Evaluation of Largemouth Bass Supplemental Stocking on a Virginia Coastal River

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Abstract: Coastal rivers can support quality largemouth bass (*Micropterus salmoides*) fishing, but recruitment failure and habitat availability can influence population size and structure because of the dynamic nature of these systems. Stocking success in coastal river systems has been rarely evaluated. This study examined stocking success of oxytetracycline (OTC) marked F_1 intergrade Florida (*M. s. floridanus*) and northern (*M. s. salmoides*) fingerling largemouth bass in the tidal Chickahominy River, Virginia. Fish were stocked at a density of 62 fish ha^{-1} in spring 2006 (mean TL = 54 mm) and 2007 (mean TL = 51 mm). We used standardized long-term electrofishing and creel surveys to assess individual cohorts and temporal population trends among various size groups. We determined percent contribution by analyzing otoliths for OTC to differentiate between stocked and wild largemouth bass. Forty percent of the preferred-size largemouth bass collected during 2009 had been stocked, dropping to 29% in 2010. Based on cohort catch-curve analysis, stocked largemouth bass had higher annual mortality than wild bass. Relative abundance of largemouth was higher in 2006–2010 as compared to other time periods. A high contribution of stocked fish existed in the fishery following stocking, which coincided with improved angler catch rates. However, fishery improvements were not solely attributed to stocking, as natural recruitment had also improved following prolonged drought. Given proper habitat conditions, supplementing largemouth bass fisheries in coastal rivers can accelerate recovery of depleted populations after prolonged or acute habitat disturbances.

Key words: Micropterus salmoides, tidal, oxytetracycline, angler catch rates

Journal of the Southeastern Association of Fish and Wildlife Agencies 4:18–24

While considered "transitional habitat" between rivers and estuaries, tidal freshwater/oligohaline systems are characterized by extreme environmental gradients often mediated by a combination of acute (e.g., hurricanes) and prolonged (e.g., extended drought, climate change; Doyle et al. 2007) impacts. Strong storms produce wind-driven storm surges and high freshwater inflows; conversely, drought conditions can greatly reduce freshwater runoff and allochthonous nutrient inputs (Lake 2008). Associated changes in salinities can cause shifts in primary production, and plant abundance in tidal freshwater marsh systems (Neubauer 2013).

Largemouth bass (*Micropterus salmoides*) can persist in coastal tidal rivers and estuaries providing important recreational fisheries (Meador and Kelso 1990), but populations are sensitive to habitat disturbances. Fish living in these dynamic systems have high energetic demands (Susanto and Peterson 1996) and must cope with associated dramatic shifts in both physical (e.g., macrophyte densities) and chemical habitat (e.g., salinity, nutrients) quality. Largemouth bass residing in brackish water can exhibit non-migratory behaviors and remain in estuaries despite salinity pulses (Lowe et al. 2009, Farmer et al. 2013). Largemouth bass recruitment in these unstable habitats can vary widely, and populations are vulnerable to extreme weather events, including hurricanes (Alford et al. 2009, DeVries et al. 2015). The establishment and maintenance of largemouth bass populations through supplemental stocking is often used in lakes and impoundments, with mixed success (Boxrucker 1986, Buynak and Mitchell 1999, Mesing et al. 2008). However, examples of supplemental stocking on existing largemouth bass fisheries in large, complex, tidal river systems are absent in the published literature, and only a couple of coastal river evaluations can be found in agency gray literature (Thomas and Dockendorf 2009, Love 2016).

Anglers consider the tidal portion of the Chickahominy River to be one of the premier largemouth bass fisheries in Virginia. However, the largemouth bass population experienced a period of poor recruitment in the early 2000s. This period of poor recruitment and the resulting declines in the largemouth bass population corresponded with prolonged drought conditions that persisted from 1999 through summer 2002 (NOAA 2016). Angler complaints, coupled with poor recruitment evidenced by monitoring data, prompted the Virginia Department of Game and Inland Fisheries (VDGIF) to initiate a supplemental stocking evaluation. If stocking was found to be viable in tidal river systems, fisheries managers would have a mechanism for augmenting weak year classes during periods of poor natural recruitment, resulting in more stable coastal largemouth bass fisheries. Thus, the objective of this study was to assess the effectiveness of supplemental largemouth bass stockings in the tidal Chickahominy River. Specifically, we wanted to evaluate the contribution and persistence of stocked largemouth bass to the fishery and assess temporal population trends.

Study Area

The Chickahominy River is located in eastern Virginia and is a tributary to the James River that drains approximately 1217 km^2 (Figure 1). A low-head dam (Walkers Dam; Figure 1) was constructed approximately 36 km upstream from the confluence with the James River to reduce salinity for upstream drinking water withdrawals. Above the dam, tidal influence is minimized, and stabilized water levels create lentic habitat. This study focused on the lotic, tidally influenced section below Walkers Dam, where spatio-temporal changes in water quality can occur daily with tide cycle and the magnitude and duration of freshwater runoff. The system supports a diverse assemblage of habitats including emergent marsh grass edge and other emergent macrophyte species (e.g., spadderdock [*Nuphar luteum*]), submersed macrophytes (e.g., hydrilla [*Hydrilla verticillata*]), various tree species including bald cypress (*Taxodium distichum*), and human-made structures such as rock bulkheads and dock pilings.

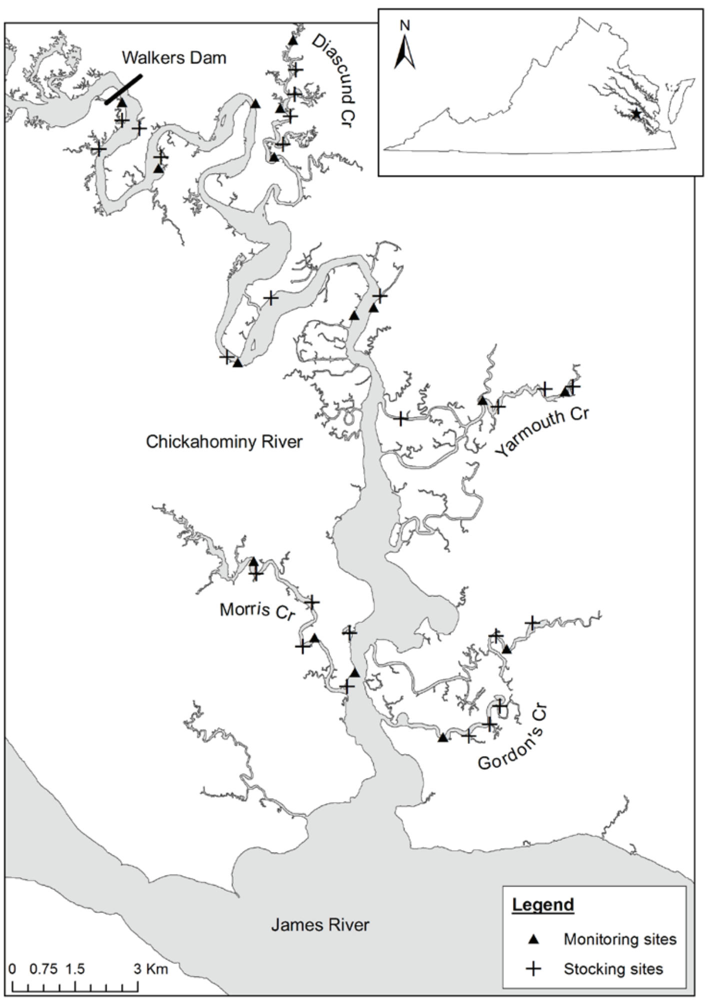

Figure 1. Stocking and boat electrofishing (monitoring) sites located in the Chickahominy River, Virginia, and its tributaries during the study period (2000–2015).

Methods

Approximately 114,000 (62 fish ha^{-1}) F_1 intergrade Florida (*M. s. floridanus*) and northern (*M. s. salmoides*) fingerling largemouth bass were marked with oxytetracycline (OTC) and stocked into the Chickahominy River in May 2006 and 2007. Hatchery personnel followed OTC marking protocols established by Fielder (2002). Fish were placed in water filled concrete raceways for 7 h with 700 ppm OTC concentration and a buffer solution of sodium phosphate. Mean total length (TL) of fish at the time of stocking was 54 mm in 2006 and 51 mm in 2007. Fish were removed from the stocking truck and placed into oxygenated livewells located on boats, whereupon they were transported to specific stocking locations and distributed throughout the mainstem and tributaries (Figure 1). Fish were stocked near visible habitat structure (e.g., macrophytes, woody debris) along shorelines. Each stocking year, a subsample of 100 fish was placed in aquaria and grown for 30 days prior to removing the sagittal otoliths for OTC mark verification (Heitman et al. 2006).

This reach of the Chickahominy River has been sampled annually in the fall (October–November) as part of the long-term VDGIF standardized sampling program, and these data were used to characterize the largemouth bass population from 2000–2015. All sampling occurred at fixed shoreline transects (generally 16 per year), which were initially chosen using a stratified random design. The river was stratified spatially based on sections between Walkers Dam and the James River confluence (i.e., upper, middle, and lower); sites within side tributaries (i.e., Morris Creek, Yarmouth Creek, Gordon's Creek, and Diascund Creek) were also stratified spatially based on distance from creek mouth. Occasionally, fewer sites (as few as 9) were sampled due to high salinity/conductivity, which caused gear efficiency issues. Sites were distributed throughout the mainstem and tributaries (Figure 1) with each site receiving 1000 sec of electrofishing effort. Surveys were conducted using a boat-mounted electrofishing unit (Smith-Root 9.0 GPP) that was operated along the shoreline. Two netters collected all largemouth bass encountered, and fish were measured (TL, mm) and weighed (g).

Otoliths were removed from sub-samples of fish collected each year to determine age and presence of an OTC mark (Table 1). Sub-sampling was used if >30 largemouth bass were collected at a site whereby every second or third largemouth bass was held back for OTC analysis. We first determined age, and otoliths from fish born

Table 1. A comparison of preferred-size (≥38 cm TL) stocked and wild largemouth bass during 2009 and 2010 for each individual cohort and the entire population in the Chickahominy River, Virginia. The number of total stocked largemouth bass was determined by oxytetracycline evaluation.

Type	Year	Total stocked	Total wild	Total	% Stocked	% Wild
Population	2009	23	35	58	40	60
2006–2007 Cohorts	2009	23	3	26	88	12
Population	2010	13	32	45	29	71
2006–2007 Cohorts	2010	13	17	30	43	57

in stocking years were examined for the presence of a fluorescent band indicative of the OTC mark. The percentage of marked fish from fall sampling in 2006 and 2007 were used to evaluate initial contribution of each stocked cohort. The persistence of these contributions was evaluated using samples collected from 2007–2010 and 2015. Due to concerns regarding long-term OTC mark degradation as well as the large sample sizes needed for evaluation, annual stocking evaluations ceased in 2010. However, an otolith collection for age and growth estimation of the largemouth bass population was conducted in 2015, and otoliths from the two stocking years were examined for OTC marks.

Access point creel surveys using non-uniform probability design were conducted in 2001, 2002, 2005, 2009, 2010, and 2014 to evaluate angler catch-per-unit-effort (CPUE: fish h^{-1}) of preferred-size (TL ≥38 cm) largemouth bass. Probabilities were stratified by time of day, day of week, and access point.

Data Analysis

We assessed the percentage of stocked fish within the 2006 and 2007 cohorts, as well as examined the percentage of stocked fish (both cohorts combined) of preferred-size largemouth bass in 2009 and 2010 to the overall population. We used the proportion of fish with OTC marks to describe percent contribution of stocked largemouth bass for the 2006 and 2007 cohorts, and calculated annual percentages through time to examine persistence of these contributions.

For each electrofishing survey and cohort, an individual Student's *t*-test ($\alpha = 0.05$ significance level) was conducted using SigmaStat version 3.5 software to evaluate if significant differences in mean TL existed between stocked and wild largemouth bass. We estimated CPUE of 2006 and 2007 cohorts individually from fall electrofishing surveys and applied percent contribution for each survey to obtain CPUE for stocked and wild largemouth bass. Stocked and wild CPUE was used to inform survival (S) estimates as a surrogate for annual mortality (i.e., $A = 1 - S$) using cohort catch curves (Miranda and Bettoli 2007).

To evaluate annual trends from the overall population, we calculated mean CPUE and 95% confidence intervals for each year and size group: <20 cm (juvenile), 20.0–29.9 cm (stock-quality), 30.0–37.9 cm (quality-preferred), and preferred ≥38 cm. We tested for differences in size groups among three time periods: 1.) pre-stocking (2000–2005), 2.) stocking and immediate post-stocking (2006–2010), and 3.) long-term (2011–2015) using the Monte Carlo analysis tool in the Poptools package for Microsoft Excel (Hood 2010). Parameter distributions (i.e, CPUE) were estimated from 1000 iterations of the Monte Carlo procedure, and differences in time periods were determined by overlap in distributions.

In 2009 and 2010, we distinguished between stocked and wild largemouth bass contributing to angler CPUE using the percent contribution of stocked fish within the preferred-size among all available cohorts. We assumed that the contribution of stocked fish obtained through electrofishing surveys would be proportional to angler catches.

Results

Validation of OTC revealed 100% marking rate on otoliths for both stockings, and a noticeable fluorescent band was found on marked fish throughout the study period (Figure 2). Fifty-five percent of largemouth bass collected in 2015 from 2006 and 2007 cohorts had a clearly marked OTC ring. We found 40% of preferred-size largemouth bass collected during the 2009 fall survey were of stocked origin while 29% were of stocked origin in 2010 (Table 1). Percentages were higher for stocked fish of preferred size among those within the 2006 and 2007 cohorts, but the drop from 2009 to 2010 was still evident (Table 1). Both stocked cohorts displayed high initial percent contribution; evaluation of the 2006 cohort

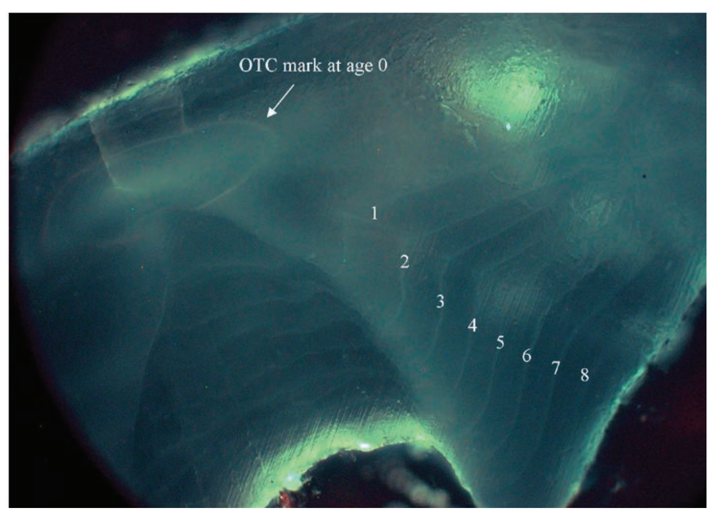

Figure 2. Photograph of sagittal otolith from a 2006 stocked largemouth bass (age 8) collected during fall 2015 sampling. The fluorescent band at age 0 clearly indicates the oxytetracycline (OTC) mark. The age is labeled to the corresponding annuli.

Table 2. Percent contribution (%) of stocked largemouth bass in the Chickahominy River, Virginia, throughout the study period. The cohort total represents the number of otoliths available within the specific cohort, and stocked bass were those marked with oxytetracycline (OTC).

				2006 Cohort			2007 Cohort		
Survey year	Survey total	Total aged	Total OTC evaluated	OTC presence	Cohort total	%	OTC presence	Cohort total	%
2006	566	418	279	158	201	79	–	–	–
2007	504	403	301	84	114	74	77	117	66
2008	352	273	151	35	50	70	47	101	47
2009	441	276	180	22	32	69	22	52	42
2010	289	194	115	8	14	57	11	30	37
2015	208	208	11	2	2	100	4	9	44

Table 3. Mean total lengths (Mean TL; cm) of stocked and wild largemouth bass for each survey and cohort in the Chickahominy River, Virginia. The mean growth differential (Mean diff.) indicates the difference between stocked and wild bass mean TL. For each sample and cohort, results are presented from a Student's *t*-test to evaluate statistical differences in mean TL between stocked and wild bass. Stocked bass were those marked with oxytetracycline (OTC), and sample size is given in parentheses. No wild fish from the 2006 cohort were collected during the fall 2015 survey.

	2006 Cohort				2007 Cohort			
Survey year	Stock mean TL	Wild mean TL	Mean diff.	Sig. diff.	Stock mean TL	Wild mean TL	Mean diff.	Sig. diff.
2006	19.0 (158)	14.4 (43)	4.6	$P < 0.05$	–	–	–	–
2007	32.0 (84)	27.3 (30)	4.7	$P < 0.05$	21.1 (77)	15.0 (41)	6.1	$P < 0.05$
2008	38.3 (35)	32.5 (15)	5.8	$P < 0.05$	31.9 (47)	28.6 (54)	3.3	$P < 0.05$
2009	40.7 (22)	34.9 (10)	5.8	$P < 0.05$	36.7 (22)	32.2 (31)	4.5	$P < 0.05$
2010	43.7 (8)	43.4 (6)	0.3	$P = 0.35$	39.7 (11)	38.9 (19)	0.8	$P = 0.45$
2015	57.6 (2)	–	–	–	47.9 (4)	48.1 (5)	0.2	$P = 0.49$

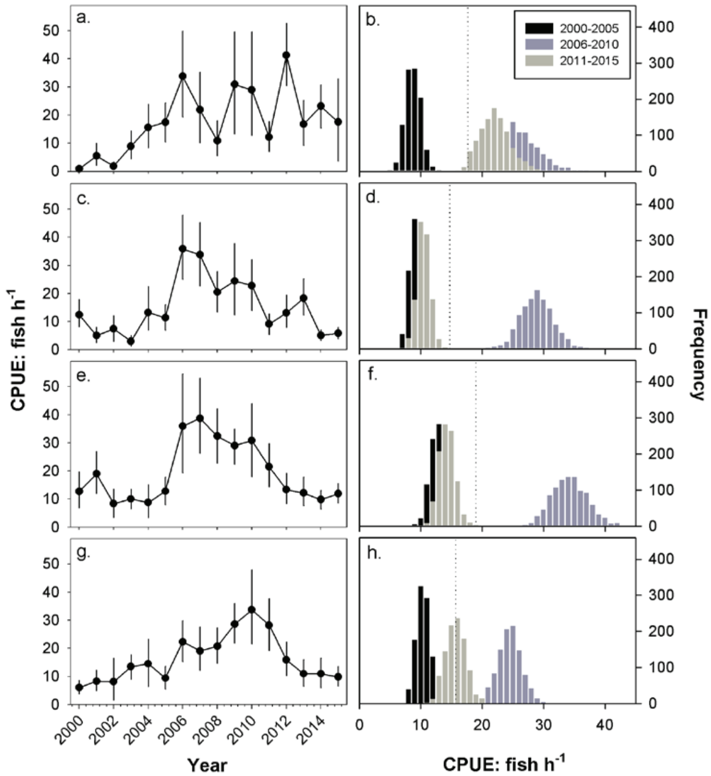

Figure 3. Largemouth bass catch-per-unit-effort data (CPUE: fish h^{-1}) are arranged by size group from top to bottom: <20 cm (a, b), 20.0–29.9 cm (c, d), 30.0–37.9 cm (e, f), and ≥38 cm (g, h). The left panels (a, c, e, and g) show temporal trends in mean CPUE (±95% confidence intervals) from 2000–2015. The right panels (b, d, f, and h) show CPUE distributions from 1000 iterations of the Monte Carlo procedure for each time period. Time periods shown in the right panels are: 2000–2005 (black bars), 2006–2010 (dark gray bars), and 2011–2015 (light gray bars). The gray vertical line indicates the long-term mean CPUE across all years.

revealed percent contribution of 79% stocked fish during the fall 2006 survey, while a 66% contribution of stocked fish to the 2007 cohort was estimated from the fall 2007 survey (Table 2). The 2006 stocked fish persisted at ≥57% contribution throughout the study, and stocked fish were still present in the system in 2015 (Table 2).

Mean TL of the 2006 stocked cohort was above the preferred size by the third fall after stocking (Table 3). Mean TL was greater in stocked fish than wild fish from 2006–2009 samples, but mean TLs were similar in 2010 and 2015 (Table 3). Based on cohort catch curves, stocked largemouth bass showed higher annual mortality than wild bass for 2006 and 2007 cohorts. Annual mortality for stocked largemouth bass was 34% and 27% in 2006 and 2007, respectively. Wild largemouth bass exhibited lower annual mortality in both years, 17% in 2006 and 10% in 2007.

Electrofishing CPUE of preferred-size largemouth generally increased from 2000–2010, and declined precipitously afterwards (Figure 3). A similar pattern was observed for stock-quality and quality-preferred largemouth bass. In contrast, electrofishing CPUE of juvenile largemouth bass increased annually through 2006, then varied unpredictably in subsequent years (Figure 3). Clear differences between size groups existed among time periods as evidenced by parameter distributions. For example, CPUE was higher during the period of stocking and immediate post-stocking (2006–2010), as compared to other time periods (Figure 3). With the exception of juvenile CPUE, there were no differences in CPUE between pre-stocking (2000–2005) and long-term (2011–2015) time periods (Figure 3).

Creel surveys in 2009, 2010, and 2014 were within the time frame when stocked fish were fully recruited to the fishery (i.e., > age 3; Table 3). Angler CPUE of preferred-size largemouth bass increased from 2001 (0.33 fish h^{-1}) through 2010 (0.68 fish h^{-1}): however, by 2014 the catch rate had decreased to 0.52 fish h^{-1} (Figure 4).

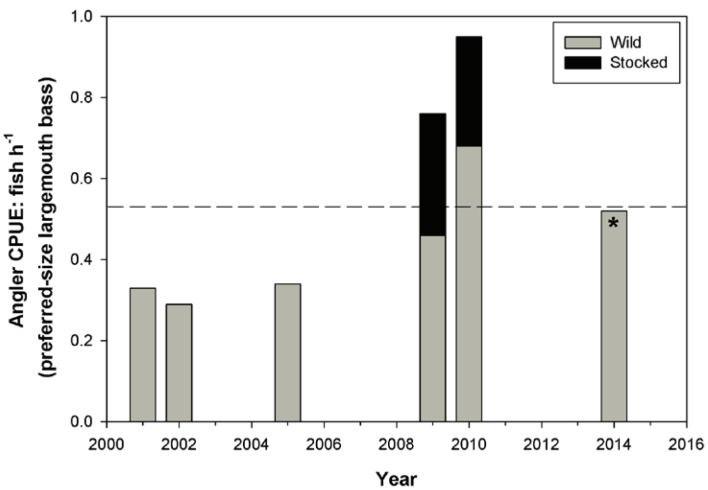

Figure 4. Angler CPUE of preferred-size (≥38 cm) stocked (black bar) and wild (gray bar) largemouth bass estimated for each survey year. The asterisk (*) indicates that otoliths were not collected and analyzed for oxytetracycline (OTC) in 2014. The average angler CPUE is represented by the dashed horizontal line.

Discussion

Stocking efforts coupled with high natural recruitment produced large cohorts entering the Chickahominy River largemouth bass fishery in 2006 and 2007. Our percent contribution data suggest that stocking resulted in a high contribution to the population, and stocked fish of preferred size were still abundant in 2009 and 2010 when angling was at its peak. Thus, improved angler success coincided with improvements in the largemouth bass population during the study. However, as also described in Buynak and Mitchell (1999), fishery improvements were not solely attributed to stocking, as natural recruitment had improved in the years following prolonged drought. Natural recovery of wild largemouth bass during supplemental stocking efforts has been documented following other weather-induced declines in largemouth bass populations (Alford et al. 2009, Thomas and Dockendorf 2009).

Stocking likely accelerated natural recovery of the largemouth bass population, but the effects of stocking were short-lived. Population trends indicate declines among all size groups from mid-2000s through 2015. With higher annual mortality of stocked cohorts relative to wild cohorts coupled with the leveling of mean length by 2010, wild largemouth bass appeared to have a competitive advantage over stocked F_1 intergrades. Dutton et al. (2005) found that the genetic structure of the Chickahominy River population had a 56.6% Florida allele frequency prior to stocking. Thus, stocked F_1 intergrades were essentially entering a bass population having similar genetic structure and experiencing selective pressures within a tidal river environment for decades.

The length advantage that F_1 intergrades retained until 2010 could be partially attributed to larger size at stocking compared to the size of naturally spawned fish during the stocking period. In both stocking years, stocked largemouth bass were significantly larger than wild bass after the first year and through ages 3–4. Mesing et al. (2008) found that an early size advantage allowed stocked largemouth bass to consume fish prey more efficiently for rapid growth over the first summer–fall. However, shorter body length of wild fish could be attributed to differing life history strategies and adaptations; estuarine largemouth bass are known to have shorter body length, higher relative weight, and shorter life span apart from typical landlocked freshwater populations (Meador and Kelso 1990, DeVries et al. 2015). The F_1 intergrades used in this study ("tiger bass," American Sportfish Hatchery LLC, Montgomery, Alabama) were the progeny of landlocked captive populations spawned and grown in highly productive rearing ponds at a lower latitude than the Chickahominy River. Other studies found no length differences between stocked and wild largemouth bass during stocking evaluations (Buckmeier and Betsill 2002, Heitman et al. 2006) or suggested poor growth relative to northern largemouth bass (Philipp and Whitt 1991).

Diana and Wahl (2008) indicated the need to evaluate stocked largemouth bass into adulthood, and found that percent contribution of stocked largemouth bass declined into adulthood in Illinois lakes. They attributed this decline to the potential advantage wild fish may have over stocked fish in terms of vulnerability to predation, susceptibility of starvation, and competitive advantage at larger sizes. We monitored stocked cohorts annually through ages 3–4, and again when fish were turning ages 7–8. Our percent contribution of stocked largemouth bass was high relative to some studies (Hoffman and Bettoli 2005, Heitman et al. 2006, Thomas and Dockendorf 2009). Thomas and Dockendorf (2009) found no detectable effects of stocked largemouth bass age-0 fingerlings on the Chowan and Roanoke rivers in North Carolina. Terre et al. (1993) showed examples of low (1%) and high (45%) stocked contributions to largemouth bass fisheries in several Texas reservoirs, and related those contributions to wild population density and historical recruitment. Stocking at a rate similar to the one used in our study, Mesing et al. (2008) documented a 40% contribution of stocked largemouth bass at age 0, and 37% at age 3 during electrofishing surveys at Lake Talquin, Florida.

During the years immediately following stocking, angler catch rates were at record highs for this fishery, but by the 2014 creel survey, anglers were experiencing average catch rates. Recent reports from local marinas indicated that fish greater than 2.3 kg are common in the system with an occasional report of a 4.5 kg fish being caught; fish of this size are highly unusual for this tidal system. Once older cohorts disappear, angler satisfaction will likely decline substantially. Electrofishing survey data in the Chickahominy River indicated below average relative abundance of largemouth bass across all major size categories for four successive years. Given the results of our study, VDGIF resumed the stocking program, stocking 40,000 and 114,000 largemouth bass in 2015 and 2016, respectively. The same source and strain of largemouth bass was used in these years because a stocking program based on wild brood stock has not been developed, and the genetic composition within the Chickahominy River shows similar allele frequency with F_1 intergrades (Dutton et al. 2005). Evaluation will continue through our tidal rivers monitoring program. We suggest that given proper habitat conditions, supplementing largemouth bass fisheries in coastal rivers can accelerate recovery of depleted populations after prolonged or acute habitat disturbances.

Acknowledgments

This project was funded by the Virginia Department of Game and Inland Fisheries under Sport Fish Restoration projects F-111-R and F-109D, Concerned Bass Anglers of Virginia, Bass Pro Shops, and FishAmerica Foundation/FLW Outdoors. Largemouth bass stocked during this work were produced by American Sport Fish Hatchery. We appreciate the efforts of C. Boyce, E. Brittle, S. Herrmann, C. Lim, D. Fowler, M. Norman, and the many volunteers who assisted with stocking. Extensive laboratory time was spent by C. Lim to age otoliths and evaluate OTC markings. The otolith photograph was taken by K. Johnson. We would like to acknowledge D. Goetz for analytical assistance. Special thanks to S. Sammons, and anonymous reviewers who offered improvements for this manuscript.

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