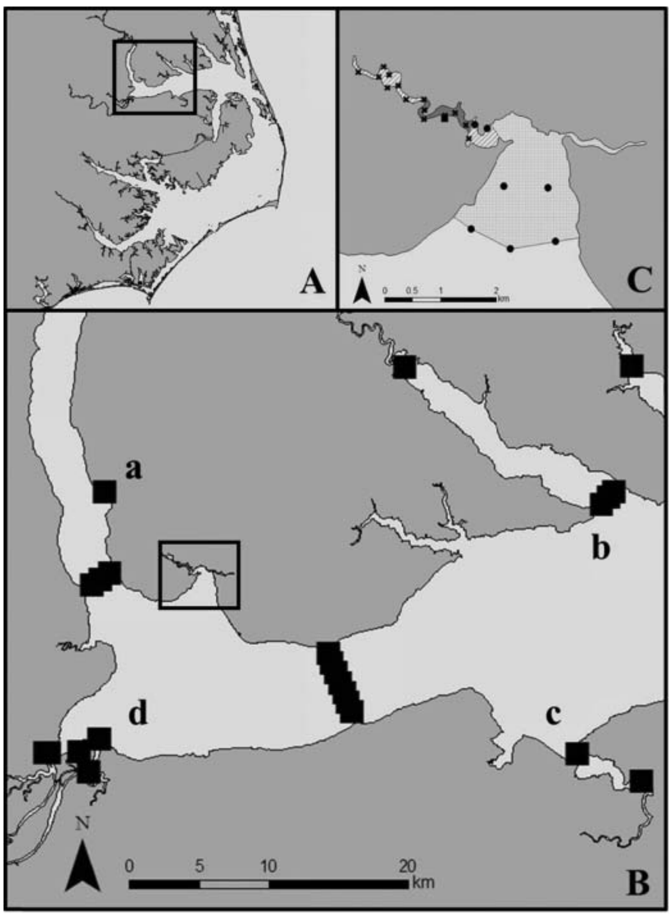

FIGURE 1. Maps related to Albemarle Sound, North Carolina, area where Largemouth Bass dispersal was studied: **(A)** the North Carolina coastal area with the square indicating approximately the western half of Albemarle Sound where the study was conducted, **(B)** area of Albemarle Sound where bass were captured from four tributaries (a = Rockyhock Creek, b = Perquimans River, c = Scuppernong River, d = Roanoke River) where the unshaded square indicates Edenton Bay and Pembroke Creek (see 1C) and black squares indicate passive receiver locations in the four tributaries and along two highway bridges, **(C)** Edenton Bay and Pembroke Creek, showing the release point (black square), manual tracking points (Xs), passive receiver locations and manual tracking points (black circles), as well as water within 500 m of the release point (dark gray), portions of Pembroke Creek >500 m from the release point (striped), and Edenton Bay (stippled).

METHODS

Fish tagging.—Forty Largemouth Bass (mean = 422 mm TL, range = 358–545 mm) were captured among the four tributaries (9–11 bass/tributary) via daytime boat electrofishing in May 2012. Each fish was exposed to air for approximately 1–2 min to simulate air exposure during handling and hook removal, then transferred to an aerated, 530-L holding tank. Once the correct number of Largemouth Bass were collected from a tributary, they were transported to the release location for tagging and release. Captured Largemouth Bass were anesthetized to stage-three sedation (partial loss of equilibrium; Summerfelt and Smith 1990) and transferred to the surgical table. Gills were continuously irrigated for the duration of surgery with a 50-mg/L solution of MS-222 (tricaine methanesulfonate). A Vemco V13-1 L acoustic transmitter (13 × 36 mm, 11 g in air; Vemco, Halifax, Nova Scotia) was implanted via a small incision along the linea alba. The Vemco tags emitted a signal every 60–180 s for 10 d followed by a period of 5 d during which they emitted a signal every 15–45 s. This cycle repeated for the duration of the study. After closing the incision with three interrupted sutures (polydioxanone absorbable synthetic monofilament 3-0 FS-1, Ethicon, Cornelia, Georgia), fish were allowed to recover from anesthesia in an aerated 150-L tank of river water treated with Stress Coat (Aquarium Pharmaceuticals, Franklin, Tennessee). Once the fish regained equilibrium and resumed normal opercular movement, they were released by hand or net into Pembroke Creek at the tournament release point. Total holding time, from capture to release, ranged from 1 to 7 h (mean = 3.5 h).

Telemetry.—Dispersal from the release point and emigration from Edenton Bay into Albemarle Sound was monitored using an array of seven passive receivers (VR2W-69kHz, VEMCO) in Pembroke Creek and Edenton Bay. Receivers maintained by North Carolina Division of Marine Fisheries and North Carolina State University (Joseph Hightower, Department of Applied Ecology) in the major tributaries and along the bridges spanning Albemarle Sound provided additional coverage of tagged Largemouth Bass movement into all of the major tributaries as well as within the sound east or west of Edenton Bay after emigration (Figure 1). These receivers also provided information on any angler-assisted movement. We determined an effective detection range of approximately 500 m for passive receivers by conducting a range test via a fixed sentinel tag. Our estimated detection range adequately covered the width of Pembroke Creek, which is relatively narrow, and receivers in lower Pembroke Creek were deployed 450 m apart to ensure high probability of detecting Largemouth Bass leaving the creek. In Edenton Bay, we deployed receivers 900 m apart and within 400 m of shore to account for variation in environmental conditions that may reduce the effective detection range (Topping and Szedlmayer 2011).

We conducted 1-d active tracking surveys approximately monthly to augment the passive receivers and collect more fine-scale information on fish location. We visited 14 fixed points in Pembroke Creek and five fixed points in Edenton Bay (Figure 1) during our active tracking surveys. At each fixed point, we deployed an omnidirectional hydrophone to detect tags in the area (range = 200–1,000 m dependent on conditions); if a tag was detected, we used a directional hydrophone to locate the tag. In a preliminary study under calm conditions, operators were able to locate a stationary tag to within 4 m of its actual location.

Dispersal and emigration.—We used telemetry data to determine movement rates away from the release point in four categories over the study period: (1) fish that remained within 500 m of the release point (stockpiling), (2) fish that dispersed over 500 m from the release point yet remained in Pembroke Creek, (3) fish that moved out of Pembroke Creek and were detected in Edenton Bay, and (4) fish that emigrated from Edenton Bay. We deemed fish in the second and third movement categories to have dispersed from the release point. Largemouth Bass in the second movement category were not detected passing the receivers in Pembroke Creek or were detected upstream of the release point during an active tracking survey. Fish placed into the third movement category were detected passing the receivers in Pembroke Creek or by a receiver in Edenton Bay. Any tagged Largemouth Bass detected passing both lines of receivers in Edenton Bay (Figure 1) or on a receiver in Albemarle Sound or its tributaries were determined to have emigrated from Edenton Bay and were included in our fourth dispersal category.

Emigration and mortality rate estimation.—We used a Bayesian multistate approach modified from Kéry and Schaub (2011) in OpenBugs software to estimate instantaneous and discrete monthly rates of fishing and nonharvest mortality as well as emigration during June 2012 to July 2013. Our model assigned individual Largemouth Bass to one of four fates, dependent on detection results during a given tracking period i: (1) alive, (2) nonharvest mortality, (3) emigrated, or (4) fishing mortality. We assumed that a tag located at the same location during three or more successive manual tracking efforts would indicate nonharvest mortality during the first of those sampling periods. However, catch-and-release mortality could not be distinguished from natural mortality and, thus, we lumped the two as "nonharvest mortality" (Hightower et al. 2001). To estimate emigration rate, we used the convention stated above, dispersal category 4, to assign the emigration fate. If a tag was undetected for three or more consecutive sampling periods at the completion of this study, we assumed this indicated a fishing mortality during the first of those periods. Estimates of fishing mortality include any tagged Largemouth Bass transported out of the study area by anglers. Data collected within one month of release were not included in our mortality model. This probationary period prevented any mortality or behavioral response due to surgery from potentially increasing the emigration and mortality estimates (Thompson et al. 2007).

Instantaneous and discrete monthly mortality estimates were determined using a natural-log-scaled uniform prior distribution to calculate the likelihood of each fate. We applied the assumptions outlined in Friedl et al. (2013) to our model: (1) all tagged Largemouth Bass that were alive within the study area at time i had the same survival rate to time $i + 1$ unless confirmed as a nonharvest mortality or emigrated, (2) tagged and untagged fish had the same survival rates, (3) the probability of a tag being shed or failing was negligible, (4) movement patterns could be used to determine whether a tagged fish remained alive or died due to nonharvest mortality, and (5) emigrating fish could be detected and censored from subsequent analysis. We determined detection probability and calculated the 2.5th and 97.5th percentiles of the posterior distribution as the credible intervals for our mortality estimates. Annual mortality rates were calculated using the same method as Brown (2014), in which the monthly instantaneous estimates were averaged and rescaled to a 12-month period before converting to discrete values.

We compared our annual estimates to mortality estimates from a reference population, located approximately 45 km from our study site in the Chowan River, another tributary of Albemarle Sound, to identify any differences in mortality due to stockpiling or stress associated with angling. The 23 Largemouth Bass used as the reference population were tagged using the same surgical procedure and handling protocols during April 2012. Due to the close proximity of the two populations, they were exposed to similar variation in environmental factors and angling activity. Mortality estimates for the reference population were calculated using only legally harvestable-size Largemouth Bass under the same Bayesian framework, allowing direct comparison with our annual estimates (Brown 2014).

Cortisol sampling.—Between May 2012 and September 2013, we collected blood samples from 54 Largemouth Bass under two tournament conditions: 34 from a simulated tournament and 20 from an actual tournament. Samples from the simulated tournament were collected prior to placement in the recovery tank during the transport and tagging procedure described above. Largemouth Bass captured during the actual tournament were exposed to typical angling, transport, and handling stress and blood samples were taken just prior to weigh-in.

We collected and analyzed samples using a method similar to Zuckerman and Suski (2013). Fish were placed ventral side up in a foam-lined V-board and approximately 0.5 mL of blood was sampled from the caudal vein using a heparin-rinsed 21-gauge needle and 1-mL syringe. Each sample was then transferred to a 1.5-mL vial for centrifugation at 10,000 × *g* for 5 min. Plasma was separated from the cell pack and placed into a 5-L dewar charged with liquid nitrogen for later laboratory analysis (Scott et al. 1980; Zuckerman and Suski 2013). Frozen plasma samples were processed at the University of Illinois, where plasma cortisol was quantified using an enzyme-linked immunoassay (ELISA; Enzo Life Sciences Cortisol ELISA Kit; Farmingdale, New York). Sink et al. (2008) validated the use of this ELISA to quantify plasma cortisol concentrations in Largemouth Bass.

We used one-way ANOVA (GLM procedure; SAS version 9.3; SAS Institute; Cary, North Carolina) to test for differences in mean cortisol concentrations between the simulated and actual tournaments to evaluate the applicability of our findings to actual tournaments. Additionally, we used one-way ANOVA comparisons to identify (1) differences in cortisol concentrations between groups of fish that dispersed more than 500 m and those that did not, (2) fish that emigrated from Edenton Bay and those that did not, (3) fish that returned to their capture location and those that emigrated but did not return to their capture location, (4) fish that crossed the sound and those that did not, and (5) fish that survived within our study area and those that died of natural causes.

RESULTS

Dispersal, Emigration, and Successful Return

We successfully tagged 40 Largemouth Bass and subsequently detected each of them at points other than the release location. Twenty-three (57%) tagged fish dispersed more than 500 m from the release point within 7 d and 35 (87%) within 21 d postrelease (Figure 2). Thirty-one fish (77%) were confirmed to have left Pembroke Creek and 28 (70%) were detected in Edenton Bay within 40 d following release (Figure 2). The remaining nine tagged bass were never detected outside of Pembroke Creek. Of the 31 bass detected in Edenton Bay, 16 were subsequently detected emigrating from Edenton Bay. Emigration rate was highest in the first two months after release (Figure 3). Of the 15 fish that were detected in Edenton Bay but did not emigrate, 9 either returned to Pembroke Creek (5) or made multiple trips between Pembroke Creek and Edenton Bay (4). Eight of the 16 fish that emigrated eventually returned to their original capture locations for an overall return rate of 20% (8 of 40). Of the four bass originally captured in the Roanoke River that emigrated from Edenton Bay three returned to the Roanoke River and five of the six Largemouth Bass originally from Rockyhock Creek that emigrated returned to their capture location. All of these fish came from the two initial capture locations nearest the release point, regardless of whether an open water crossing was required (Roanoke River) or not (Rockyhock Creek). None of the bass from the Perquimans River (2) or from the Scuppernong River (3) that emigrated from Edenton Bay returned to their capture location.

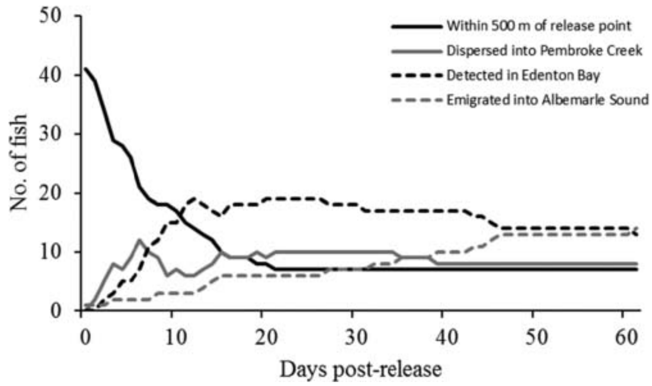

FIGURE 2. The number of tagged Largemouth Bass in each of the four dispersal categories during the first 60 d postrelease in Albemarle Sound, North Carolina.

Mortality Estimation

Fishing mortality was <1% from July 2012 through April 2013 and highest in May 2013, when an estimated 40% of the Largemouth Bass remaining within our study area were harvested (Figure 4). Despite detecting only six nonharvest

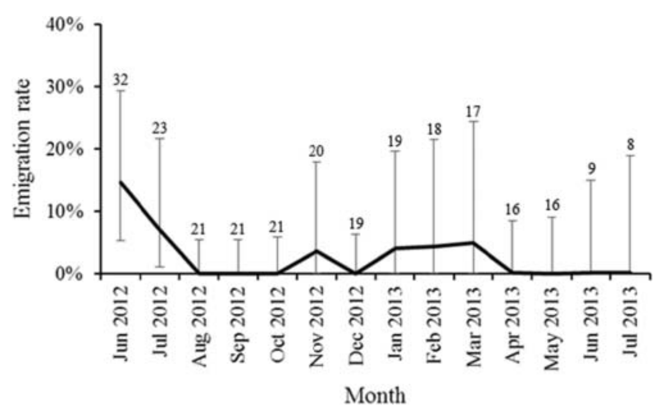

FIGURE 3. Monthly emigration rate estimates (during 2012 and 2013) from Edenton Bay (Albemarle Sound, North Carolina) of Largemouth Bass tagged during a simulated tournament in May 2012. Numbers indicate sample size for each monthly estimate, and error bars indicate 95% credible intervals.

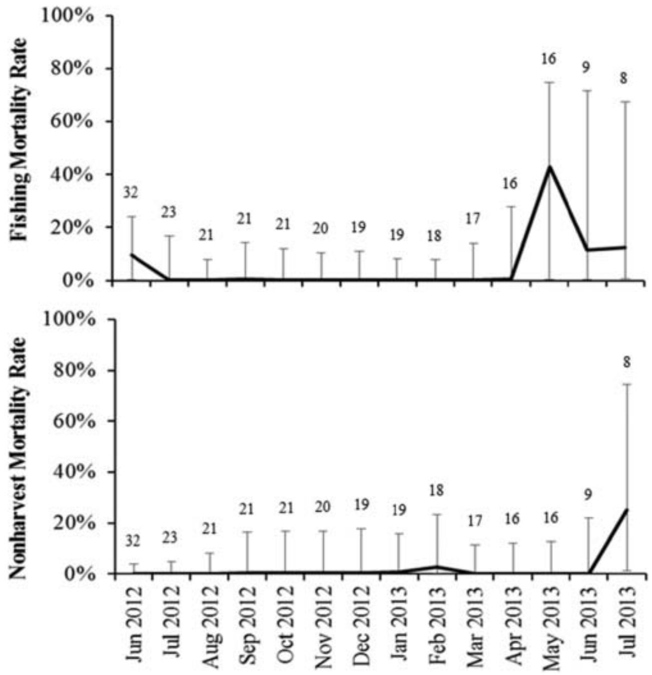

FIGURE 4. Monthly fishing and nonharvest mortality rates (2012 and 2013) in Edenton Bay and Pembroke Creek of Largemouth Bass tagged during a simulated tournament in May 2012. Numbers indicate sample size for each monthly estimate, and error bars indicate 95% credible intervals.

mortalities, we observed a similar pattern in the monthly estimates of nonharvest mortality. Monthly nonharvest mortality estimates were <3%, throughout the study, except for a marked increase in the last month of the mortality estimation period. No mortalities were detected during our probationary period. Only 8.6% (95% credible interval [CI] = 2–21%) of tagged bass were alive within our study area at the completion of this study. This survival was lower than in our reference population from the Chowan River, where survival was over 27% (95% CI = 12–45%; $\chi^2 = 10.97$, df = 3, $P = 0.01$). Nonharvest mortality was similar in this study (12%) and the reference population (6%) bass was similar ($\chi^2 = 2.69$, df = 3, $P = 0.44$), as were fishing mortality (28% and 30%, respectively; $\chi^2 = 0.02$, df = 3, $P = 0.99$) and emigration (12% and 4%, respectively; $\chi^2 = 4.35$, df = 3, $P = 0.23$).

Despite monthly active tracking efforts and continuous passive monitoring, our detection probability was low at times during this study (13 tracking efforts; mean = 53%, range = 31–73%) and some fish detected on receivers outside of Edenton Bay were not detected emigrating from the bay. Therefore, additional Largemouth Bass may have emigrated from our study area without detection. To account for this, we calculated the probability of a fish moving past the inner and outer receivers in Pembroke Creek and the inner and outer line of receivers in Edenton Bay without detection. We based these probabilities on the detection histories of tagged Largemouth Bass found downstream of the receivers in Pembroke Creek and Edenton Bay. Then, we applied these calculated probabilities to any tagged Largemouth Bass undetected for three or more consecutive periods at the completion of the study, based on its last known location. In this manner, we determined that approximately two additional fish might have emigrated from our study area without detection (Brown 2014). Accounting for this in our annual estimates resulted in only modest increases in fishing (0.2%) and nonharvest mortality (1.9%) as well as emigration (1.4%).

Effects of Cortisol on Movement and Survival

Despite different capture methods and postcapture procedures, cortisol concentrations were similar between the simulated (mean = 126.7 ng/mL, SD = 55.8, range = 43.3–322.4 ng/mL) and actual (mean = 118.4 ng/mL, SD = 74.6, range = 21.8–302.7 ng/mL) tournaments ($F = 0.21$, df = 53, $P = 0.65$). There were no significant differences in cortisol concentrations between Largemouth Bass that dispersed at least 500 m from the release point within 7 d of release versus those that did not, and of those fish that emigrated from Edenton Bay there was no significant differences between those that did or did not return to their original capture locations (Table 1). There was some evidence that Largemouth Bass that did not emigrate from Edenton Bay had higher cortisol concentrations than fish that did emigrate (Table 1). Cortisol concentrations did not differ between Largemouth Bass that died due to nonharvest mortality or survived (Table 1).

DISCUSSION

Contrary to some inland studies that indicate displaced Largemouth Bass tend not to disperse from release locations (Lantz and Carver 1976; Gilliland 1999; Wilde and Paulson 2003), we found that the coastal Largemouth Bass in this study not only dispersed from the release point, but did so within 7–21 d postrelease. This finding is consistent with studies conducted in other coastal systems by Richardson-Heft et al. (2000) and Norris et al. (2005). In those studies, the authors also found that a majority of displaced Largemouth Bass moved more than 500 m from the release point within 7–21 d. Further, we found that 70% of our tagged Largemouth Bass dispersed over 1.6 km (out of Pembroke Creek) within 40 d following release, compared to 33% in Shasta Lake, California (Healy 1990) and 12% in Lake Mead in Arizona and Nevada (Wilde and Paulson 2003). This rapid dispersal continued beyond Pembroke Creek and Edenton Bay, as our highest observed emigration rates occurred in the first few months of the study. The coastal Largemouth Bass displaced in our study appear to disperse more quickly and move farther in greater proportions than those in inland populations. This may be due, in part, to the highly variable environmental conditions experienced by Largemouth Bass inhabiting coastal or tidal systems (Heft and Richardson-Heft 2002), potentially allowing coastal Largemouth Bass to acclimate more quickly to environmental

TABLE 1. Comparison of blood plasma cortisol concentrations of tagged Largemouth Bass based on dispersal from release point in Pembroke Creek and survival. Cortisol concentration (mean ± SE) and sample size (*N*) are given for each group; ANOVA statistics are shown for each comparison.

Status	Mean cortisol concentrations (ng/mL)	*N*	*F*	*P*	df
Dispersed more than 500 m within 7 d	137.6 ± 3.6	20	1.26	0.27	31
Did not disperse within 7 d	118.1 ± 4.5	12			
Emigrated from Edenton Bay	113.2 ± 2.3	14	3.46	0.07	31
Did not emigrate	143.7 ± 3.0	18			
Returned to capture location	105.1 ± 5.3	7	0.83	0.38	13
Did not return	121.2 ± 4.0	7			
Surviving fish and fishing mortalities	132.3 ± 1.6	29	0.49	0.49	31
Nonharvest mortalities	111.7 ± 18.3	3			

conditions at the release point and expend more energy emigrating.

Largemouth Bass in our study did not return to their original capture location at the same rate. Displacement distance appeared to influence homing ability more than continuous shoreline because fish returned to the tributaries nearest to the release point (16.5 km; Rockyhock Creek and Roanoke River), regardless of shoreline connectivity. Additionally, none of the Largemouth Bass captured in the tributaries farthest from the release point (35–45 km; Scuppernong River and Perquimmans River) returned to those locations. The two tributaries farthest from the release point exceeded all previously examined displacement distances for Largemouth Bass (approximately 21 km; Richardson-Heft et al. 2000), yet Nack et al. (1993) observed Largemouth Bass in the Hudson River estuary moving over 60 km to reach spawning grounds. Active tracking did not occur in Albemarle Sound due to the size of the sound and the detection range of our tags. Also, acoustic receiver coverage in some areas could not be confirmed, which means that our estimates of return rate to areas farthest from the release point should be considered conservative. Other studies have suggested that salinity may influence Largemouth Bass movement (Richardson-Heft et al. 2000; Norris et al. 2005). It is possible that higher salinity in the eastern part of Albemarle Sound may have inhibited movement to the farthest capture locations; however, we did not have the data necessary to test this hypothesis.

There was little evidence of stockpiling within 500 m of the release point. This is consistent with other studies using a 500-m perimeter to designate the area of stockpiling of displaced Largemouth Bass in coastal systems. We detected 87% of our tagged Largemouth Bass outside the stockpiling area within 21 d of release. This is consistent with Norris et al. (2005), who reported complete dispersal within 23 d postrelease. Richardson-Heft et al. (2000) also reported nearly complete dispersal from their release points in the Chesapeake Bay, but over a much longer period (within 20 months). At the end of our study, no live tagged fish were detected within 500-m of the release point. It is important to note however, that tagged Largemouth Bass were able to disperse yet remain within Pembroke Creek, possibly creating a higher density of fish in the general vicinity of the release point. This may help explain the difference between our results and North Carolina Wildlife Resources Commission sampling, which suggested stockpiling near our release point. Our study focused on the postrelease dispersal of a finite number of displaced fish, not the general population around the release point. Despite the rapid dispersal we observed, a temporary stockpile of displaced fish could occur near release points due to the high frequency of tournaments in Albemarle Sound and the relatively low number of release points.

Both fishing and nonharvest mortality were low throughout our study period, except for peaks observed during late spring and early summer 2013. These high monthly estimates may have been an artifact of the small number of tagged Largemouth Bass at risk within our study area toward the end of the study. When a small number of individuals are at risk the model is estimating the fate of the few and applying it to the fate of the whole population, making estimates particularly sensitive to the fates of remaining individual tagged fish. Thus, the credible intervals expand, and the stability of the estimates is reduced. Our estimates of fishing mortality are probably an overestimate due to the convention we used to determine a fishing mortality, i.e., a bass not detected for three or more consecutive tracking periods at the end of our study. Following this convention, we assumed that any fish that escaped detection was a fishing mortality; however, these bass may have escaped detection by using habitats that we were unable to access or that presented problems for our equipment (e.g., forested shallows), they may have been transported out of the study area by anglers, or they may have emigrated from Edenton Bay without detection and survived for the duration of this study.

The annual fishing mortality rates were high for the population used in this study and the reference population, indicating significant fishing pressure throughout the basin. Similarity between these two estimates indicates that if anglers are targeting popular tournament release locations, this effort is not influencing mortality (as suggested by Gilliland 1999). The slightly higher, though not significant, nonharvest mortality rate in our study area may indicate the effect of increased fishing pressure (via catch-and-release mortality) not detected in the estimate of fishing mortality, although this remains unclear. An alternative explanation may be the number of individuals that emigrated without detection. As indicated in the comparison between our initial estimates and those adjusted for potential undetected emigration, even a small increase in emigration can have an effect on overall survival.

Based on the varying reported rates of Largemouth Bass dispersal from release location and return to capture locations, we suspected that stress associated with tournament angling might negatively influence postrelease dispersal. Specifically, we hypothesized that Largemouth Bass with the highest concentrations of cortisol would be less likely to disperse from the release point and more likely to die. However, our results did not support this hypothesis. Rather, we found no evidence that cortisol concentration influenced postrelease movement or survival of our tagged Largemouth Bass. The rapid movement away from the release point we observed may indicate that cortisol production in response to our simulated tournament was adaptive, allowing the individual to recover from stress, rather than maladaptive (Wendelaar Bonga 1997). Even short-term (5 d) supraphysiological elevations in cortisol have been found to be adaptive by increasing Largemouth Bass mean swimming velocity and mean daily distance traveled (O'Connor et al. 2010).

The mean cortisol concentrations we observed in our simulated tournament and in the actual tournament were higher than prestress concentrations in hatchery Largemouth Bass (7–20 ng/mL; Carmichael et al. 1984a, 1984b) and similar to poststress concentrations reported from other wild populations in Ontario, Canada (70–120 ng/mL; Suski et al. 2003), and Alabama (45–115 ng/mL; Davis and Parker 1986). These poststress cortisol concentrations are similar to other teleost fishes exposed to transport stress, although higher values were reported for a number of different species (Barton and Iwama 1991 and references within). The significant increase in cortisol concentration observed in both our simulated and actual tournament samples over reported prestress concentrations (Carmichael et al. 1984a, 1984b; Brown 2014) indicates that tournament activities cause significant physiological disturbances in Largemouth Bass, as suggested by Suski et al. (2004). We believe that due to the similarity between the cortisol concentrations in our simulated tournament and the actual tournament, the postrelease movement of our tagged Largemouth Bass can be used to estimate the movement of Largemouth Bass captured during actual tournaments.

While the rates of dispersal, emigration and successful return observed in our study are encouraging for managers of coastal Largemouth Bass populations, stockpiling near popular tournament release points is possible. We observed no stockpiling using the convention of Richardson-Heft et al. (2000) to determine initial dispersal from the release point. However, dispersing fish could remain in the creek beyond 500 m, which may constitute stockpiling under a different definition. In such cases, the use of live-release boats or fish-hauling trucks or trailers to move fish away from release points (as suggested by Gilliland 1999) may help maximize dispersal. In large open systems, restricting smaller tournaments to individual rivers or designating waiting periods between tournaments at a particular boat ramp may alleviate the risk of stockpiling and allow fish to disperse. As tournament angling continues to gain popularity across the USA, tournament anglers and fishery managers will need to adopt a strategy to ensure the health and distribution of Largemouth Bass captured during tournaments without reducing the survival of released fish (Healy 1990).

ACKNOWLEDGMENTS

This research was funded by the North Carolina Wildlife Resources Commission through Federal Aid in Sport Fish Restoration grant F-100-R. We thank our collaborators from the North Carolina Wildlife Resources Commission (K. J. Dockendorf, J. W. McCargo, B. R. Ricks) for logistical and fish collection assistance, the North Carolina Department of Marine Fisheries (M. Loeffler) for help tracking Largemouth Bass in Albemarle Sound, J. E. Hightower for assistance with mortality estimation, the Suski laboratory for aid with cortisol analysis, and the members of the Fisheries Ecology and Aquatic Sciences laboratory at North Carolina State University for assistance with field collections.

REFERENCES

Barton, B. A., and G. K. Iwama. 1991. Physiological changes in fish from stress in aquaculture with emphasis on the response and effects of corticosteroids. Annual Reviews of Fish Diseases 1:3–26.

Brown, D. T. 2014. Responses of Largemouth Bass to seasonal hypoxia and tournament displacement in a coastal system. Master's thesis. North Carolina State University, Raleigh.

Carmichael, G. J., J. R. Tomasso, B. A. Simco, and K. B. Davis. 1984a. Characterization and alleviation of stress associated with hauling Largemouth Bass. Transactions of the American Fisheries Society 113:778–785.

Carmichael, G. J., J. R. Tomasso, B. A. Simco, and K. B. Davis. 1984b. Confinement and water quality-induced stress in Largemouth Bass. Transactions of the American Fisheries Society 113:767–777.

Cooke, S. J., D. P. Philipp, J. F. Schreer, and R. S. McKinley. 2000. Locomotory impairment of nesting male Largemouth Bass following catch-and-release angling. North American Journal of Fisheries Management 20:968–977.

Davis, K. B., and N. C. Parker. 1986. Plasma corticosteroid stress response of fourteen species of warmwater fish to transportation. Transactions of the American Fisheries Society 115:495–499.

Dockendorf, K. J., C. D. Thomas, and J. W. Kornegay. 2004. Chowan River recreational angling survey, 2001–2002. North Carolina Wildlife Resources Commission, Federal Aid in Sport Fish Restoration, Project F-22, Final Report, Raleigh.

Driscoll, M. T., K. M. Hunt, and H. L. Schramm. 2012. Trends in fishery agency assessments of black bass tournaments in the southeast United States. Proceedings of the Annual Conference of Southeastern Association of Fisheries and Wildlife Agencies 66:25–32.

Duttweiler, M. W. 1985. Status of competitive fishing in the United States trends and state fisheries policies. Fisheries 10(5):5–7.

Fewlass, L., and T. Groves. 1991. PIT tag study at tidal Potomac River black bass fishing tournaments to analyze fish movement patterns, effects of fish displacement, and recapture rates. Pages V-87–V-103 *in* R. M. Davis, editor. Statewide fisheries survey and management. Maryland Department of Natural Resources, Federal Aid in Fish Restoration, Project F-29-R, Study V, Final Report, Annapolis.

Friedl, S. E., J. A. Buckel, J. E. Hightower, F. S. Scharf, and K. H. Pollock. 2013. Telemetry-based mortality estimates of juvenile spot in two North Carolina estuarine creeks. Transactions of the American Fisheries Society 142:399–415.

Gilliland, E. R. 1999. Dispersal of black bass following tournament release in an Oklahoma reservoir. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 53:144–149.

Healy, T. P. 1990. Movement and survival of tournament-caught black bass at Shasta Lake. California Fish and Game 76:36–42.

Heft, A. A., and C. A. Richardson-Heft. 2002. Home range of Largemouth Bass in the tidal upper Chesapeake Bay. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 56: 17–25.

Hightower, J. E., J. R. Jackson, and K. H. Pollock. 2001. Use of telemetry methods to estimate natural and fishing mortality of Striped Bass in Lake Gaston, North Carolina. Transactions of the American Fisheries Society 130:557–567.

Kerr, S. J., and K. K. Kamke. 2003. Competitive fishing in freshwaters of North America. Fisheries 28(3):26–31.

Kéry, M., and M. Schaub. 2011. Bayesian population analysis using WinBUGS: a hierarchical perspective. Academic Press, San Diego, California.

Lantz, K. E., and D. C. Carver. 1976. Dispersal of tournament caught bass from a central release point. Proceedings of the Annual Conference Southeastern Association of Game and Fish Commissioners 29(1975):115–125.

McCargo, J. W., K. J. Dockendorf, and C. D. Thomas. 2007. Roanoke River recreational angling survey, 2005–2006. North Carolina Wildlife Resources Commission, Federal Aid in Sport Fish Restoration, Project F-22, Final Report, Raleigh.

Mommsen, T. P., M. M. Vijayan, and T. W. Moon. 1999. Cortisol in teleosts: dynamics, mechanisms of action, and metabolic regulation. Reviews in Fish Biology and Fisheries 9:211–268.

Nack, S. B., D. Brunnell, D. M. Green, and J. L. Forney. 1993. Spawning and nursery habitats of Largemouth Bass in the tidal Hudson River. Transactions of the American Fisheries Society 122:208–216.

Norris, A. J., R. A. Wright, D. R. DeVries, D. L. Armstrong Jr., and J. Zolczynski. 2005. Movement patterns of coastal Largemouth Bass in the Mobile–Tensaw River delta, Alabama: a multi-approach study. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 59:200–216.

O'Connor, C. M., K. M. Gilmour, R. Arlinghaus, C. T. Hasler, D. P. Philipp, and S. J. Cooke. 2010. Seasonal carryover effects following the administration of cortisol to a wild teleost fish. Physiological and Biochemical Zoology 83:950–957.

Pearson, J. 2002. Movements of displaced Largemouth Bass in two Indiana natural lakes. Lake and Reservoir Management 18:257–262.

Richardson-Heft, C. A., A. A. Heft, L. Fewlass, and S. B. Brandt. 2000. Movement of Largemouth Bass in northern Chesapeake Bay: relevance to sportfishing tournaments. North American Journal of Fisheries Management 20:493–501.

Ricks, B. R., and M. J. Maceina. 2008. Effects of catch-and-release tournament fishing on dispersal and population metrics of black bass in Lake Martin, Alabama. Pages 293–308 *in* M. S. Allen, S. M. Sammons, and M. J. Maceina, editors. Balancing fisheries management and water uses for impounded river systems. American Fisheries Society, Symposium 62, Bethesda, Maryland.

Ricks, B. R., and J. W. McCargo. 2013. Sportfish survey of coastal rivers in northeast North Carolina before and after Hurricane Irene. North Carolina Wildlife Resources Commission, Federal Aid in Sport Fish Restoration, Project F-108, Final Report, Raleigh.

Ridgway, M. S. 2002. Movements, home range, and survival estimation of Largemouth Bass following displacement. Pages 525–533 *in* D. P. Philipp and M. S. Ridgway, editors. Black bass: ecology, conservation, and management. American Fisheries Society, Symposium 31, Bethesda, Maryland.

Schramm, H. L. Jr., M. L. Armstrong, A. J. Fedler, N. A. Funicelli, D. M. Green, J. L. Hahn, D. P. Lee, R. E. Manns Jr., S. P. Quinn, and S. J. Waters. 1991a. Sociological, economic, and biological aspects of competitive fishing. Fisheries 16(3):13–21.

Schramm, H. L. Jr., M. L. Armstrong, N. A. Funicelli, D. M. Green, D. P. Lee, R. E. Manns Jr., B. D. Taubert, and S. J. Waters. 1991b. The status of competitive sport fishing in North America. Fisheries 16(3):4–12.

Schramm, H. L. Jr., and K. M. Hunt. 2007. Issues, benefits, and problems associated with fishing tournaments in inland waters of the United States: a survey of fishery agency administrators. Fisheries 32:234–243.

Scott, A. P., V. J. Bye, S. M. Baynes, and J. R. C. Springate. 1980. Seasonal variations in plasma concentrations of 11-ketotestosterone and testosterone in male Rainbow Trout, *Salmo gairdneri* Richardson. Journal of Fish Biology 17:495–505.

Sink, T. D., R. T. Lochmann, and K. A. Fecteau. 2008. Validation, use and disadvantages of enzyme-linked immunosorbent assay kits for detection of cortisol in Channel Catfish, Largemouth Bass, Red Pacu, and Golden Shiners. Fish Physiology and Biochemistry 34:95–101.

Stang, D. L., D. M. Green, R. M. Kindt, T. L. Chiotti, and W. W. Miller. 1996. Black bass movements after release from fishing tournaments in four New York waters. Pages 163–171 *in* L. E. Miranda and D. R. DeVries, editors. Multidimensional approaches to reservoir fisheries management. American Fisheries Society, Symposium 16, Bethesda, Maryland.

Summerfelt, R. C., and L. S. Smith. 1990. Anesthesia, surgery, and related techniques. Pages 213–272 *in* C. B. Schreck and P. B. Moyle, editors. Methods for fish biology. American Fisheries Society, Bethesda, Maryland.

Suski, C. D., S. S. Killen, S. J. Cooke, J. D. Kieffer, D. P. Philipp, and B. L. Tufts. 2004. Physiological significance of the weigh-in during live-release angling tournaments for Largemouth Bass. Transactions of the American Fisheries Society 133:1291–1303.

Suski, C. D., S. S. Killen, M. B. Morrissey, S. G. Lund, and B. L. Tufts. 2003. Physiological changes in Largemouth Bass caused by live-release angling tournaments in southeastern Ontario. North American Journal of Fisheries Management 23:760–769.

Thompson, J. S., D. S. Waters, J. A. Rice, and J. E. Hightower. 2007. Seasonal natural and fishing mortality of Striped Bass in a southeastern reservoir. North American Journal of Fisheries Management 27: 681–694.

Topping, D. T., and S. T. Szedlmayer. 2011. Home range and movement patterns of Red Snapper (*Lutjanus campechanus*) on artificial reefs. Fisheries Research 112:77–84.

Wendelaar Bonga, S. E. 1997. The stress response in fish. Physiological Reviews 77:591–625.

Wilde, G. R. 2003. Dispersal of tournament-caught black bass. Fisheries 28 (7):10–17.

Wilde, G. R., and L. J. Paulson. 2003. Movement and dispersal of tournament-caught Largemouth Bass in Lake Mead, Arizona–Nevada. Journal of Freshwater Ecology 18:339–342.

Zuckerman, Z. C., and C. D. Suski. 2013. Predator burden and past investment affect brood abandonment decisions in a parental care-providing teleost. Functional Ecology 27:693–701.