Relationship between Discharge and Electrofishing Catch-per-unit-effort of Largemouth Bass in the Neuse River, North Carolina

Justin M. Homan, *North Carolina Wildlife Resources Commission, Division of Inland Fisheries, 1721 Mail Service Center, Raleigh, NC 27699-1721*

Robert D. Barwick, *North Carolina Wildlife Resources Commission, Division of Inland Fisheries, 1721 Mail Service Center, Raleigh, NC 27699-1721*

Abstract: Sportfish managers in coastal North Carolina are often challenged with interpreting estimates of largemouth bass (*Micropterus salmoides*) relative abundance (catch-per-unit-effort, CPUE) due in part to the influence of environmental factors on boat electrofishing techniques. To accurately assess population abundance using relative abundance indices, the effects of environmental variables on largemouth bass catch should be quantified. We sampled largemouth bass populations in Neuse River tributaries weekly in spring 2006 and 2007 to investigate the relationship between CPUE and streamflow. Catch-per-unit-effort appeared to be strongly related to discharge, but the relationship was not linear. Instead, we found that small increases in streamflow between 60 and 100 m^3 sec^{-1} had a large effect on electrofishing CPUE. Above this streamflow threshold, CPUE was usually low and only exceeded 20 fish h^{-1} in 3 of 41 observations in 2006 and 2007. At lower streamflows, CPUE commonly exceeded 100 fish h^{-1}, especially in 2007. In most cases, CPUE was higher when discharge was <85 m^3 sec^{-1} in both years for all largemouth bass collected ($P < 0.01$), except for largemouth bass less than stock size (200 mm) in 2006 ($P = 0.59$). We recommend that spring sampling for largemouth bass on the Neuse River be limited to days when discharge is <85 m^3 sec^{-1}. Application of these methods could be applied on a broader scale to evaluate the influence of streamflows on the variability in CPUE of largemouth bass in other coastal rivers.

Key words: largemouth bass, catch-per-unit-effort, discharge, coastal rivers

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 64:184–189

In coastal North Carolina, sportfish managers with the North Carolina Wildlife Resources Commission (NCWRC) primarily rely on boat-mounted electrofishing gear to collect largemouth bass (*Micropterus salmoides*) along shoreline habitats. This annual sampling method yields information about largemouth bass relative abundance, typically expressed using catch rates (catch-per-unit-effort, CPUE). Sportfish managers need reliable data to assess the population structure and monitor response to management strategies. However, our electrofishing catch and corresponding CPUE has been highly variable in coastal river systems of North Carolina (Barwick and Rundle 2007), possibly due in part to fluctuating streamflows, though that relationship has not been formally evaluated. This variability in CPUE often limits the ability to compare CPUE between years and detect trends in largemouth bass abundance. Because CPUE is interpreted as a quantitative measure of catchability and fish density (Arreguin-Sanchez 1996), a change in CPUE may reflect a change in density or catchability between sampling periods. Factors affecting catchability should be considered to ensure that observed changes in CPUE are related to changes in density.

Because certain aspects of electrofishing may contribute to the variation in catchability, assessment of individual environmental variables is necessary. Reynolds (1996) discussed electrofishing efficiency in great detail and mentioned three categories of factors that may affect efficiency: biological, environmental, and technical factors. Biological factors are related to the fish community and population characteristics (e.g., behavior, schooling, spawning), while environmental factors are related to water chemistry (e.g., conductivity, clarity, dissolved oxygen) and prevailing environmental conditions (e.g., water temperatures, approaching cold fronts, available habitat). Technical factors that may affect electrofishing efficiency include experience of personnel, electrofishing equipment, and sample design. Many technical factors may be controlled during electrofishing, unlike environmental or biological factors. During our annual sampling, the technical factors are usually similar (e.g., number of personnel, electrofishing boat, sample sites). To a lesser degree environmental factors are also similar because collections typically occur during the same time of the year at similar water temperatures. The same sites are sampled at the same time every year in an effort to limit variability from environmental and biological factors. However, estimates of CPUE are still highly variable between years, most likely due to differences in environmental conditions.

Electrofishing catch rates often vary with different environmental conditions. Electrofishing catch rates vary diurnally (McInerny and Cross 2000), between seasons (Sammons and Bettoli 1999, McInerny and Cross 2000), and within seasons (Van Horn et al. 1991). Electrofishing catch rates are correlated to water clarity, water temperature, and water conductivity (McInerny and Cross 2000), river stage (Pierce et al. 1985), annual rainfall and reservoir discharge (Buynak et al. 1999), and reservoir substrate (Sammons and Bettoli 1999). When sportfish managers determine what environmental variables affect catch, then that variability can be accounted for when designing sampling strategies, yielding more reliable comparisons between CPUE estimates. Our study objectives were to obtain weekly CPUE estimates of all largemouth bass collected and two size classes of largemouth bass, assess the relationship between CPUE and streamflow, and recommend modifications to sampling strategies to account for prevailing environmental conditions.

Study Area

The Neuse River originates in the north central piedmont of North Carolina and flows southeastward toward the central coastal plain before entering southern Pamlico Sound. The 16,037-km^2 Neuse River basin is the third largest in North Carolina, lies entirely within the state, and includes all or portions of 19 counties (NCDWQ 1998). From the base of Milburnie Dam, a small private hydropower facility located near Raleigh, the Neuse River flows unimpeded southeasterly into an estuary at New Bern and then continues into Pamlico Sound. Our study took place in the lower end of the freshwater (salinities 0.1–0.3 ppt in this study) portion of the river near Fort Barnwell downstream to New Bern (Figure 1). This area is generally composed of wide floodplains with low-lying swamplands. Monthly mean discharge (March–May) during a 10-year period in the study area ranged from 87–167 m^3 sec^{-1}, and the area is affected by wind and astronomical tides (USGS 2007). Primary littoral habitat consisted of flooded timber and wooded shoreline.

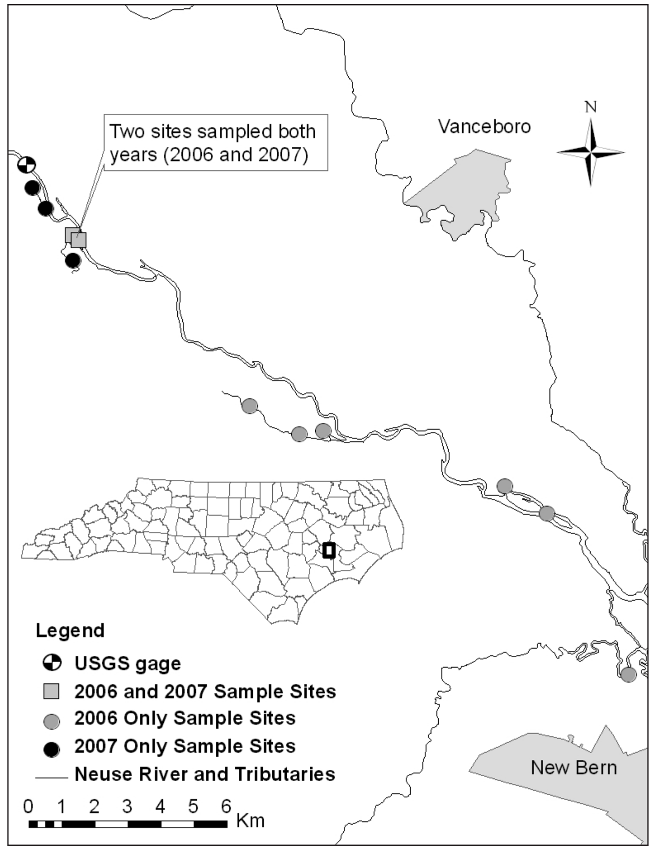

Figure 1. Map of sample sites within the lower Neuse River drainage in 2006 and 2007 and their relation to the USGS gage station. Gray squares indicate the two sites that were sampled both years. Gray circles indicate sites that were sampled only in 2006 and black circles indicate sites there were sampled only in 2007.

Methods

We evaluated largemouth bass electrofishing catch rates on a weekly basis from March to May in 2006 and 2007 on Neuse River tributaries in eastern North Carolina. In 2006, we sampled eight 400-m sites in four tributaries and in 2007 we sampled five 400-m sites in two tributaries (Figure 1) with boat-mounted electrofishing techniques (Smith-Root 7.5 GPP, 60 pps, DC) during daylight hours with one dip-netter and one boat operator. Sample sites were located in tributaries where we conduct our annual largemouth bass stock assessment to ensure that this study would relate to our typical stock assessments and that all available habitat was sampled. We sampled fewer sites in 2007 due to time constraints. Most sites were separated by at least 200 m, and time between samples at each site ranged from four to nine days. This sample design was chosen to eliminate bias from fish movement and repeated electrofishing (Cross and Stott 1975, Mesa and Schreck 1989). Because conductivities varied among sample sites in 2006, we varied electrical output from 500–1000 volts and 3–10 amps. At each shoreline site, the electrofishing boat was maneuvered to sample all accessible habitats available. Duration of electrofishing (time of current output) at each site was recorded (sec). Largemouth bass were collected as encountered, held in a livewell, and processed after each site was sampled. During processing, largemouth bass were enumerated and measured (TL, mm). Relative abundance of largemouth bass at each site was indexed by CPUE and expressed as number of largemouth bass captured per electrofishing hour (fish h^{-1}). Ambient conductivity (μS cm^{-1}) was measured at each sample site. Mean daily discharge (m^3 sec^{-1}) for each sample day was recorded at the U.S. Geological Survey (USGS) Neuse River Gaging Station near Fort Barnwell (Figure 1; USGS 2006, USGS 2007).

In 2007, we calculated wetted area (ha) at three gage heights

(0.8, 1.9, and 2.7 m) in the river basin around the sample sites. To calculate wetted area, we used 20 m LIDAR digital elevation models (DEMs) of the sample area (NCFMIP 2008) to create models of inundated river and floodplain habitat using a geographic information system (ESRI ArcMap 9.3). The models were created using the USGS gage heights as a reference. Because the Neuse River gage near Fort Barnwell is at sea level, every grid in the DEM with an elevation less than the gage height was considered inundated. The sum of the inundated grids in the DEM was used to quantify the amount of available habitat under different gage heights. Wetted area for each gage height was calculated in a separate data frame; however, each data frame was analyzed at the same fixed extent.

We analyzed the relationship between largemouth bass CPUE and environmental variables using two categories of largemouth bass size: less than stock size (< 200 mm), greater than or equal to stock size (≥ 200 mm), as well as all largemouth bass collected. Because preliminary analyses suggested that CPUE was higher and more variable when discharge was <85 m^3 sec^{-1}, we compared CPUE at high (>85 m^3 sec^{-1}) and low flows (<85 m^3 sec^{-1}) using a Wilcoxon rank sum test. To determine if sampling only during low flows increased our ability to detect a change in CPUE between sample years, we compared CPUE of all size ranges of largemouth bass from 2006 and 2007 at all flows, as well as low flows at two sites that were sampled in both years using a Wilcoxon rank sum test. Results were considered significantly different at $P \leq 0.05$. All statistical analyses were completed using program Statistix (Analytical Software 2000).

Results

Electrofishing CPUE of largemouth bass appeared to be strongly related to discharge in the lower Neuse River, but the relationship was not linear (Figure 2). Instead, we found that minor increases in streamflow between 60 and 100 m^3 sec^{-1} greatly reduced electrofishing CPUE. Above streamflow of 85 m^3 sec^{-1}, CPUE was usually low and only exceeded 20 fish h^{-1} in 3 of 41 observations in 2006 and 2007. At lower streamflows, CPUE commonly exceeded 100 fish h^{-1}, especially in 2007. In 2006, median CPUE (all largemouth bass) at low streamflow was 22.4 fish h^{-1}, but significantly lower (13.9 fish h^{-1}, $P < 0.01$) when streamflow exceeded 85 m^3 sec^{-1}. The differences in CPUE between high and low streamflow sampling events were larger in 2007. In 2007, median catch-per-unit-effort of all largemouth bass from sample days when streamflow exceeded 85 m^3 sec^{-1} was 7.1 fish h^{-1}, while median CPUE was an order of magnitude higher (87.8 fish h^{-1}) on days when streamflow was less than this threshold. In 2006 and 2007, we found that CPUE differed significantly between high and low flows for all size categories except for largemouth bass less than stock size in 2006.

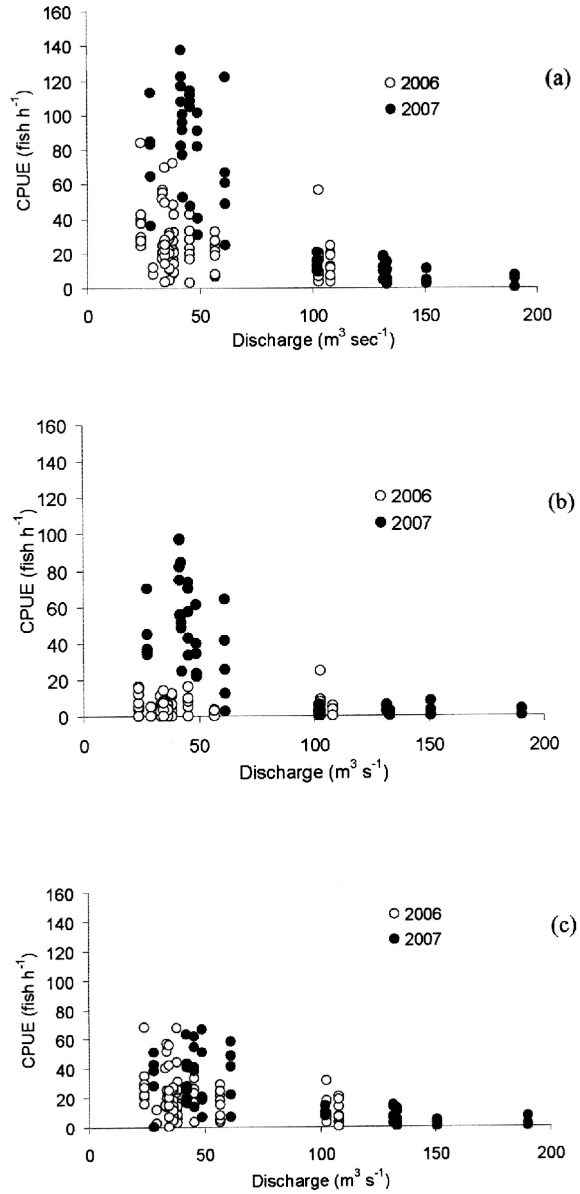

Figure 2. Relationship between discharge and CPUE of (a) all largemouth bass collected, (b) largemouth bass less than stock size, (c) and largemouth bass greater than or equal to stock size during 2006 and 2007.

In 2006, CPUE of largemouth bass less than stock size was higher during low streamflows, but the difference was not significant ($P = 0.59$, Table 1).

We documented increases in inundated habitat as streamflow increased (Figure 3). In the middle Neuse River area, inundated habitat increased by 859 ha (264 %) as gage height increased from 0.9 m to 2.7 m. However, the largest increases in wetted area (582 ha; 179 %) occurred between gage heights of 0.9 m and 1.8 m when water levels initially exceeded bank full elevation. This doubling of gage heights corresponds to a nearly threefold increase in available

Table 1. Wilcoxon rank sum test results for the difference in CPUE of largemouth bass at low (<85 m^3 sec^{-1}) and high (>85 m^3 sec^{-1}) discharge in 2006 and 2007 to determine if CPUE was similar at high and low flows.

Year	Size	Streamflow range	*n*	Median (fish h^{-1})	Mann Whitney *U*	*P*-value
2006	All fish	Low flow	64	22.4	762	< 0.01
		High flow	16	13.9	262	
	<Stock size	Low flow	64	3.7	557	0.59
		High flow	16	3.5	467	
	≥Stock size	Low flow	64	19.1	755	< 0.01
		High flow	16	7.6	270	
2007	All fish	Low flow	30	87.8	750	< 0.01
		High flow	25	7.1	0	
	<Stock size	Low flow	30	46.6	772	< 0.01
		High flow	25	2.1	9	
	≥Stock size	Low flow	30	32.9	704	< 0.01
		High flow	25	5.0	46	

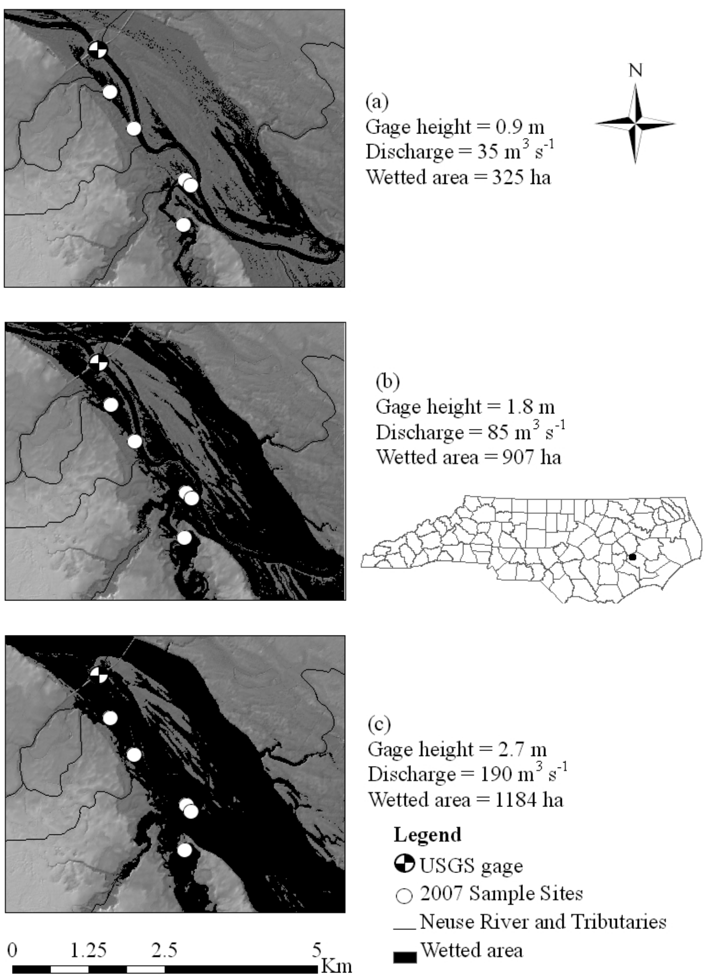

Figure 3. Map of 2007 sample sites within the Neuse River drainage (white dots) demonstrating the change in wetted area (black area) at 3 different discharges (wetted area estimate includes water that may not be connected to the main river channel).

habitat for largemouth bass. At higher gage heights (e.g., 1.8 and 2.7 m) the tributaries, adjacent floodplains, and main river channel habitat are interconnected with no clear boundaries among these three components of the river-floodplain system (Figure 3c).

To determine if streamflow masked differences in CPUE between years, we compared CPUE in 2006 to CPUE in 2007 at all observed levels of discharge, as well as CPUE at low flows (< 85 m^3 sec^{-1}) at two sites that were sampled in both years. Median CPUE of largemouth bass less than stock size was higher in 2007 (27.7 fish h^{-1}) than in 2006 (3.4 fish h^{-1}, $P = 0.02$) at all flows (Table 2). There were no significant differences in CPUE of all other size ranges of largemouth bass between 2006 and 2007 regardless of discharge. However, when analyses were limited to discharge < 85 m^3 sec^{-1}, median CPUE of all largemouth bass was higher in 2007 (79.3 fish h^{-1}) than in 2006 (22.4 fish h^{-1}, $P < 0.01$) and median CPUE of largemouth bass less than stock size was still significantly different (3.8 fish h^{-1} in 2006 vs. 56.3 fish h^{-1} in 2007, $P < 0.01$, Table 3). Accounting for the effects of higher discharge (i.e., exclusion of CPUE information collected when streamflows were > 85 m^3 sec^{-1}), we found significant differences in CPUE between 2006 and 2007 for all largemouth bass and largemouth bass less than stock size. When the effect of streamflow was not controlled during analysis, we found significant differences for only one size class of largemouth bass (less than stock size). However, significant

Table 2. Wilcoxon rank sum test results for the difference in CPUE of largemouth bass between 2006 and 2007 at all ranges of discharge at two sites sampled in both years to determine if CPUE was similar between years at all flows.

Size	Year	*n*	Median (fish h^{-1})	Mann Whitney *U*	*P*-value
All fish	2006	20	21.2	186	0.40
	2007	22	38.1	254	
<Stock size	2006	20	3.4	126	0.02
	2007	22	27.7	314	
≥Stock size	2006	20	17.8	284	0.11
	2007	22	11.8	157	

Table 3. Wilcoxon rank sum test results for the difference in CPUE of largemouth bass between 2006 and 2007 at low (<85 m^3 sec^{-1}) discharge at two sites sampled in both years to determine if CPUE was similar between years at low flows.

Size	Year	*n*	Median (fish h^{-1})	Mann Whitney *U*	*P*-value
All fish	2006	16	22.4	6	<0.01
	2007	12	79.3	186	
<Stock size	2006	16	3.8	0	<0.01
	2007	12	56.3	192	
≥Stock size	2006	16	19.3	91	0.83
	2007	12	19.9	101	

differences in CPUE of largemouth bass greater than or equal to stock size between 2006 and 2007 were not detected regardless of the amount of streamflow.

Discussion

Despite the high variability in CPUE at low flows, we detected significant differences in CPUE between high and low flows in 2006 and 2007. Largemouth bass CPUE during spring was consistently low when streamflow was high, suggesting CPUE statistics are strongly influenced by river discharge. Sampling during low streamflow conditions appeared to provide a more reliable estimate of largemouth bass relative abundance. Spring electrofishing for largemouth bass on the lower Neuse River should be limited to days when discharge is < 85 m^3 sec^{-1} if spring electrofishing is necessary. Barwick and Rundle (2007) concluded that fall electrofishing in the Neuse, Tar, and Northeast Cape Fear rivers of North Carolina was a viable alternative to spring electrofishing for largemouth bass stock assessments. Also, river discharges during fall should be more stable than spring discharges in these rivers. Thus, fall sampling for largemouth bass in these systems should be considered because environmental variables may be more consistent between years, yielding less variable estimates of CPUE between years.

While these results suggest that largemouth bass catchability is higher when discharge is <85 m^3 sec^{-1}, the relationship between largemouth bass density and CPUE remains unknown. Catch-per-unit-effort is the product of catchability and density (Arreguin-Sanchez 1996); therefore, to understand fluctuations in CPUE it is important to determine the relationship between density and CPUE. As a result, largemouth bass population estimates are needed to determine if differences in CPUE at different levels of discharge are the result of changes in catchability or density of largemouth bass.

In this study we found that largemouth bass CPUE was consistently low at discharges exceeding 85 m^3 sec^{-1}, suggesting that largemouth bass are less vulnerable to capture when streamflow is high. Norris et al. (2010) also noted reduced electrofishing catch rates of largemouth bass in the Mobile-Tensaw River Delta during periods of high flow. Pierce et al. (1985) found a similar negative relationship between CPUE of freshwater drum (*Aplodinotus grunniens*), white bass (*Morone chrysops*), bluegill (*Lepomis macrochirus*), and sauger (*Sander canadensis*) with river stage on the upper Mississippi River. They attributed the low CPUE at high river stage to reduced fish abundance along the shoreline of their sample sites. In our study, low CPUE at high streamflow was most likely related movement of largemouth bass toward floodplain habitat. As streamflows approached 85 m^3 sec^{-1} in our study area, river-floodplain connections became established and floodplain habitat was readily available to largemouth bass (Figure 3b). At streamflows higher than this threshold, few boundaries appear to prevent largemouth bass from moving among floodplain, main channel and secondary channel habitats (Figure 3c). We suspect largemouth bass may move into the floodplain to take advantage of forage or spawning habitat. Raibley et al. (1997) found that largemouth bass year class strength on the Illinois River was higher in years with high discharge when floodplain habitat was available. They suggested that largemouth bass opportunistically occupy floodplain habitat for spawning and nursery functions. Therefore, CPUE in our study may have been affected by high discharge because largemouth bass occupied floodplain habitat that was inaccessible to our boat electrofishing gear. In the Neuse River, in the area of our 2007 sample sites, the amount of available habitat triples after a twofold increase in gage height and discharge (Figure 3b). If population levels remain stable, but amount of available habitat increases, capture vulnerability may decline resulting in a decrease in CPUE at high flows. Telemetry studies will be necessary to confirm these suspected behavior and movement patterns under high streamflow conditions.

Changes in other environmental variables at high flows as may have contributed to low CPUE estimates. Reynolds (1996) considered conductivity to be the most important environmental factor affecting electrofishing efficiency. During this study we noted that ambient conductivity decreased with increasing discharge. We also observed an increase in mean depth at sites and decreased water clarity at higher flows. These changes may have led to a decline in sampling efficiency due to poor visibility of stunned fish in muddy water or not stunning fish at all because electrofishing is a shallow water sampling gear (Reynolds 1996).

In this study, we demonstrated that largemouth bass electrofishing CPUE in Neuse River tributaries is lower and less variable during spring when discharge exceeds 85 m^3 sec^{-1}. To facilitate better comparisons between sample years, electrofishing efforts for largemouth bass should be implemented when discharge is < 85 m^3 sec^{-1} during spring in the lower Neuse River. Population estimates are needed to determine the relationship between CPUE and largemouth bass population size. Telemetry studies may provide additional information on largemouth bass behavior in response to changes in river discharge and help explain why largemouth bass CPUE is low during periods of high river discharge. Ultimately, application of these methods could be applied on a broader scale to evaluate the influence of river discharge on the variability in electrofishing CPUE of largemouth bass in other coastal rivers.

Acknowledgments

This project was funded through the Federal Aid in Sport Fish Restoration Project F-22. We thank Dr. Paul Vos, Department of Biostatistics in the School of Allied Health Sciences at East Carolina University for statistical consultation. K. Dockendorf, B. McRae, K. Nelson, C. Thomas, and D. Yow provided helpful comments on previous versions of this manuscript.

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