SMALLMOUTH BASS STOCKING ASSESSMENT IN THE BROAD RIVER AND LAKE JOCASSEE

COMPLETION REPORT

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Study Title: SMALLMOUTH BASS STOCKING ASSESSMENT IN THE BROAD RIVER AND LAKE JOCASSEE

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Summary

Smallmouth Bass *Micropterus dolomieu* have been stocked intermittently into the Broad River and Lake Jocassee, South Carolina, since 1984 and 1980, respectively. Each of those systems has developed popular Smallmouth Bass fisheries that produce trophy-sized fish. Numbers and sizes of Smallmouth Bass stocked have varied depending on availability. Small and large fingerling Smallmouth Bass are stocked each year; however, it was not known which size had the higher survival and contribution to the fishery. The contribution and relative survival of small (mean TL = 42 mm) and large fingerling (mean TL = 150 mm TL) Smallmouth Bass stocked during 2005 – 2010 into the Broad River, and during 2005 – 2006 in Lake Jocassee was evaluated by differentially marking with oxytetracycline. During 2005 – 2010 the total contribution of stocked smallmouth bass at age-1 to each year class in the Broad River ranged from 4% to 47% and was positively related to mean Spring (March – May) water flows. In the Broad River the relative survival of large fingerlings was 7.7 (Wald 95% CI 4.9 – 11.9) times greater than small fingerlings. In Lake Jocassee the contribution of stocked fish to each year class, during two years with adequate sample sizes, was 100% and the relative survival of large fingerlings was 177 times greater (Wald 95% CI 44 – 718) than small fingerlings. In Lake Jocassee Smallmouth Bass should be stocked each year; however, in the Broad River stocking Smallmouth Bass is only beneficial when mean spring water flows are average or above average. If SCDNR Smallmouth Bass production costs are similar to the national average ($0.69/small

fingerling and $2.49/large fingerling) then large fingerling Smallmouth Bass should be stocked in lieu of small fingerlings into both systems.

Introduction

Micropterus spp. stockings, especially Largemouth Bass *Micropterus salmoides*, are common throughout the United States. These stockings occur to satisfy various management goals including supplemental stockings to enhance year class strength (Boxrucker 1986; Mesing et al. 2008; Colvin et al. 2008), reestablishing sport fisheries (Buynak et al. 1991; Porta 2006) or altering the genetic composition of wild populations (Maceina et al. 1988; Gilliland 1994; Buckmeier et al 2003; Hoffman and Bettoli 2005). For Largemouth Bass the benefit (i.e., contribution and relative survival of various size stockings) of these stockings, particularly in reservoirs, has been extensively evaluated with widely varying success among studies (Boxrucker 1986; Hoxmeier and Wahl 2002; Mesing et al. 2008; Diana and Wahl 2009). Although Smallmouth Bass *Micropterus dolomieu* stockings are reportedly common throughout the United States, few published studies have evaluated the success of these management actions. The only published accounts of the contribution of stocked Smallmouth Bass to existing populations have occurred in streams (Larimore 1954; Brown 1961; Funk and Fleener 1974) and a large natural lake (Forney 1972) and have concluded that supplemental stocking of Smallmouth Bass is not an effective management technique. The year class contribution and relative survival of stocking various sizes of Smallmouth Bass into a large southeastern piedmont river and reservoir have not been reported in the literature.

Smallmouth Bass have been stocked intermittently into the Broad River and Lake Jocassee, South Carolina since 1984 and 1980, respectively. Each of those systems has developed popular fisheries that have demonstrated the ability to grow trophy-size Smallmouth Bass; the South Carolina state record (4.3 kg) was angled from Lake Jocassee. Numbers and sizes of fish stocked have varied greatly depending on availability. Routinely, small and large fingerling Smallmouth Bass are stocked each year; however, it is not known which of these stockings has the higher survival and contribution to the fishery. Identifying which stocking size has the greater relative survival and adjusting that value for production costs will allow hatchery managers to focus production on the most economically beneficial size group. The objectives of this study were to: 1) estimate year-class contribution of Smallmouth Bass stocked as small and large fingerlings into the Broad River and Lake Jocassee, and 2) determine which stocking strategy is the most cost effective.

Materials and Methods

Study Area

The Broad River basin is a major division of the Santee River drainage. It originates in North Carolina and dominates the central Piedmont of South Carolina (Figure 1). Within South Carolina, the Broad River basin encompasses 9,819 square km; the river flows approximately 170 km until it merges with the Saluda River, near Columbia, South Carolina, to form the Congaree River. Average annual discharge, based on mean daily averages, of the Broad River approximately 11 km downstream from the North Carolina state line was 1,546 cfs, while average discharge 16 km below Parr Reservoir, near Columbia, South Carolina, was 3,912 cfs during 1999-2009. Average annual water temperature at Carlisle, South Carolina (mid-length of the river), based on mean daily average was 17.9º C during 1999 through 2009, and average annual minimum and maximum water temperatures for that period were 2.7º C and 32.1º C, respectively. The Broad River is relatively shallow with few unimpounded areas deeper than 3 m. The majority of the habitat in the river is shallow sand-filled pools separated by bedrock shoals and gravel riffles. The river is interrupted by seven hydroelectric dams with run-of-the-river impoundments ranging in size from 101 ha to 1,781 ha.

This study focused on three sections of the Broad River; 1) the 11 km section between Gaston Shoals and Cherokee Falls dams (Gaston Shoals), 2) the 23 km section between Ninety-nine Islands Dam and the impounded area of Lockhart Reservoir (Ninety-nine Islands), and 3) the 25 km section between Neal Shoals Dam and the impounded area of Parr Shoals Reservoir (Neal Shoals) (Figure 1).

Lake Jocassee is a 3,061-ha impoundment on the Toxaway and Whitewater rivers in northwest South Carolina (Figure 2). The Lake Jocassee Dam was constructed in 1973 by Duke Power Company and is operated as a pump-storage reservoir for hydroelectric power generation. Lake Jocassee has a surface elevation of 338 m above mean sea level, a maximum depth of 107 m and an average depth of 46 m. The oligotrophic reservoir supports a two-story fishery that includes four *Micropterus spp.*, the introduced Smallmouth Bass and Spotted Bass *Micropterus punctulatus* as well as the native Largemouth Bass and Redeye Bass *Micropterus coosae*, and two introduced Salmonids (Brown Trout *Salmo trutta* and Rainbow Trout *Oncorhynchus mykiss*).

During the study period (2006 – 2011) Smallmouth Bass fisheries in both Lake Jocassee and the Broad River were managed with a 10 fish creel limit with no minimum size. As of 2012 both fisheries were managed under the statewide black bass regulation which allows no more than 5 combined Smallmouth Bass, Redeye Bass, and Largemouth Bass per day with a minimum length limit of 305 mm TL.

OTC Marking and Efficacy

Small fingerling (mean TL = 42 mm; range 26 - 63 mm TL) and large fingerling (mean TL = 150 mm; range 89 – 234 mm TL) Smallmouth Bass were reared and marked with oxytetracycline (OTC) at the Cheraw State Fish Hatchery in accordance with the SCDNR protocol for immersion marking juvenile fish (SCDNR 2005). Smallmouth Bass fry collected from spawning ponds were transferred to rearing ponds for 25-30 d until they reached small fingerling size and were harvested. Small fingerlings received a single OTC mark and were released at stocking locations or trained on commercial feed for 10-14 d, generally received a second OTC mark, and were then stocked into grow-out ponds where they were fed commercial feed until they reached large fingerling size. During 2007 large fingerlings did not receive their second OTC mark until their stocking date. All fish were marked in a 6-hour immersion at a concentration of 500 ppm OTC. Fish stocked as small fingerlings (single mark) were stocked during May and large fingerlings (double mark) were stocked during late October or early November 2005 - 2010.

To evaluate OTC marking efficacy up to 30 fish from each marking event were collected before fall stocking of large fingerlings, at that time both the first and second mark were evaluated, except during 2007 when fish received their second OTC mark just before fall stocking and were retained over winter and then reviewed for marks. Sagittal otoliths were removed from each fish, cleaned of connective tissue, dried with paper towels and placed in vials for storage. One otolith from each fish was then placed in a mold and embedded in an epoxy resin (Araldite®). A 1–2 mm-thick section was cut from the transverse plane of each embedded otolith with an Isomet® Low Speed saw (Buehler LTD, Lake Bluff, Illinois) equipped with a diamond wafering blade. Sections were mounted with an adhesive (Crystalbond ™ 509, Electron Microscopy Sciences) onto numbered microscope slides, sanded with 400-1500 grit sandpaper to remove saw marks, and polished on a felt pad with a 0.3-µm polishing compound. Prepared sections were examined independently by two experienced readers for fluorescent OTC marks with a Motic BA400 compound microscope (Speed Fair Co., Ltd, Hong Kong) equipped with a 100 W mercury arc light source.

Long-term OTC mark retention was evaluated to ensure that age-1 fish collected from the wild, up to 18 months post- marking, would retain their marks. Marked fish that were retained in hatchery raceways as broodstock and later expired were collected and their otoliths reviewed for OTC marks. Occasionally wild fish (unmarked) were added to existing broodstock; although the proportion of wild and hatchery reared broodstock in each hatchery pond was unknown the proportion of wild fish was much lower than hatchery-reared fish. The number of single- and double –marked fish retained as broodstock was also unknown.

Stocking

Stocking of small and large fingerling Smallmouth Bass occurred each year from 2005 through 2010. During late May small fingerlings were stocked into the Broad River and Lake Jocassee. Approximately 10,000 small fingerlings were equally divided and stocked at five sites into three sections (Gaston Shoals, Ninety-nine Islands, and Neal Shoals) of the Broad River (Figure 1) at an average rate of 16.2 fish/ha. Approximately 8,000 small fingerlings were divided equally and stocked into Lake Jocassee at two locations at an average rate of 2.6 fish/ha. During October approximately 2,800 large fingerlings were stocked in equal proportions into the Broad River (4.9 fish/ha) and Lake Jocassee (0.9 fish/ha), respectively, at the small fingerling stocking locations.

Field Data Collection

Boat electrofishing during late summer and early fall, prior to fall stocking of fingerlings, was used to collect Smallmouth Bass from each Broad River section during 2006-2011. Angling was also used to collect Smallmouth Bass when sufficient numbers were not collected with boat electrofishing gear. In Lake Jocassee during 2006 and 2007 spring (April and May) boat electrofishing was used to collect Smallmouth Bass from Lake Jocassee during standardized Largemouth Bass sampling that utilized a stratified random design; during 2008 – 2010 smallmouth bass were collected with targeted boat electrofishing along the Jocassee Dam and from an ongoing littoral gillnet sampling program.

All collected Smallmouth Bass were returned to the lab for processing. Total length (mm) and weight (g) were recorded and sagital otoliths removed from each fish. Age estimation and OTC mark evaluation were conducted for each otolith using the previously described methods.

Analytical Methods

The contribution of small and large fingerlings as well as naturally reproduced fish to each year-class was calculated by dividing the number of otoliths from each category by the total number collected. For the Broad River, linear regression was used to investigate the relationship between the total (small and large fingerlings) contribution of stocked Smallmouth Bass and mean water discharge (cfs) during spring (March – May) of each stocking year. Mean discharge was calculated from the Carlisle USGS gage (approximate midpoint of the river).

For the Broad River multinomial logistic regression was used to model the recapture probabilities (a measure of relative survival) of small and large fingerlings at age-1. The dependent variables were small-recaptured/small-stocked and large-recaptured/large-stocked. The independent variables were river section, collection year, standardized mean discharge (cfs) in each river section during spring (March – May) of each stocking year, and the interaction between size of Smallmouth Bass stocked (small or large) and standardized mean spring discharge during each stocking year. Mean spring discharge was calculated from daily average discharges collected from United States Geological Service (USGS) gages in each river section; Gaston Shoals (USGS #02153200), Ninety-nine Islands (USGS #02153551) and Neal Shoals (USGS #021564493). Standardized mean discharge was used to account for natural longitudinal variation in river discharge and was calculated for each section by subtracting the overall mean spring discharge during the study period from the observed mean spring discharge for each year class stocked and dividing that value by the standard deviation of mean spring discharges during the study period. To investigate the relationship between mean spring discharges and recapture probabilities of small and large fingerling stocked Smallmouth Bass a reduced regression model was used that included only the significant effects. A similar model was used to evaluate the recapture probabilities of Smallmouth Bass stocked into Lake Jocassee during 2005 and 2006.

Because production costs increase significantly with fish size due to a variety of factors (e.g., extended feeding, maintenance, mortality), recapture probability was used in conjunction with production costs to determine the cost benefit of each stocking size. Based on current national production costs of $0.69 for a two inch “small fingerling” and $2.49 for a 6-inch “large fingerling” Smallmouth Bass (Southwick and Loftus 2003) the recapture probability ratio would need to be at least 3.7:1 in favor of large fingerlings to warrant their stocking instead of small fingerlings.

Differences in CPUE of Smallmouth Bass collected during standardized spring electrofishing of Lake Jocassee were investigated using a two-way ANOVA by year and zone. Pairwise comparisons were facilitated with a Tukey test. Due to multiple collection methods (electrofishing and angling) in the Broad River CPUE was not calculated or compared. In the Broad River, mean lengths of age-1 fish were used to compare growth of the two sizes at stocking and wild fish. Differences in mean length of age-1 fish, in the Broad River, was investigated with a three factor ANOVA that included year class, river section, and fish type (small-stocked, large-stocked, or wild).

<u>Results</u>

OTC Marking Efficacy

Otoliths from at least 30 fish were reviewed from each marking event to evaluate marking efficacy during 2005 – 2010. Of the 413 otoliths reviewed only three otoliths were not marked (all other otoliths contained the appropriate number of OTC marks). Each unmarked otolith was from the 2007 year class; however, marking efficacy for that year class was > 97% and no adjustments were made to percent contribution for any year class based on marking efficacy. Long-term OTC mark retention was good. Between 2009 and 2012 fifty-four Smallmouth Bass broodstock between age-2 and age-5 expired and their otoliths were reviewed for OTC marks (Table 1). Ninety-six percent of otoliths reviewed had at least one OTC mark and most (71%) of those otoliths had two marks.

Broad River

During each year an average of 9,480 small and 2,800 large fingerlings were divided equally and stocked into the Broad River, South Carolina (Table 2). The number of otoliths from age-1 Smallmouth Bass successfully reviewed for OTC marks ranged from 39 to 193 per year. Reader agreement of the number of OTC marks from the otoliths of age-1 fish collected from the Broad River was excellent. The two readers independently agreed on 98% (N = 628) of the otoliths they reviewed. Between 2005 and 2010 the contribution of small fingerling fish at age-1 averaged 6% (range, 1% - 15%) while that of large fingerling-stocked fish averaged 17% (range, 1% - 44%) (Table 2). The total contribution of both sized stockings ranged from 4% to 47% and averaged 23%. There was a positive linear relationship between total contribution of stocked Smallmouth Bass and mean spring flows (March – May) ($P = 0.017$, $R^2 = 0.79$) (Figure 3). At flows < 3,500 cfs stocked Smallmouth Bass made a small contribution (< 9%) to each year class, while higher flows (> 3,800 cfs) resulted in larger contributions (>27%) of stocked Smallmouth Bass to each year class.

Collection year and standardized mean spring flow did not influence recapture probabilities of small and large fingerlings ($P > 0.05$) (Table 3). River section approached significance ($P = 0.055$). There were significant differences in recapture probabilities of small and large fingerlings and an interaction between stocking size and standardized mean spring flow. The overall odds of recapturing a large fingerling were 7.7 times greater (Wald 95% Confidence Limits 4.9 – 11.9) than recapturing a small fingerling.

To investigate the relationship between spring flows and recapture probabilities of small and large fingerlings a reduced regression model was used that included only the significant effects (Table 4). Recapture probabilities were low (≤ 0.01) in all river sections, especially at lower flows, for both stocking sizes and positively related to standardized mean flow (Figure 4). As flow increased the recapture probability of large fingerlings increased dramatically while that of small fingerlings remained low. For example, in the river section below Neal Shoals during low spring discharges (standardized mean flow = -1.3) large fingerling recapture rates were 2.3 time greater than small fingerling recapture rates and during high spring discharge (standardized mean flow = 1.2) large fingerling recapture rates were 12.9 times greater than small fingerling recapture rates (Figure 4).

There was no difference (ANOVA; P = 0.87) in mean length at age-1 of recaptured small fingerling (234 mm TL), large fingerling (235 mm TL) or wild (229 mm TL) Smallmouth Bass; however, mean size varied by year class (ANOVA; P < 0.0001) and section (ANOVA; P<0.0001); and there was a significant interaction between year class and section (ANOVA; P<0.0001) that precluded simple interpretation of the main effects. Mean length of age-1Smallmouth Bass at the Ninety-nine Islands and Neal Shoals sections showed similar trends in size among most years (Figure 5); however, the Gaston Shoals section had a much different relationship in mean size among years. As a result a two factor ANOVA, including fish type and section, was used to evaluate each section independently. Independent ANOVA by section resulted in no significant differences in mean length at age-1 among fish types (ANOVA; P > 0.11) and none of the interactions were significant.

Lake Jocassee

During each year an average of 8,395 small and 3,013 large fingerlings were divided equally and stocked at two sites into Lake Jocassee, South Carolina (Table 5). The number of otoliths from age-1 Smallmouth Bass successfully reviewed for OTC marks ranged from 2 to 94.

During the three years (2005, 2006 and 2009) when otoliths from at least 6 age-1 Smallmouth Bass were successfully reviewed for OTC marks the contribution of small fingerling stocked fish at age-1 averaged 7% (range, 1% - 17%) while that of large fingerling-stocked fish averaged 88% (range, 67% - 99%) (Table 5). The total contribution of both sized stockings ranged from 83% to 100% and averaged 94%.

Collection year did not influence recapture probability of Smallmouth Bass stocked into Lake Jocassee (Table 6). Size at stocking did influence recapture probability ($P < 0.0001$). The odds of recapturing a large fingerling were 177 times greater (Wald 95% CI 44 – 718) than recapturing a small fingerling. During 2006 – 2007 boat electrofishing CPUE of age-1 Smallmouth Bass did not vary between years (ANOVA; $P = 0.21$), but did vary among zones (ANOVA; $P < 0.001$). CPUE was significantly higher in Zone 1 (27.7 fish/h) than Zone 2 (0.8 fish/h) or Zone 3 (0.2 fish/h) (Figure 2).

Discussion

OTC marking was very effective for Smallmouth Bass. The only year when 100% of fish were not clearly marked was during 2007 when 97% of the fish reviewed for marks were properly marked with OTC. During that year, fish received a single mark before stocking into growout ponds for large fingerling production and as such received their second mark right before fall stocking. The fish that were retained to evaluate marking efficacy were not grown out sufficiently and most of the otoliths had their second mark at or near the otolith margin. OTC mark retention in the otoliths of expired broodstock was excellent with 96% of age-2 to age-5 fish containing at least one mark and most fish (71%) containing two marks. Although the exact number of marked fish in the broodstock collections was unknown, due to periodically adding wild-caught fish, and the number of OTC marks for each individual fish was unknown high mark retention was demonstrated. Jenkins et al. (2002) found that after 4.5 yr 100% of Red Drum *Sciaenops ocellatus* retained OTC marks in their otoliths.

In the Broad River the total contribution of stocked Smallmouth Bass in the fall of their second year to each year class averaged 23% (Range 4 – 47%). Contribution of stocked fish in the Broad River was considerably higher than that observed in a Missouri river where over a 6 year period of stocking 198 fish/ha a creel census found only 3.3% of Smallmouth Bass harvested were hatchery stocked fish (Funk and Fleener 1974). In Oneida Lake, New York a three year Smallmouth Bass stocking program resulted in a 6% contribution of stocked fish to the population three years after the final stocking (Forney 1972). Return rates of hatchery stocked Smallmouth Bass to the creel in previous studies have been poor (< 9.5%) (Brown 1961; Funk and Fleener 1974). Contribution of stocked fish to the 2005 and 2006 year classes in Lake Jocassee was 100%; no wild fish were detected in those year classes. The high contributions of stocked Smallmouth Bass to some year class's in South Carolina waters are atypical for supplemental *Micropterus spp.* stockings which generally have poor contributions to each year class (Ryan et al. 1998; Hoffman and Bettoli 2005), although some studies have experienced moderate (Mesing et al. 2008) and high contributions of stocked fish (Porta 2006).

In the Broad River the contribution of stocked fish to the 2005 and 2009 year class was 47 % and 46%, respectively, but the contribution of stocked fish to the 2006 - 2008 year classes averaged only 6%. During 2010 the contribution of stocked fish was intermediate (27%). Based on six years of data it appears that there is large annual variation in the contribution of stocked fish to each year class. That variation appears to be due, in part, to varying levels of river discharge. During 2005 and 2009 the Broad River experienced slightly below average spring water levels with a wet summer during 2005 (Figure 6). In each of those years stocked fish, particularly large fingerlings, made a substantial contribution to their respective year classes. However, during 2006-2008 river discharge was well below average for most of the year and the contribution of stocked fish was poor for both sized stockings, wild-spawned fish were a much larger proportion of the year class suggesting that natural reproduction was greater during low water years. Large variation in year class strength is common in lotic Smallmouth Bass populations (Cleary 1956; Funk and Fleener 1974; Paragamian 1984; Slipke et al. 1998; Buynak and Mitchell 2002; Smith et al. 2005) and has been frequently related to river discharge (Cleary 1956; Slipke et al. 1998; Buynak and Mitchell 2002; Smith et al 2005). Typically high flows have been associated with poor year classes (Slipke et al. 1998; Buynak and Mitchell 2002; Smith et al. 2005) and can result in year class failures (Buynak and Mitchell 2002; Smith et al. 2005). In the Broad River such a year class failure was evident during 2003 when mean spring flows (10,827 cfs) exceeded the 74-year period of record by 223%. Despite annual sampling during 2005-2011, that resulted in the collection and ageing of 1,579 Smallmouth Bass from 14 year classes (1997 – 2011), no fish from the 2003 year class were collected. In the Broad River it appears low spring flows produce stronger Smallmouth Bass year classes while average and presumably above average spring flows result in weaker year classes.

In both the Broad River and Lake Jocassee the recapture probability of stocked Smallmouth Bass was positively related to size at stocking. The overall recapture probability of fish stocked as large fingerlings was 7.7 times greater than those stocked as small fingerlings in the Broad River and in Lake Jocassee the recapture probability of large fingerlings was 177 times greater than small fingerlings. Brown (1961) noted that small size classes (< 113 mm TL) of stocked Smallmouth Bass had significantly lower returns to the creel than fish stocked at two larger size classes (114 mm – 176 mm TL and 177 mm – 239 mm TL). Few studies have evaluated the contribution of *Micropterus spp.* stocked at various sizes into the same system during the same year. Diana and Wahl (2009) evaluated the survival of Largemouth Bass stocked at four sizes and found small fingerling (55 mm TL) survival was very low and they were not collected in subsequent sampling, but there was no difference in the survival of 3 other sized stockings (med = 100 mm, large = 150 mm, and advanced 200 mm). Colvin et al. (2008) did not detect a difference in the contribution of Largemouth Bass stocked at 50 mm TL and 100 mm TL into backwaters of the Arkansas River; however, the 50 mm TL fish were stocked at five times the rate of 100 mm TL fish indicating the latter had greater relative survival. Conversely, recruitment to age-3 of stocked Shoal Bass *Micropterus cataractae* was related to size at stocking with large fingerlings (65 mm TL) contributing more to the adult population than small fingerlings (30 mm TL) (Porta 2006).

While the overall recapture probability of large fingerlings was greater than small fingerlings in the Broad River that discrepancy was largely related to spring flows. During years with low spring flows the recapture probability of small and large fingerlings was similar with each making a small (< 5%) inconsequential contribution to each year class. As flows increased the recapture probability of large fingerlings increased dramatically over that of small fingerlings. Small fingerlings stocked in May were subjected to the same flow conditions as wild fish during spring-summer and whatever mechanisms (e.g., reduced foraging success and reduced habitat availability) resulted in poor natural year classes likely negatively impacted small fingerlings stocked in the spring as well. High stream flows during and immediately following spawning has resulted in poor year class strength for Smallmouth Bass (Cleary 1956; Slipke et al. 1998; Buynak and Mitchell 2002; Smith et al 2005). Fish stocked in the fall were not subjected to high spring flow conditions during their early development which likely lead to their increased survival and year class contribution. Studies conducted in the southeastern United States have concluded that year class strength of lotic Smallmouth Bass populations are established before the end of their first year (Funk and Fleener 1974) and as early as September (Smith et al. 2005).

No differences in mean length at age-1 were detected among either sized stocked Smallmouth Bass or wild Smallmouth Bass within river sections of the Broad River. Larimore (1952) found only slight differences in growth of 4 stockings of Smallmouth Bass in a stream their first year and noted that the growth of stocked fish was similar to wild fish a year after stocking. In studies of Largemouth Bass that evaluated growth of wild and stocked fish one year after stocking no differences in growth were detected (Buckmeier and Betsill 2002; Colvin et al. 2008). Similarly growth of Largemouth Bass stocked at various sizes has generally not resulted in differences in fish size at age-1. Differences in long-term growth were not observed for three sizes (100 mm, 150 mm and 200 mm) of Largemouth Bass stocked into four Illinois reservoirs although a fourth stocking of small fingerlings (55 mm) had slower growth and poor survival (Dianna and Wahl 2009). In backwaters of the Arkansas River there were no differences in growth of Largemouth Bass stocked at 50 and 100 mm TL or wild fish (Colvin at al. 2008). In the Broad River there appeared to be differences in the mean TL of Smallmouth Bass at age-1 among year classes and river sections; however, an interaction between year class and river section clouded the analysis.

In Lake Jocassee CPUE of age-1 Smallmouth Bass collected with boat electrofishing gear was significantly different among sample zones with catch rates significantly higher in Zone 1 which was the zone where fish were stocked. The higher recapture rates from sites near the stocking locations may be due to limited dispersal of Smallmouth Bass stocked into reservoir habitat. Eighty-seven percent (n = 134) of Smallmouth Bass recaptured the spring following stocking were collected less than 800 m from the nearest stocking location. In lotic systems stocked smallmouth bass typically make long downstream movements. The majority of large juveniles and adult Smallmouth Bass stocked into Ohio streams moved more than 10 km (Wickliff 1933). In a Ohio river Brown (1961) found that the majority (64%) of Smallmouth Bass stocked in one year of the study were recaptured within ½ mile of their release location, although a smaller portion of the fish made rapid downstream movements of up to 70 miles; however, in the second year of the study all stocked fish were recaptured at least ½ mile downstream of the stocking location. The post stocking movements of Smallmouth Bass stocked into lentic systems have not been evaluated; however, studies that evaluated the movement of Largemouth Bass fingerlings stocked into reservoirs have consistently found limited dispersal of stocked fish. In a North Carolina reservoir the mean dispersal of stocked Largemouth Bass fingerlings from stocking sites was 1,100 m (Jackson et al. 2002) and in Texas and Tennessee reservoirs the majority (> 80%) of stocked fish remained within 1 km of the stocking location their first summer (Buckmeier and Betsill 2002; Hoffman and Bettoli 2005) leading the authors to suggest that dispersal may not be adequate to prevent localized competition for resources (Jackson et al. 2002) and that numerous stocking points located roughly 2 km apart would maximize the area affected by stocking (Buckmeier and Betsill 2002). Given the limited natural recruitment of Smallmouth Bass in Lake Jocassee, based on the high contribution of stocked fish at age-1, and the low recapture rates of stocked fish outside the zone where they were stocked it would appear that increasing the stocking locations may more evenly distribute fish throughout the lake and ameliorate possible density dependent factors (e.g., competition for food/habitat) that could negatively influence the survival of stocked Smallmouth Bass.

Recommendations

Broad River

In the Broad River the overall recapture rate of large fingerlings was 7.7 (95% CI 4.9-11.9) times that of small fingerlings and those recapture rates were significantly higher in four of the six study years (Figure 4). In three of those years stocked fish made a significant contribution to the year class (> 27%). If SCDNR Smallmouth Bass production costs are similar to the national average ($0.69/small fingerling and $2.49/large fingerling – Southwick and Loftus 2003) then large fingerlings should be stocked instead of small fingerlings. Based on the results of this study stocked Smallmouth Bass only make a significant contribution (> 25%) during years with average or above average water discharge and Smallmouth Bass stocking should be discontinued during low water years when average Spring flows (March – June) are less than 3,500 cfs at the Carlisle USGS gage.

Unfortunately, not knowing whether or not fish are needed for stocking into the Broad River until June, long after spawning and fry rearing, creates a logistical problem for hatchery production. Hatchery and fishery managers could consider multiple alternatives for distributing the annual Smallmouth Bass hatchery production. One method would be to produce only what is needed for Lake Jocassee and during average or above average discharge years divert some of that production to the Broad River. Alternatively, hatchery production could be maintained at current levels, to support both the Broad River and Lake Jocassee, and during low water years all fish could be stocked into Lake Jocassee. In years when all fish are stocked into Lake Jocassee the surplus fish should be divided equally and stocked at additional sites to maximize the area affected by stocking and reduce localized competition for resources.

Lake Jocassee

In Lake Jocassee the overall recapture probability of large fingerlings was 177 (Wald 95% CI 44 – 718) times that of small fingerlings. Small fingerling Smallmouth Bass should not be stocked into Lake Jocassee, but given their high contribution to each year class (> 67%) large fingerling Smallmouth Bass should be stocked each year if the objective is to maintain a quality Smallmouth Bass fishery. Given the limited catch rates outside the stocking area, managers should consider increasing the number of stocking locations with at least one stocking site in each zone.

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Tables

Table 1. The number of otoliths reviewed by age and number of OTC marks present for expired Smallmouth Bass broodstock at Cheraw State Fish Hatchery, South Carolina during 2009 -2012.

	Number OTC marks		
Age	0	1	2
2		5	7
3		1	17
4	1	2	11
5	1	7	2

Table 2. The number of small (mean TL = 42 mm) and large (mean TL = 152 mm) fingerling smallmouth bass stocked each year, the number of otoliths collected from age-1 smallmouth bass the following year and successfully reviewed for OTC marks, percent contribution of each size stocking at age-1, and the total contribution of stocked fish in the Broad River, South Carolina.

	Number stocked			Percent Contribution		
Year Class	Small	Large	N	Small	Large	Total
2005	8,200	2,800	55	4%	44%	47%
2006	11,340	2,000	160	3%	1%	4%
2007	12,000	3,226	193	5%	3%	8%
2008	8,500	3,500	97	1%	4%	5%
2009	10,000	3,500	39	15%	31%	46%
2010	9,000	2,100	84	10%	18%	27%

Table 3. Multinomial logistic regression results for the probability of recapturing smallmouth bass stocked at two sizes into three Broad River sections during 2005 – 2010.

Effect	DF	Estimate	SE	Wald Chi-Square	Pr>chiSq
Section	2			5.88	0.0553
Year	5			7.38	0.1938
Size	1	1.72	0.26	45.34	<0.0001
Standardized mean	1			2.26	0.1326
Standardized mean*type	1	0.83	0.30	7.50	0.0062

Table 4. Multinomial logistic regression results for the probability of recapturing smallmouth bass stocked at two sizes into three Broad River sections during 2005 – 2010.

Effect	DF	Estimate	SE	Wald Chi-Square	Pr>chiSq
Section	2			5.88	0.0529
Size	1	1.72	0.26	49.55	<0.0001
Standardized mean	1			0.59	0.4430
Standardized mean*type	1	0.69	0.26	7.03	0.00800

Table 5. The number of small (mean TL = 42 mm) and large (mean TL = 152 mm) fingerling Smallmouth Bass stocked each year, the number of otoliths collected from age-1 smallmouth bass the following year and successfully reviewed for OTC marks, percent contribution of each size stocking at age-1, and the total contribution of stocked fish in Lake Jocassee, South Carolina.

	Number stocked			Percent Contribution		
Year Class	Small	Large	N	Small	Large	Total
2005	9,000	5,000	94	1%	99%	100%
2006	10,000	2,375	44	2%	98%	100%
2007	7,500	2,500	3	0%	33%	33%
2008	7,975	2,688	2	50%	0%	50%
2009	7,500	2,500	6	17%	67%	83%

Table 6. Multinomial logistic regression results for the probability of recapturing smallmouth bass stocked at two sizes into Lake Jocassee during 2005 – 2010.

Effect	DF	Estimate	SE	Wald Chi-Square	Pr>chiSq
Year	1			0.024	0.876
Size	1	5.179	0.713	52.69	<0.0001

Figures

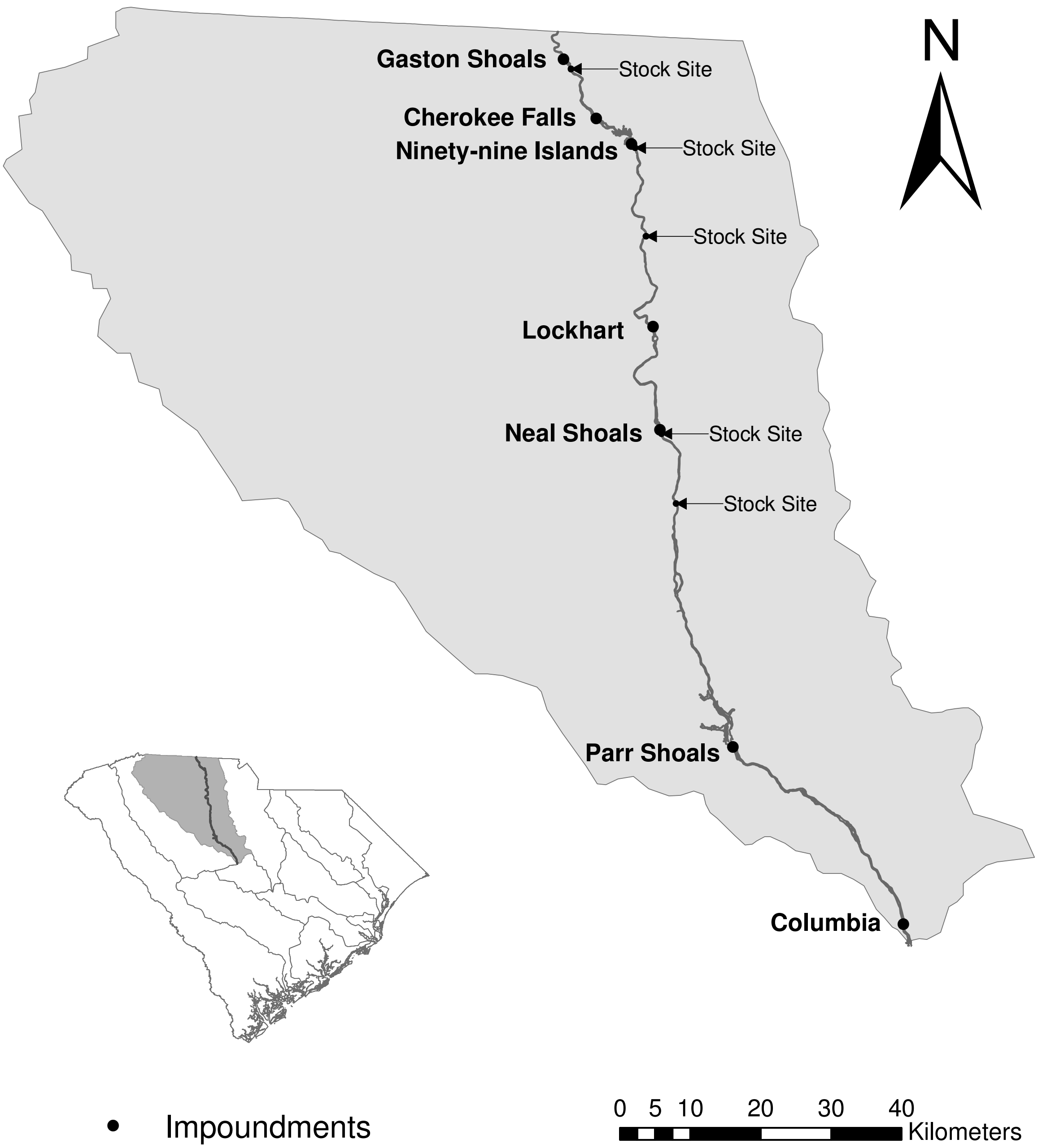

Figure 1. Impoundments and smallmouth bass stocking locations in the Broad River, South Carolina.

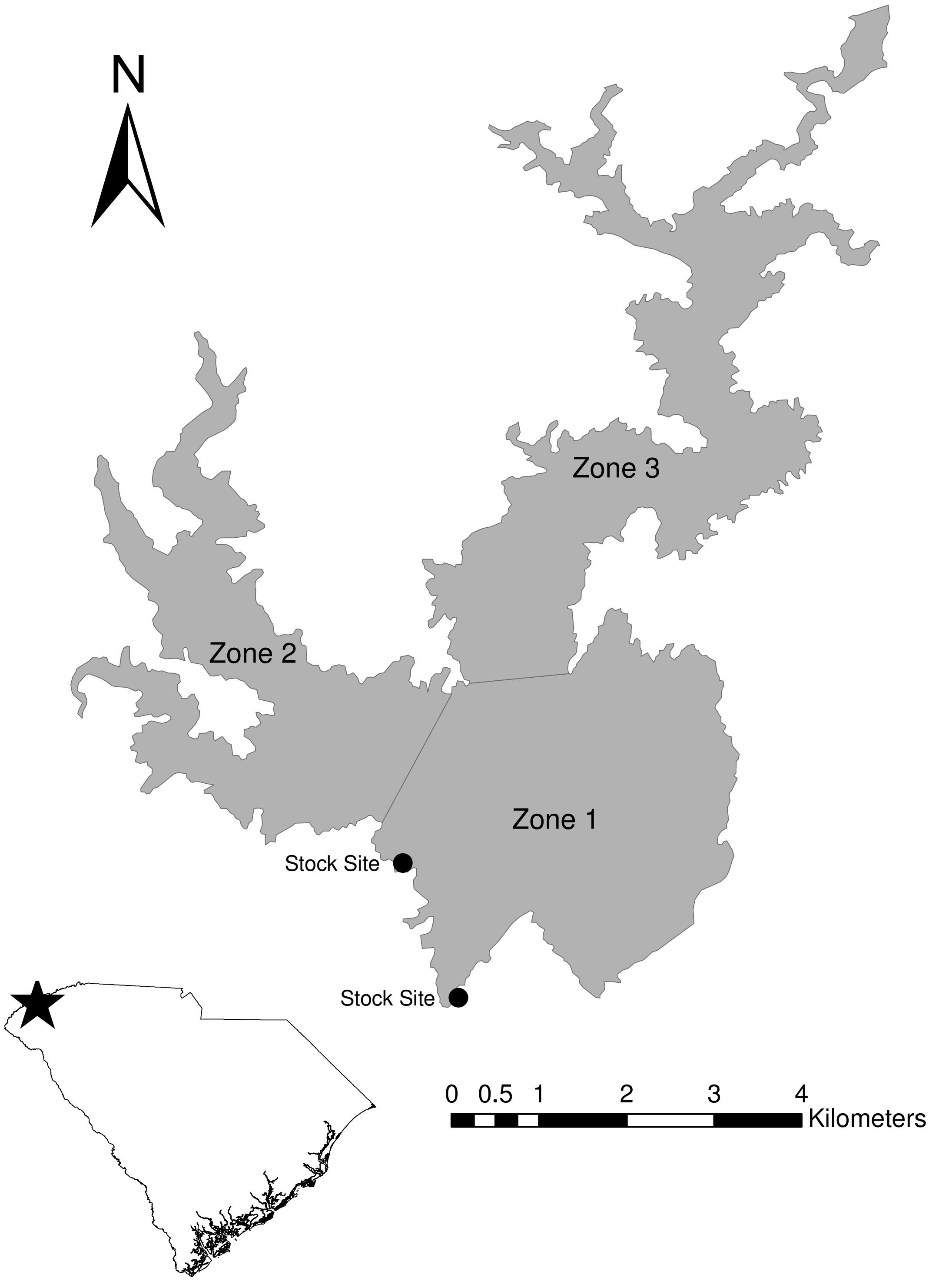

Figure 2. Stocking locations and boat electrofishing sampling zones in Lake Jocassee, South Carolina.

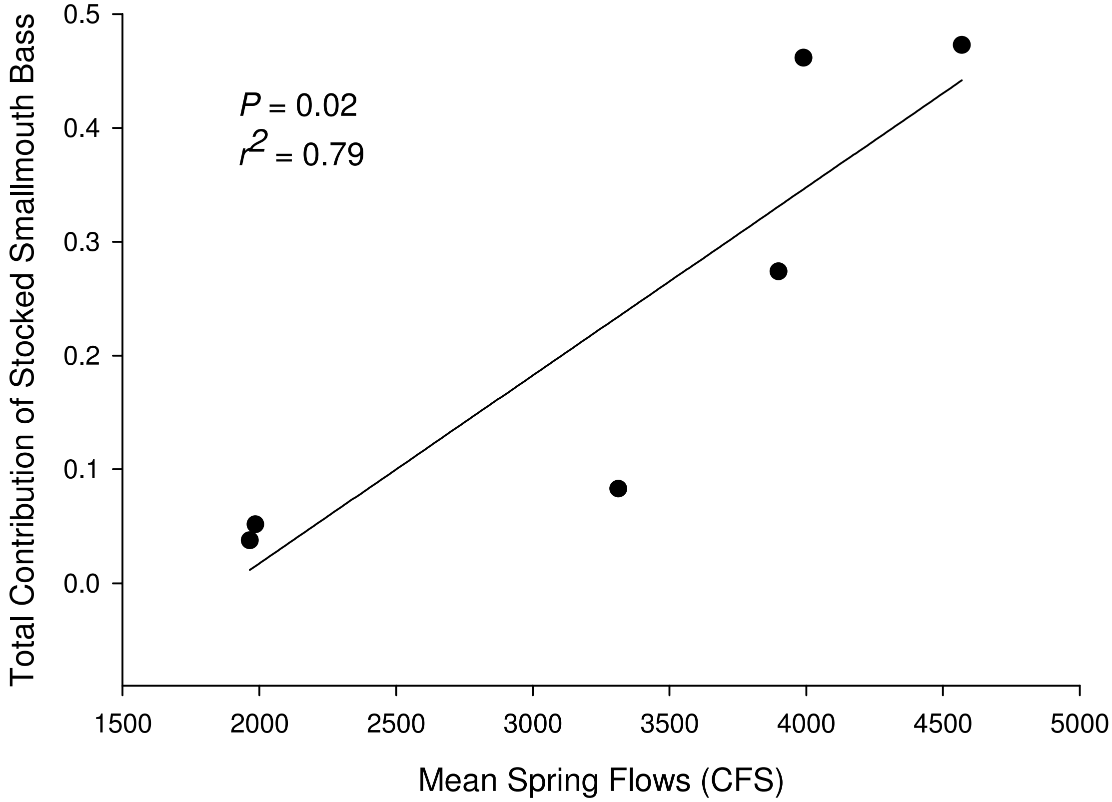

Figure 3. Total contribution of stocked smallmouth bass at age-1 versus mean flows (cfs) during spring (March – May) of each stocking year 2005 - 2010 in the Broad River, South Carolina.

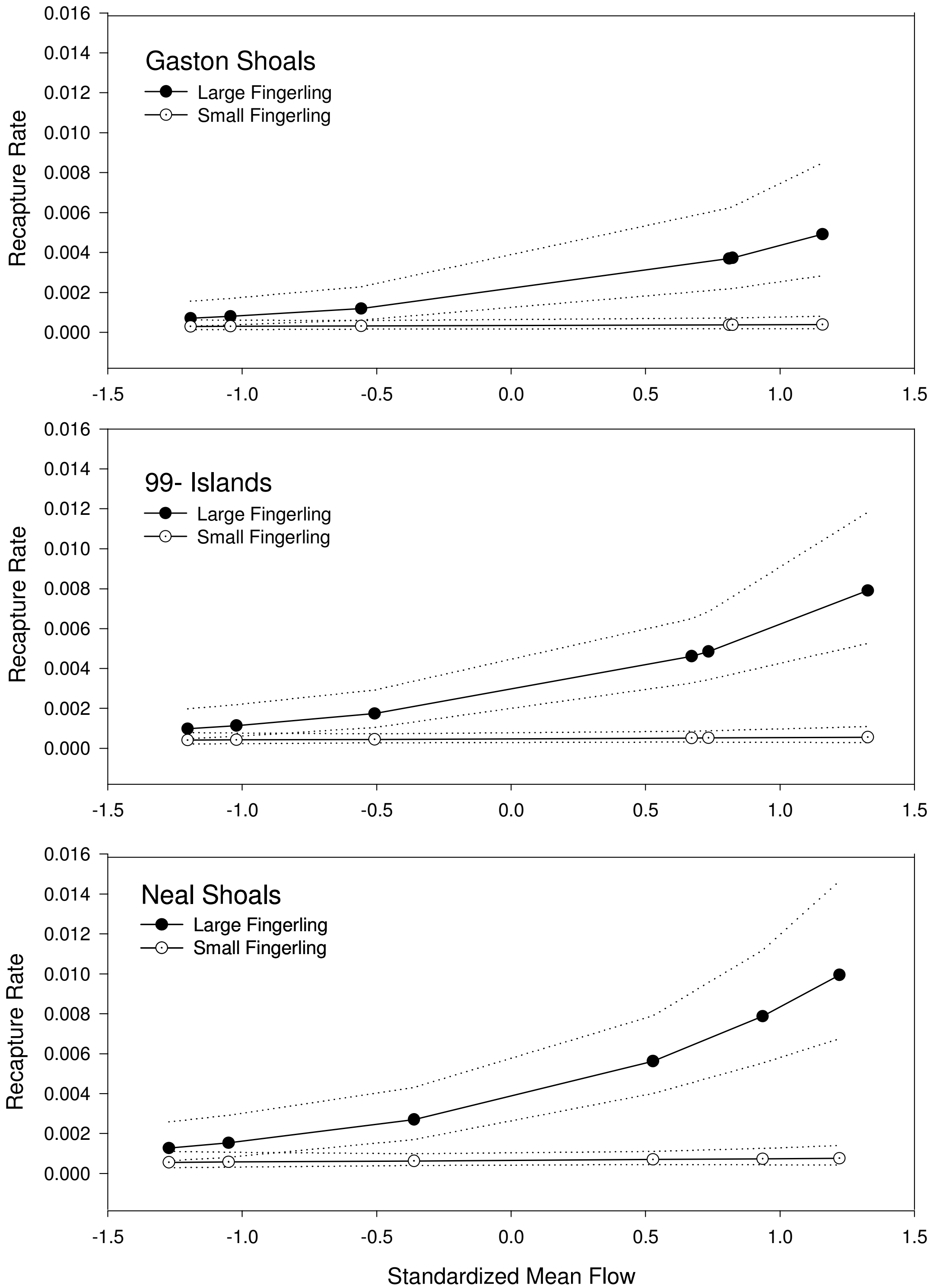

Figure 4. Recapture probabilities, and associated 95% confidence limits, at age-1 for small and large fingerling smallmouth bass stocked into three sections of the Broad River, South Carolina during 2005 – 2010 versus standardized mean flow during spring (March – May) of each stocking year.

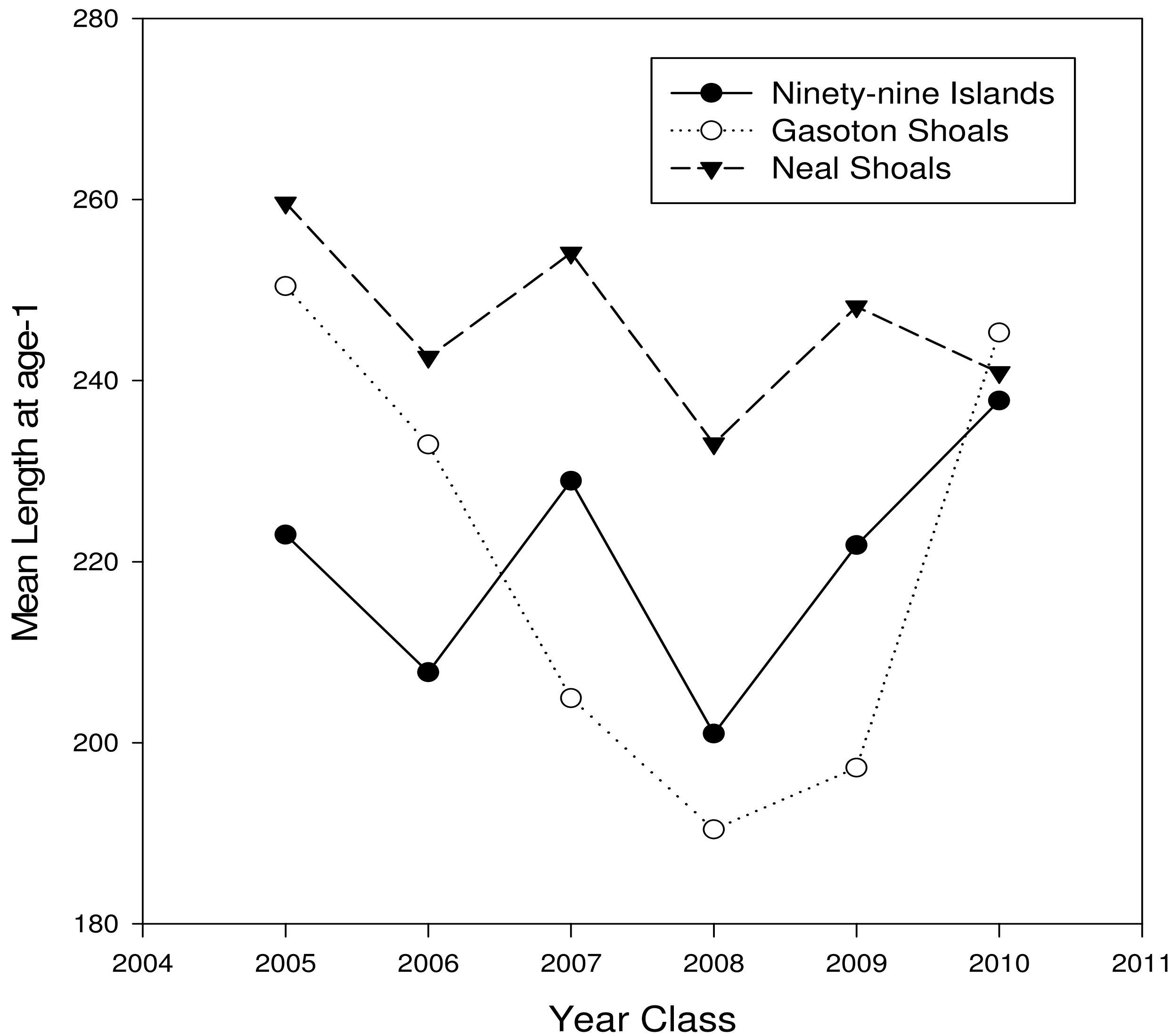

Figure 5. Mean total length (mm) at age-1 for six smallmouth bass year classes collected from three river sections during 2006 – 2011 in the Broad River, South Carolina.

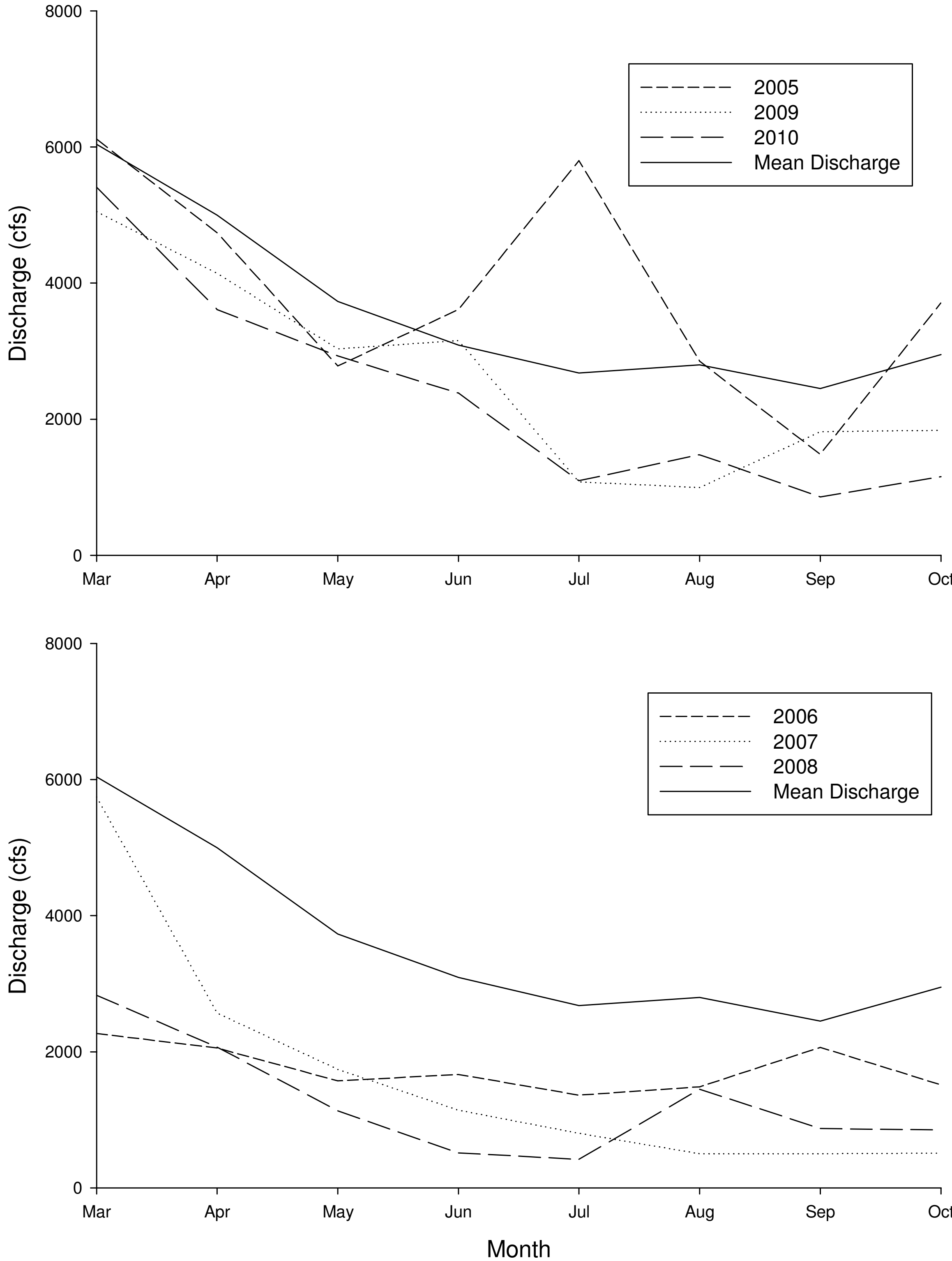

Figure 6. Average monthly discharge (cfs) of the Broad River at Carlisle, South Carolina, mid-point of the river, during 2005 – 2011.