Evaluation of the Supplemental Stocking of Largemouth Bass Fingerlings into Lake Nottely, Georgia

Nick D. Jamison, *Georgia Department of Natural Resources, 2150 Dawsonville Highway, Gainesville, GA 30501*

Oda R. Weaver, *Georgia Department of Natural Resources, 2150 Dawsonville Highway, Gainesville, GA 30501*

Abstract: A five-year supplemental fingerling-stocking program was initiated in 2003 to counter decreases in largemouth bass (*Micropterus salmoides*) abundance and angler catch rates in Lake Nottely. Normal (25 mm TL) and advanced production (50 mm TL) fingerlings were stocked annually (April to June) from 2003 to 2007; all fingerlings were mass marked in oxytetracycline hydrochloride (OTC) to differentiate between stocked and wild largemouth bass. Age-1 stocked fingerling contribution ranged from 17%–100%, age-2 contribution ranged from 0%–44%, and age-3 contribution ranged from 8%–54%. Mean total length was similar between normal production and advanced production fingerlings at age 1 and age 3 ($P \geq 0.3137$). Normal production largemouth bass fingerlings contributed to each age cohort and cost less than advanced production fingerlings.

Key words: fingerling, largemouth bass, *Micropterus salmoides*, oxytetracycline, supplemental stocking

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According to the 2006 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation (U.S. Department of Interior et al. 2006), more than 161 million days of fishing were expended in the pursuit of black bass (*Micropterus spp.*); approximately 5% of these days were expended in Georgia. In a 2005 survey of state fishery agencies, there were 13 confirmed supplemental stocking programs for largemouth bass (*M. salmoides*) (i.e., northern strain largemouth bass (*M. s. salmoides*), Florida strain largemouth bass (*M. s. floridanus*), and intergrades [northern largemouth bass x Florida strain hybrid largemouth bass]) (Siepker and Casto-Yerty 2008). Largemouth bass supplemental stocking programs have been initiated to enhance population size (Hoxmeier and Wahl 2002), alter genetic composition (Hoffman and Bettoli 2005) or meet expectations of angling constituents (Buynak et al. 1999). Researchers have attempted to relate largemouth bass supplemental stocking efficacy to various factors including total length at stocking (Colvin et al. 2008), stocking date (Neal et al. 2002), hatchery diet (Heidinger and Brooks 2002, Porak et al. 2002), prey availability (Hoxmeier and Wahl 2002), and stocking density (Buynak and Mitchell 1999).

The success of supplemental largemouth bass stocking programs has varied among reservoirs. Based on literature review, Loska (1982) concluded that stocked bass provided little benefit to the sport fishery in large impoundments (≥200 ha). Neal et al. (2002) concluded that stocked largemouth bass contributed to a Puerto Rico reservoir fishery through age 2, but were almost absent by age 3. Despite high average stocked fish contribution (74%) over two seasons, Boxrucker (1986) reported angler catch rates and harvest were unaffected by supplemental stocking of largemouth bass fingerlings ranging from 35–64 mm total length (TL). Conversely, Buynak and Mitchell (1999) stocked advanced fingerlings (107–114 mm TL) into a Kentucky reservoir and observed an 11.6% contribution of stocked bass to legal harvest.

In many cases, stocking programs are evaluated based on stocked fish contribution to the age-0 cohort. Hoffman and Bettoli (2005) observed a 9% average contribution of stocked largemouth bass to the age-0 cohort in a Tennessee River impoundment. Relatively low age-0 stocked largemouth bass contributions (i.e., 2.0%– 2.6%) were also observed in a large North Carolina impoundment (Jackson et al. 2002). Stocked Florida largemouth bass contribution at age 0 ranged from 17%–40% on Lake Talquin, Florida (Mesing et al. 2008). In a two-year supplemental stocking study on 15 small (≤250 ha) impoundments in Illinois, age-0 contributions ranged from 0%–62% (Hoxmeier and Wahl 2002). Overall, age-0 stocked largemouth bass contributions have varied widely throughout the central and southeastern United States.

In order to determine stocked fish contribution, researchers have used oxytetracycline (OTC) immersion to differentiate stocked individuals from wild fish. OTC immersion has been used to evaluate black-nosed crappie (morphological variant of black crappie [*Pomoxis nigromaculatus*]) (Isermann et al. 2002), walleye (*Sander vitreus*) (Brooks et al. 2002), and sauger (*Sander canadense*) (Heidinger and Brooks 1998) supplemental stocking programs. Hoffman and Bettoli (2005) were the first to utilize OTC marking in a largemouth bass stocking assessment. Colvin et al. (2008) later used single and double-marking OTC techniques to evaluate the supplemental stocking of 50-mm TL and 100-mm TL largemouth bass fingerlings in the Arkansas River.

Historically, Lake Nottely has supported a largemouth bass fishery with an excellent reputation (Weaver 1985). Largemouth bass were of great importance to Lake Nottely anglers during the 1970s, but densities began declining by the late 1970s (England 1977). Prior to 1999, largemouth bass dominated the fishery by comprising 41% to 71% of the black bass catch. The decline in largemouth bass coincided with the illegal introduction and rapid population expansion of blueback herring (*Alosa aestivalis*), which were first collected in 1995. By 2003, abundance of adult largemouth bass (>290 mm TL) had declined 66% to 3.6 bass per hour of electrofishing, compared to 10.6 bass/hour for the period 1993-2000. Mean angler "fished for" success rate for largemouth bass in 2003 was 0.11 fish/hour, a 48% decline from the 1988–1999 mean of 0.22 bass/hour.

A five-year supplemental stocking program was initiated in 2003 to restore the largemouth bass fishery in Lake Nottely. The goals of the study were to: (1) restore adult largemouth bass (>290 mm TL) relative abundance estimates to >10 bass/hour of electrofishing, (2) measure the contribution of stocked fingerlings to the largemouth bass population, and (3) evaluate the cost-effectiveness of the supplemental stocking program.

Study Site

Lake Nottely, located in Union County, is a 1,692-ha impoundment of the Nottely River. The reservoir was impounded in 1941 and is operated by the Tennessee Valley Authority (TVA) as a multipurpose tributary reservoir (i.e., flood control, hydroelectric power, and recreation). Full pool elevation is 547 m above msl (mean sea level) and the reservoir level fluctuated an average of 10.5 m between summer and winter pool from 1972 to 2002. In 2003, TVA authorized an operations plan that provide for a reduced winter drawdown ranging from 7-8 m below full pool.

Methods

OTC Marking and Stocking Procedures

All stocked largemouth bass were mass marked with oxytetracycline hydrochloride (OTC) at hatcheries or in transit to Lake Nottely. Fingerlings were immersed in a 500 mg/L OTC bath for 6 h as described by Brooks et al. (1994). Normal production fingerlings (~25 mm TL) were single-marked and advanced production fingerlings (~50 mm TL) were double-marked. Single-marked fingerlings were immersed in OTC as fry, at 25 mm TL, or at 50 mm TL. Double-marked fingerlings were immersed in OTC at two of three developmental stages (i.e., fry, 25 mm TL, or 50 mm TL). To determine OTC marking efficacy, 360 fingerlings (165 single-marked and 195 double-marked) were held in aquaria for a minimum of 14 d before being frozen and sent to Southern Illinois University-Carbondale staff for mark verification.

Table 1. Fingerling type, average total length (TL mm), stocking date, OTC mark type, number stocked, stocking rate, and cost per fingerling of largemouth bass fingerlings stocked into Lake Nottely from 2003 to 2008.

Year	Production type	Mean total length (mm)	Stocking date(s)	OTC mark(s)	Number stocked	Stocking rate (*n*/ha)	Cost per fingerling (USD)
2003	Normal	59	6–28 May	Single	76,355	18.3	0.08
	Advanced	64	4 Jun	Double	10,239	2.4	0.30
2004	Normal	23	28 Apr	Single	21,000	5.0	0.09
	Advanced	56	7–16 Jun	Double	20,010	4.8	0.94
2005	Normal	25	28 Apr	Single	52,000	12.4	0.04
	Advanced	53	18 May–1 Jun	Double	52,127	12.5	0.18
2006	Normal	28	28 Apr–3 May	Single	100,603	24.1	0.05
	Advanced	47	16–19 May	Double	100,720	24.1	0.12
2007	Normal	27	20–27 Apr	Single	136,621	32.7	0.04
	Advanced	51	11–15 May	Double	136,662	32.7	0.09

Fingerlings were stocked by boat and distributed lakewide by targeting optimal habitat (i.e., coves with littoral vegetation or woody debris). Normal production fingerlings and advanced production fingerlings were stocked annually from 2003 to 2007 (Table 1). Normal production largemouth bass fingerlings were 23–59 mm mean TL and stocked in late April. Advanced production fingerlings were 47–64 mm mean TL and were retained in hatchery ponds to reach the 50-mm target stocking length. Overall, 386,579 normal production and 319,758 advanced production fingerlings were stocked from 2003 to 2007. Total annual stocking densities varied from 24.2 fish/ha in 2004 to 161.5 fish/ha in 2007.

Sampling and Analysis

Standardized sampling was conducted at a minimum of 29 fixed stations for 15 min each spring with boat-mounted DC electrofishing gear to collect representative samples of the largemouth bass population from 2004–2008. A maximum of 40 stations were sampled during an annual sampling event; total spring electrofishing effort ranged from 7.25–10.0 h annually. Spring sampling occurred 329–370 d after the final summer stocking event of the previous year. All black bass collected were weighed (g) and measured (mm TL). Additional non-standardized (i.e., effort and location) boat-mounted DC electrofishing was performed in the fall between 118 and 178 d after the final summer stocking event to provide insight on relative year-class strength and age-0 stocked fingerling contribution.

Pre-stock size (<230 mm TL) largemouth bass were retained each year from 2004 through 2008 during standardized spring electrofishing. A maximum of 54 adult largemouth bass (>290 mm TL) were sacrificed annually for OTC mark detection from 2006 through 2008. Sagittal otoliths were removed and sent to South-

Table 2. Number of bass collected *(N)*, percent contribution to age cohort, average TL (mm), and standard error (SE) for stocked and wild fingerlings collected during spring and fall electrofishing on Lake Nottely from 2003 to 2008. Age-2 stocked fingerlings recruited to the population in spring 2005; however, they were not retained for analysis.

Sample year	*N*	Percent contribution	Average total length (mm)	SE	*N*	Percent contribution	Average total length (mm)	SE
		Stocked age-0 bass				Wild age-0 bass		
2003	15	48	148	5.5	16	52	149	4.3
2004	0	0			4	100	129	11.3
2005	23	48	132	7.4	25	52	127	7.5
2006	3	25	171	22.6	9	75	155	6.3
		Stocked age-1 bass				Wild age-1 bass		
2004	23	56	184	5.7	18	44	186	6.1
2005	6	100	168	10.5	0	0		
2006	15	28	172	6.6	38	72	157	4.3
2007	9	47	179	8.4	10	53	173	10.5
2008	2	17	175	1.0	10	83	164	5.2
		Stocked age-2 bass				Wild age-2 bass		
2006	4	44	310	19.4	5	56	292	3.9
2007	34	38	267	6.7	56	62	263	4.6
2008	0	0			3	100	305	0.9
		Stocked age-3 bass				Wild age-3 bass		
2006	1	8			11	92	329	6.
2007	8	24	303	12.8	25	76	331	6.9
2008	15	54	325	5.9	13	46	324	5.5

ern Illinois University-Carbondale for aging and verification of the presence or absence of OTC mark(s). Annual contributions of stocked bass (i.e., normal and advanced production fingerlings) were composition percentages for wild and stocked fish within each length group (Gablehouse 1984) or age cohort. Potential differences in stocked contribution from age 1 to age 2 and age 2 to age 3 were determined using a chi-square test.

Largemouth bass catch rates (i.e., bass/hour) calculated from spring electrofishing were used as an index of largemouth bass relative abundance. A *t*-test was used to compare relative abundance of pre-stock (<230 mm TL) largemouth bass prior to supplemental stocking (1999–2003) and pre-stock size bass during and after supplemental stocking (2004–2008). A *t*-test was also used to measure relative abundance of adult largemouth bass (>290 mm TL) prior to stocking (2001–2004) and after stocked fish recruited to adult size (2005–2008). For all statistical tests, significance was determined at $\alpha = 0.10$.

Results

OTC Marking Efficacy and Stocking Mortality

Marking efficacy for single OTC marked fish was 100% across five years of stocking. On 25 of 195 double-marked otoliths, one of two marks was not visible. These 2004 advanced production fingerlings were marked as fry and at 50 mm TL. Even though fry markings were not visible, staff was still able to differentiate the advanced fingerlings from the normal production fingerlings (marked at 25 mm TL) by the location of the OTC mark on the otolith. Double OTC marking efficacy over the five-year supplemental stocking program was 87%. Overall, cumulative marking efficacy was 93% in single and double OTC-marked fingerlings.

Initial stocking mortality was estimated via visual observation of fingerlings upon release into the reservoir. Stocking mortality was generally estimated at 0.5%, with the exception of 2004 when high mortality was observed in a hauling tank loaded with 22,000 advanced fingerlings (58 mm mean TL) in transit to Lake Nottely. Based on the direct observation of 1,000 fingerlings held in aquaria, mortality of the 2004 advanced fingerlings was 55% after 70 h. The 2004 stocking numbers were adjusted accordingly to account for the high stocking mortality.

Stocked Fingerling Contribution and Abundance

Forty-one of 95 (43%) age-0 largemouth bass collected during fall electrofishing were stocked as fingerlings (Table 2). From 2003 to 2006, stocked fingerling contributions to age-0 samples ranged from 0%–48% (mean contribution = 30%). Normal production stocked fingerling age-0 contributions ranged from 0%–39%

Table 3. Number of stocked bass collected *(N)*, percent contribution to stocked cohort, average TL (mm) and standard error (SE) for advanced production and normal production fingerlings collected during spring and fall electrofishing on Lake Nottely from 2003–2008. Age-2 stocked fingerlings recruited to the population in spring 2005; however, they were not retained for analysis.

Sample year	*N*	Percent contribution	Average total length (mm)	SE	*N*	Percent contribution	Average total length (mm)	SE
	Normal production age-0 bass				Advanced production age-0 bass			
2003	12	39	147	6.6	3	10	150	9.8
2004	0	0			0	0		
2005	2	4	120	67.9	21	44	133	7.4
2006	2	17	153	23.0	1	8		
	Normal production age-1 bass				Advanced production age-1 bass			
2004	17	41	182	6.8	6	15	189	11.2
2005	6	100	168	10.5	0	0		
2006	0	0			15	28	172	6.6
2007	1	5			8	42	178	9.4
2008	0	0			2	17	175	1.0
	Normal production age-2 bass				Advanced production age-2 bass			
2006	4	44	310	19.4	0	0		
2007	6	7	285	22.4	28	31	263	6.6
2008	0	0			0	0		
	Normal production age-3 bass				Advanced production age-3 bass			
2006	1	8			0	0		
2007	1	3			7	21	303	14.8
2008	3	11	332	19.4	12	43	323	6.1

(mean contribution = 15%), while advanced production fingerling contributions ranged from 0%–44% (mean contribution = 16%).

Fifty-five largemouth bass fingerlings were retained and identified by OTC mark(s) as stocked age-1 fish and 76 fingerlings were identified as wild age-1 largemouth bass. Age-1 stocked fingerling annual contribution ranged from 17%–100% (mean contribution = 50%) and contribution of wild age-1 fingerlings ranged from 0%–83% (mean contribution = 50%). Mean age-1 advanced fingerling and normal fingerling annual contributions were 25% and 12%, respectively. Age-1 stocked contribution was not related to stocking density (bass/ha) ($F_{1, 3}$; $r^2 = 57\%$; $P = 0.1426$) or mean TL of stocked age-1 bass ($F_{1, 3}$; $r^2 = 9\%$; $P = 0.6222$). With the exception of 2005 sampling (advanced fingerling contribution = 0%), advanced fingerling contributions to the age-1 cohort exceeded 14%. Twenty-four normal production age-1 fingerlings and 31 advanced production age-1 fingerlings were collected from 2004–2008 (Table 3). Mean total length was similar between advanced and normal production age-1 stocked fingerlings ($t = 0.28$, df = 48, $P = 0.7842$).

Thirty-eight largemouth bass fingerlings were retained and identified by OTC mark(s) as stocked age-2 fish and 64 fingerlings were identified as wild age-2 largemouth bass. Age-2 stocked contribution ranged from 0%–44% (mean contribution = 27%). Stocked contribution was similar in the 2005 year class from age 1 to age 2 ($\chi^2 = 1.33$, df = 1, $P = 0.2488$). Age-2 advanced production fingerling contribution reached 31% in 2007, but advanced fingerlings were absent in 2006 and 2008.

From 2006 to 2008, 24 (33%) age-3 largemouth bass were collected and identified as stocked fish and 49 age-3 largemouth bass were collected and identified as wild fish. The 2004 and 2005 year-class contributions were similar between the age-2 and age-3 cohort ($P \geq 0.1385$). Stocked age-3 contribution ranged from 8% in 2006 to 54% in 2008 (mean contribution = 29%). Advanced fingerling contribution at age-3 more than doubled from 21% in 2007 to 43% in 2008. Age-3 mean total length was similar between advanced and normal production fingerlings ($t = 1.10$, df = 6, $P = 0.3137$).

Adult largemouth bass abundance prior to stocked fish recruitment into the population (2001–2004) ranged from 4.0 to 5.0 bass/hr (mean CPUE = 4.7, SE = 0.2). After stocked fish recruitment (2005–2008), adult abundance increased ($t = -2.80$, df = 3, $P = 0.0679$) and ranged from 5.2 to 10.6 bass/hr (mean CPUE = 7.9, SE = 1.1). Pre-stock size abundance (bass/hr) and adult size abundance were not related to age-1 contribution ($P > 0.50$).

Pre-stock size largemouth bass abundance ranged from 0.2 to 6.2 bass/hr before supplemental stocking (1999–2003) and from 1.0 to 8.8 bass/hr after the inception of the stocking program (2004–2008). Mean abundance of pre-stock size largemouth bass did not differ between the pre-stocking and post-stocking periods ($t = -0.52$, df = 7, $P = 0.6167$). Mean pre-stock and adult (>290 mm TL) abundance were maximized at an annual stocking rate of 62 fish/ha.

Production Costs

Normal production fingerlings and advanced production fingerlings averaged US$0.06 and $0.33 per fish, respectively. The approximate total cost of the five-year fingerling- stocking program was $75,000 ($15,000 annually). Normal production fingerling costs ($0.06 per fish) were 82% less than advanced fingerling production costs ($0.33 per fish).

Discussion

The range of stocking rates used in the current study (i.e., 24–162 fingerlings/ha) was similar to rates used in previous stocking evaluation studies. Mesing et al. (2008) stocked advanced fingerlings into a Florida reservoir at rates of 15–60 fingerlings/ha. In a stocking evaluation of a large Kentucky reservoir, a stocking rate of 24–32 bass/ha was found to be the optimal rate (Buynak and Mitchell 1999), as this was characterized by high fingerling survival and low production costs. The optimal stocking rate in the current study (i.e., maximum pre-stock and adult abundance) was slightly higher at 62 fingerlings/ha. Similarly, Mesing et al. (2008) observed the greatest age-0 contribution at a stocking rate of 60 fingerlings/ha.

Mean age-0 stocking contributions in the current study (i.e., 0%–48%) coincide with contribution ranges of 0%–62% and 17%–40% observed in Illinois and Florida reservoir stocking evaluations, respectively (Hoxmeier and Wahl 2002, Mesing et al. 2008). Fewer studies have used age-1 stocked contribution to evaluate stocking efficacy. Hoffman and Bettoli (2005) and Diana and Wahl (2008) recorded mean age-1 contributions of 2% and 17%, respectively. The age-1 mean contribution of 50% on Lake Nottely was double the observed contribution of Diana and Wahl (2008). Methods for assessing stocked contributions to adult age-classes have varied and include: contribution of bass >300 mm (Boxrucker 1986), contribution of bass >250 mm (Diana and Wahl 2008), and contribution of age-3 fish (Mesing et al. 2008). In the current evaluation, age-3 contribution was used to assess the contribution of stocked fish to the adult population. Mean adult contributions observed in previous studies were <11% (Boxrucker 1986, Diana and Wahl 2008), whereas mean age-3 contribution on Lake Nottely was 29%. Colvin et al. (2008) did not observe differences in mean total length amongst 50-mm fingerlings, 100-mm fingerlings, or wild fish collected 3 to 11 months after stocking. Mean total lengths of normal and advanced production fingerlings collected at age 1 and age 3 were also similar on Lake Nottely.

Stocking costs were lower on Lake Nottely compared to previous studies. Hoffman and Bettoli (2005) stocked largemouth bass fingerlings 35–64 mm TL into Chickamauga Lake, Tennessee, at an estimated cost of $0.35 per fingerling. In the present study, normal production fingerlings cost 5.8 times less to produce. Over a four-year period, Buynak et al. (1999) stocked subadult bass into a Kentucky reservoir at an estimated cost of $2.53 per fish.

Over the five-year supplemental stocking program, largemouth bass fingerlings contributed directly to the adult population. Contribution rates at age 1 and age 3 exceeded rates observed in previous studies. Based upon post-stocking period increases in adult largemouth bass abundance, stocked bass recruitment did not displace wild bass recruitment and adult abundance exceeded the established 10-bass/hr goal in 2007. To further evaluate stocking efficacy, a creel study should be performed to compare pre-stock and post-stock largemouth bass angler catch rates.

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