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[Article]

Growth, Dispersal, Mortality, and Contribution of Largemouth Bass Stocked into Chickamauga Lake, Tennessee

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Abstract.—Marked fingerling largemouth bass *Micropterus salmoides* (both northern *M. s. salmoides* and Florida subspecies *M. s. floridanus* and their hybrid) were stocked into Chickamauga Lake, Tennessee, to enhance angling and introgress the Florida subspecies into the local gene pool. We evaluated mass marking and stocking success by sampling the stocked fish for 1 year poststocking. More than 128,000 fingerlings (35–64 mm total length) were immersed in a solution of 500 mg/L oxytetracycline (OTC) for 6 h and stocked into four embayments in the lake in spring 2002; two additional embayments served as controls and were not stocked (these embayments contained only wild, indigenous fish). In a blind test, 97% of sagittal otoliths were correctly scored as marked or unmarked. In a subsequent test, the OTC marks were clearly visible on every otolith removed from 240 OTC-treated bass held for 30 d. Age-0 largemouth bass were sampled with DC electrofishing gear at 7–19, 44–61, and 119–139 d after stocking, and sampling was conducted along 100-m transects within 1 km of the stocking sites in each embayment. Of all recaptures in the first sample, 31% occurred more than 600 m from the nearest stocking site, indicating rapid dispersal by some fish. Survival of stocked and wild age-0 largemouth bass was similar and low (4.5–6.9%) in two embayments; in the other two embayments, stocked fish survived at lower rates (0–4.3%) than wild fish (33.7–49.9%). Mean catches of all age-0 largemouth bass in the first sample were positively related to the number of fish stocked. By October 2002, the mean catch of all age-0 largemouth bass was similar among embayments. Contribution of stocked fish declined to approximately 2% (2 of 91 fish) the following spring. Cost per fingerling increased from US$0.35 at stocking to $12.00 at 140 d poststocking. Increasing the abundance of largemouth bass was not the primary objective of this stocking effort, but stocked fish will have to survive much better if managers hope to introgress Florida largemouth bass genes into the resident population genome.

Fishery managers stock largemouth bass *Micropterus salmoides* into large reservoirs for several reasons, including enhancing weak year-classes, altering the population genetics of resident largemouth bass, or responding to angler demand (Keith 1986). Stocking programs are often initiated to produce results at whole-lake levels instead of at embayment-specific levels; consequently, the impacts of stocking programs are often underestimated (Copeland and Noble 1994). Not surprisingly, largemouth bass stocking programs have reported mixed results.

One subspecies, the Florida largemouth bass *M. salmoides floridanus*, is often stocked to improve the trophy potential of receiving waters through introgression. In Texas alone, more than 8 million fingerling Florida largemouth bass are stocked annually to increase trophy fish potential in the receiving waters (Schlechte et al. 2005). Stocked Florida largemouth bass sometimes contribute directly to cohort strength. For instance, Terre et al. (1993) reported that Florida largemouth bass stocked in three Texas reservoirs at rates of 30–200 fish/ha composed 1–45% of each cohort at 1–3 years after stocking. The contribution of Florida largemouth bass stocked into another Texas reservoir was 16% at 2–3 years poststocking (Maceina et al. 1988).

For each successful stocking of Florida largemouth bass outside its native range, there are just as many or more unsuccessful efforts documented

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in the literature. Florida largemouth bass stocked into a Texas reservoir at rate of 62 fish/ha contributed only 4% to cohort strength after 150 d (Buckmeier and Betsill 2002). Florida largemouth bass stocked into two other Texas reservoirs at rates of 2.8 and 8.8 fish/ha did not contribute to either population after 2–3 years (Ryan et al. 1998). Philipp et al. (2002) recommended discontinuing all stocking programs using Florida largemouth bass that were outside its native range due to concerns over outbreeding depression. Despite concerns over introducing nonnative stocks of largemouth bass into new habitats, stocking programs that aim to increase the trophy bass potential persist.

To determine the efficacy of any stocking program, stocked fish must be distinguished from wild fish, and many techniques have been developed to mark hatchery fish. Oxytetracycline (OTC) immersion has been used to successfully mark many species of fish, such as American shad *Alosa sapidissima* (Lorson and Mudrak 1987), walleyes *Sander vitreus* (Brooks et al. 1994), crappies *Pomoxis* spp. (Conover and Sheehan 1996), and yellow perch *Perca flavescens* (Brown et al. 2002). However, we found no reports in the primary literature of using oxytetracycline to mark largemouth bass.

In the late 1990s, local anglers perceived fishing for largemouth bass in Chickamauga Lake to be poor, which prompted supplemental stocking of hatchery-reared fingerlings by the Tennessee Wildlife Resources Agency (TWRA). Local anglers partially funded the costs of purchasing fingerling largemouth bass from private hatcheries. The primary objective of the stocking program was to establish a trophy Florida largemouth bass fishery via introgression of the Florida bass genome into the resident intergrade largemouth bass population. However, certified Florida largemouth bass fingerlings were not available in the numbers sought by TWRA (about 175,500); therefore, smaller numbers of northern largemouth bass *M. salmoides salmoides* and F_1 hybrids (northern largemouth bass × Florida largemouth bass) were also stocked. Our objectives were to (1) evaluate the utility of OTC to mass mark hatchery-reared age-0 largemouth bass, (2) describe dispersal and estimate growth and mortality of stocked and wild age-0 largemouth bass, (3) compare foraging efficiency of wild and stocked fish, and (4) determine the percent contribution of stocked largemouth bass to cohort strength.

Our experimental design did not allow us to compare the fate and performance of each subspecies; therefore, all fish were treated as the same species in our analyses and discussion. The unavoidable use of both subspecies and their F_1 hybrid added a potentially confounding effect to our experimental design because differences in growth and survival among largemouth bass subspecies have been noted for decades (e.g., Zolczynski and Davies 1976; Isely et al. 1987; Philipp and Whitt 1991; Philipp et al. 2002).

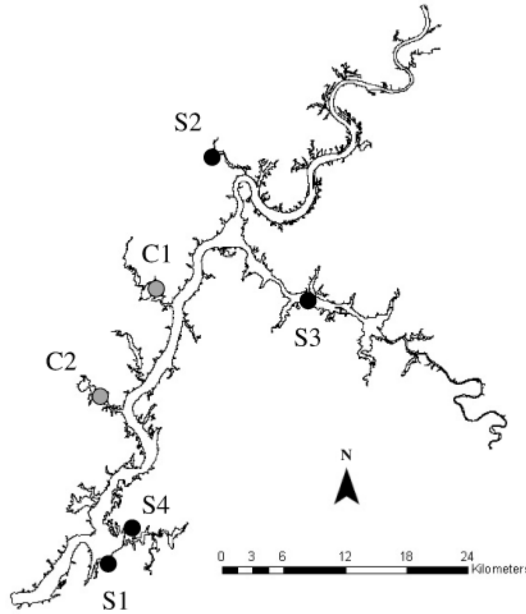

FIGURE 1.—Largemouth bass fingerling stocking sites (dark circles) and control sites (no stocking; gray circles) in separate embayments of Chickamauga Lake, Tennessee, where growth, mortality, dispersal, and contribution were subsequently evaluated in 2002.

Study Area and Stocking Sites

Chickamauga Lake is a eutrophic main-stem reservoir on the upper Tennessee River in eastern Tennessee. It was impounded in 1940, covers 14,330 ha at summer pool, and has a mean depth of 5.5 m. Water levels fluctuate about 2.3 m between summer and winter pools. Four embayments (Figure 1) were stocked in 2002 with a total of 128,265 largemouth bass that averaged 43 mm total length (TL; range, 35–64 mm). Stockings took place at a single boat ramp within each embayment (Table 1). Embayment S1, near Booker T. Washington State Park, was stocked with 14,825 northern largemouth bass on 17 June 2002. The Dayton Boat Dock embayment, S2, received 23,440 Flor-

TABLE 1.—Number and subspecies of stocked largemouth bass and study site descriptions of stocked (S) and not-stocked control (C) embayments in Chickamauga Lake, Tennessee. Habitat descriptions at electrofishing transects are from Hoffman (2003).

Embayment	Embayment code	Number stocked	Subspecies	Area (ha)	Shoreline length (m)	Mean shoreline slope (%)	Shoreline vegetation coverage (%)
Booker T. Washington State Park	S1	14,825	Northern	23	14,392	24.0	3.7
Dayton boat dock	S2	23,440	Florida	123	72,816	22.2	57.0
Hiawassee River	S3	75,000	Florida	630	129,435	32.3	5.7
Wolftever Creek	S4	15,000	F_1 Hybrid	330	135,969	40.0	0.6
Sale Creek	C1	0	NA	268	62,113	34.0	4.4
Soddy Daisy	C2	0	NA	287	106,689	23.5	0.3

ida largemouth bass on 30 May. In embayment S3, at the boat ramp where Highway 58 Bridge crosses the Hiwassee River embayment, 75,000 Florida largemouth bass were stocked on 31 May. The Wolftever Creek embayment, S4, was stocked on 31 May with 15,000 F_1 hybrid largemouth bass. All sites were separated by at least 17 km of shoreline. Two other embayments, C1 and C2, that were not stocked served as control embayments that contained only wild, indigenous fish. We did not anticipate that bass stocked at a single site in each embayment would disperse throughout each embayment, based on the findings of Jackson et al. (2002). Therefore, we did not calculate or consider the density of stocked fish in each embayment (i.e., number/ha or number/km of shoreline) in any analyses or discussions.

Compared with many large Tennessee reservoirs, the shorelines in the stocked and control embayments had modest slopes (22% to 40%; Table 1). When shoreline habitats were surveyed in August 2002, submersed, emergent, and floating aquatic vegetation was scarce (<6% coverage) at all but one embayment (Hoffman 2003).

Methods

Oxytetracycline marking.—Largemouth bass were marked in transit with 500 mg/L of OTC (Terramycin-343; Phizer Animal Health, Inc.) and 300 mg/L of sodium phosphate dibasic buffer for 6 h. The OTC and buffer came in powder form and were mixed in buckets using the water from the hatchery tanks. When the solution was mixed and the pH stabilized, the solution was poured back into the hauling tanks of the hatchery truck. When each truckload of fish was stocked, a random sample of at least 100 fish was removed and held for 30 d for subsequent verification of an OTC mark. Otoliths were mounted on microscope slides via cyanoacrylate glue. Otoliths were viewed with an epifluorescent microscope equipped with a 100-W halogen light source, a 450–490-nm excitation filter, a 515-nm barrier filter, and a 510-nm dichroic mirror. In a blind test, otoliths from 18 control fish (age-0 control fish collected from embayments where no fish were stocked) and 22 treated fish were randomly mixed and subsequently examined to determine ability to detect OTC marks.

Fish collection.—Ten 100-m transects were established to the right and left (N_{total} = 20) of each boat ramp where fish were stocked. All sampling during the first summer was within 1 km on each side of each stocking site, based on the finding by Jackson et al. (2002) that most age-0 largemouth bass did not move more than 1 km after they were stocked in a North Carolina reservoir. Age-0 largemouth bass were sampled using hand-held electrofishing gear (Jackson and Noble 1995), which consisted of a 2,000-W generator, a converter box that delivered 260 V of straight DC, and a handheld anode fitted with a triangular net. Age-0 fish were sampled at 7–19 d, 44–61 d, and 119–139 d after stocking. All sampling was conducted in shallow (<1 m) water near the shoreline at night. Of the 20 transects in each embayment, 8 were sampled per sampling date, except S1, where only 6 transects were sampled per date. In general, the odd-numbered transects were sampled on the first and third sampling dates, and the even-numbered transects were sampled on the second sampling date. This sampling scheme (i.e., not sampling the same transects in consecutive samples) was employed to reduce any concerns that declining catches over time were, in fact, due to our sampling and removal of fish. All age-0 largemouth bass observed were collected and measured (mm; TL), and their sagittal otoliths were removed and examined for OTC marks. The two control embayments were also sampled for age-0 largemouth bass the same weeks that stocked embayments were sampled.

We also sampled largemouth bass using boat-mounted electrofishing gear in the four stocked and two control embayments the following spring (April 2003) to assess stocking contributions at age 1. Within each embayment, five 100-m transects were sampled. Transects were located at 1 km and at 2–3 km on each side of the ramp, as well as adjacent to the boat ramp where fish were stocked. Each transect was electrofished for 10 min. Otoliths were removed from all fish less than 275 mm TL (maximum length at age 1). Otoliths of all age-1 fish were mounted and viewed under a microscope with an epifluorescent light source (as described above) to determine the percent contribution of stocked fish.

Diet.—Stomach contents were removed from a random subsample of five age-0 largemouth bass per electrofishing transect in each embayment on each of the three sampling dates. Prey items were categorized as either fish or invertebrates, and the presence or absence of fish and invertebrates was recorded.

Data analysis.—The percent contribution of stocked fish on each sample date in each embayment was simply the ratio of stocked age-0 fish to all age-0 fish in the electrofishing samples. Variation in the abundance of all age-0 largemouth bass (wild and stocked fish combined) among embayments for each sample period was examined using one-way analysis of variance (ANOVA) of log-transformed data, $\log_{10}(\text{catch} + 1)$, because of zero catches at some transects. Geometric mean [GM] catches were subjected to catch curve analysis ($\log_e$GM versus calendar day) to estimate instantaneous mortality rates of age-0 largemouth bass (wild and stocked fish combined) in each embayment. Relations between mortality during the first summer and instantaneous growth, initial mean catches, and numbers of fish stocked into each embayment were explored using simple linear regression and correlation analyses. Growth rates of stocked and wild fish were expressed as instantaneous growth in total length (percent per day) between sample periods.

Mortality rates (Z_{daily}) were also calculated separately for each cohort (six wild and four stocked cohorts) based on their geometric mean catches in the first and third samples. Mean interval survival rates of wild and stocked age-0 largemouth bass through the third (October 2002) sample were compared using a *t*-test after determining that the variances of the arcsine-transformed percentage data were similar ($P > 0.10$). The chi-square statistic was computed to compare diets of wild and stocked age-0 largemouth bass in terms of the percentages of empty stomachs, stomachs with invertebrate prey items, and stomachs with fish prey items.

All statistics were calculated and compared using SAS program statements (SAS 1996). Sample sizes were small (i.e., six cohorts of wild fish and four cohorts of stocked fish); thus, statistical power was going to be low for several important tests (e.g., comparing mean survival of wild and stocked fish). Therefore, we chose a significance level of $\alpha = 0.10$ for all tests to reduce the chance of making a type II error and possibly missing important biological effects. Accepting a type I error rate of 10% is common in field studies where the number of replicates is small (e.g., Bettoli et al. 1993; Sammons and Bettoli 2000; Binns 2004).

Results

Marking Efficacy

No initial mortality was observed for treated fish when they were stocked or when they were returned to the laboratory for the mark retention study. Of the 40 otoliths examined in the blind test, 97% were correctly identified (KJH) as marked or unmarked. There was one error of omission, but a mark was detected on subsequent review of the second otolith. Marks were visible on the otoliths of all 240 fish held for 30 d.

Dispersal, Growth, and Mortality

Of the 111 recaptures in the first sample (7–19 d poststocking), 32% were within 100 m of stocking sites and 31% were greater than 600 m from stocking sites. At 44–61 d poststocking, 44% of 30 recaptures were within 200 m of stocking sites, and 30% were greater than 600 m from the stocking sites. Similarly, at 119–139 d poststocking, two of six recaptures were within 200 m of the closest stocking site and two others were captured more than 600 m away from the nearest stocking site. The proportions of stocked fish found at different distances were similar on the first three sample dates, indicating that dispersal of stocked fish stabilized by 19 d poststocking.

In the first sample (7–19 d poststocking), stocked fish were longer on average ($N = 111$, $\bar{x} = 56.3$, SE $= 0.3$) than wild fish ($N = 867$, $\bar{x} = 45.8$, SE $= 1.0$) in the four stocked embayments ($t = -12.77$, df $= 977$, $P < 0.001$). Stocked fish maintained their length advantage over wild fish and were 26 mm longer on average than wild fish by the third sample at 119–139 d poststocking ($t = 1.82$, df $= 112$, $P = 0.0719$). However, only six stocked fish were recaptured in the October 2002 sample, and they displayed a wide range in lengths

TABLE 2.—Geometric mean catch (N/100 m), instantaneous mortality rate (Z_{daily}), and survival of wild and stocked age-0 largemouth bass in four stocked (S) and two not-stocked control (C) embayments of Chickamauga Lake, Tennessee. Interval refers to the number of days between the first electrofishing samples (June 17–24, 2003) and the third samples (October 14–17, 2002).

Embayment	Mean catch: First sample	Second sample	Third sample	Interval (d)	Z_{daily}	Interval survival (%)
			Wild fish			
S1	6.36	5.21	2.14	112	0.0097	33.7
S2	23.23	9.27	1.59	119	0.0225	6.9
S3	31.56	11.19	1.41	118	0.0263	4.5
S4	1.92	1.21	0.96	120	0.0058	49.9
C1	18.94	4.98	3.30	120	0.0146	17.3
C2	8.01	0.49	1.07	121	0.0166	13.4
			Stocked fish			
S1	2.79[a]	0.00	0.12	112	0.0281	4.3
S2	3.03[b]	1.28	0.19	119	0.0233	6.3
S3	4.68[b]	1.87	0.25	118	0.0248	5.4
S4	0.80[c]	0.00	0.00	120		0.0

[a] Northern subspecies.
[b] Florida subspecies.
[c] F_1 hybrid.

(76–156 mm). Stocked fish grew faster on average (0.5 mm/d) than wild fish (0.4 mm/d).

First-summer survival of stocked and wild age-0 largemouth bass was similar but low (4.5–6.9%) in two embayments: S2 and S3 (Table 2). In the other two stocked embayments, stocked fish also survived poorly (0% and 4.3%), but wild fish experienced high survival (33.7% and 49.9%). Mean survival between June and October for the six cohorts of wild fish and four cohorts of stocked fish averaged 21% (SE = 7.2) and 4.0% (1.4), respectively, and the means differed ($t = -2.27$, df = 8, $P = 0.0525$).

Stocking fingerling bass did not appear to affect the mortality of wild age-0 largemouth bass. Although instantaneous mortality of wild fish tended to increase with the number of fingerlings stocked, the relation was not significant ($F_{1,4} = 2.85$, $P = 0.1666$). Our failure to reject the null hypothesis (no effect) does not mean survival of wild fish was unaffected by the stocking program. If there was an effect, it was too small to detect with a sample size of only six observations.

Compensatory mortality was evident because instantaneous mortality was positively correlated ($r = 0.96$, $P = 0.0020$) with initial mean catch of all age-0 largemouth bass. Thus, cohorts in those embayments with high initial abundance (wild and stocked fish combined) experienced high mortality, and vice versa. Compensatory growth was not evident because instantaneous growth of all age-0 fish was positively correlated ($r = 0.86$, $P = 0.0290$) with initial mean catch.

Diet

Stocked and wild fish appeared to forage in a similar manner based on our examination of the stomach contents of 63 stocked and 732 wild age-0 largemouth bass. The proportions of stocked (44%) and wild (51%) age-0 largemouth bass that had empty stomachs were similar ($\chi^2 = 0.52$, df = 1, $P = 0.4705$), as were the proportions that contained fish (stocked = 54% and wild = 55%; $\chi^2 = 0.15$, df = 1, $P = 0.6979$) and invertebrates (stocked = 49% and wild = 47%; $\chi^2 = 0.27$, $P = 0.6014$).

Abundance and Stocking Contributions

Mean catches of age-0 largemouth bass (wild and stocked fish combined) varied by an order of magnitude among embayments in the first (June 2002) electrofishing sample (ANOVA: $F_{5, 40} = 8.63$; $P < 0.0001$; Table 3) and were positively related to the number of fish stocked (linear regression: $F_{1, 4} = 5.6$; $r^2 = 58\%$; $P = 0.0779$). However, the effects of stocking did not persist. By October 2002, catch rates of all age-0 largemouth bass were similar among embayments (ANOVA: $F_{5, 40} = 0.94$, $P = 0.4651$).

We collected 1,024 age-0 largemouth bass in the stocked embayments; 147 were marked with OTC. The contribution of stocked fish to the age-0 cohort

TABLE 3.—Geometric mean catch (*N*/100 m) of age-0 largemouth bass (wild and stocked fish combined) by sample period and study embayment in Chickamauga Lake, Tennessee, 2002. Means within each sample period with the same letter were statistically similar (Tukey's test; $P < 0.05$). Four embayments were stocked and two were unstocked control embayments.

Embayment	Day of the year	Mean catch	95% Confidence interval
Sample period 1			
S1	175	8.8 zyx	1.1–44.0
S2	168	26.5 zy	19.1–36.5
S3	169	36.9 z	29.0–46.9
S4	170	2.4 x	0.4–7.5
C1	169	18.9 zy	5.6–59.0
C2	168	8.0 yx	4.6–13.5
Sample period 2			
S1	212	5.2 zy	2.0–12.0
S2	210	10.5 z	7.5–14.7
S3	211	13.1 z	5.5–29.7
S4	212	1.2 yx	0.1–3.4
C1	211	5.0 zy	0.9–18.0
C2	210	0.5 x	0.0–1.2
Sample period 3			
S1	287	2.2 z	0.5–5.8
S2	287	1.9 z	0.6–4.0
S3	287	1.7 z	0.3–4.4
S4	290	1.0 z	0.1–2.4
C1	290	3.3 z	0.9–5.4
C2	290	1.1 z	0.1–2.8

in each embayment ranged from 13% to 29% after 7–19 d (Figure 2). Two embayments (S1 and S4) where the percent contributions of stocked fish were highest in the first sample yielded only 1 stocked fish, of 82 collected in total, in the two subsequent samples. The contributions of largemouth bass stocked in the other two embayments (S2 and S3) remained consistent at 10–14% through 119–139 d poststocking. By October 2002, only 9% of the 70 age-0 largemouth collected in the four stocked embayments were stocked fish and most of those were in the two embayments (S2 and S3) stocked with the most fish.

Transects that were sampled for age-1 largemouth bass in April 2003 extended at least 3 km from each stocking site to account for further dispersal. In those samples we recaptured only 2 marked fish or less than 2% of the total catch of 91 age-1 largemouth bass captured in the stocked embayments. No OTC-marked largemouth bass were ever collected in the two control embayments. Electrofishing samples in 2002 encompassed only 2 km of shoreline in each embayment, and less than 6 km of shoreline were sampled in each embayment in 2003; therefore, percent contributions on a complete embayment or reservoir scale were miniscule.

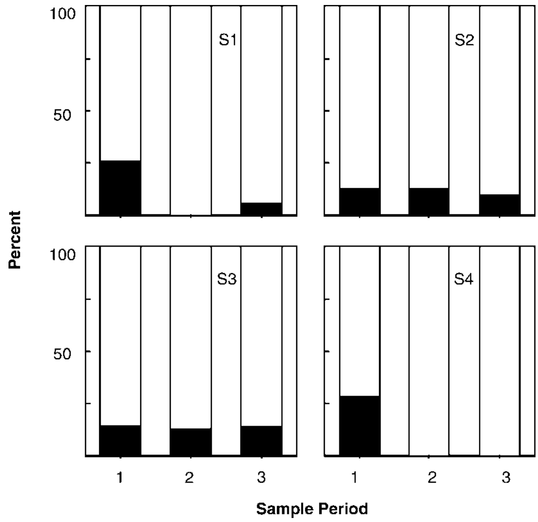

FIGURE 2.—Percent contribution of stocked largemouth bass (dark bars) to age-0 cohort strength along transects in four embayments (S1–S4) of Chickamauga Lake, Tennessee, by electrofishing sampling period: 1 = June 17–24, 2 = July 29–31, and 3 = October 14–17, 2002.

Discussion

Oxytetracycline immersion was a useful technique for mass-marking juvenile largemouth bass. It took little effort to mark the fish and we observed 100% marking efficacy. Recent studies have also reported high (98–100%) oxytetracycline mark retention for black crappies *P. nigromaculatus* (Isermann et al. 1999), walleyes (Brooks et al. 1994), and yellow perch (Unkenholz et al. 1997). Retention of oxytetracycline marks for up to 4 and 5 years has been reported for red drum *Sciaenops ocellatus* (Jenkins et al. 2002) and sauger *Sander canadensis* (Heidinger and Brooks 1998). The oxytetracycline marks on otoliths of recaptured and efficacy fish were clearly visible, and autofluorescence of the otolith did not affect mark clarity, which is similar to findings of Isermann et al. (1999) for black crappies stocked in Tennessee.

The largemouth bass stocked in Chickamauga Lake dispersed farther and faster than those in a North Carolina reservoir (Jackson et al. 2002). For instance, after only 7 d almost 30% of our recaptures in one embayment (S1) occurred more than 700 m from the stocking site. Dispersion appeared to stabilize by 19 d poststocking in all embayments, which is similar to reported dispersion of

Florida largemouth bass stocked into a Texas reservoir (Buckmeier and Betsill 2002). All sampling of age-0 largemouth bass in our study was conducted within 1 km of each stocking site because it was assumed that stocked largemouth bass would not move more than 1 km during their first summer of life. It is possible that stocked fish dispersed further than 1 km during their first summer; however, no fish were recaptured the following spring in transects that were extended beyond 1 km from each stocking site. Also, only 3% of all the age-0 recaptures occurred at transects located more than 900 m from the nearest stocking site.

Stocked largemouth bass can suffer high rates of handling and stocking mortality (e.g., Porak et al. 2002), but the stocked fish in our study experienced high mortality that was probably due to factors other than marking and stocking. No mortality (other than cannibalism) was observed for OTC-immersed fish that were retained for the efficacy study. Brown et al. (2002) marked yellow perch with OTC in a similar manner, and initial mortality was also low (<1%). Isermann et al. (2002) also concluded that OTC-immersion did not increase mortality of black crappies.

Predation was probably the most important factor regulating stocked fish survival. In the stocked embayments of Chickamauga Lake, age-0 largemouth bass were consumed by 63% of potential fish predators that had recently consumed a meal (Hoffman 2003). Most of those fingerlings were probably stocked fish because the samples were collected within a few hours of stocking, and there were few prey items other than fingerling bass found in the stomachs of potential predators. Stocking a large number of fish at one location may induce predators to feed on stocked fish. Hoxmeier and Wahl (2002) concluded that initial losses to predation could have been an important factor limiting the success of largemouth bass stockings in Illinois lakes. Initial loss of stocked fish to predation might be decreased by stocking fish in suitable habitat; however, if fish are disoriented when released from the hatchery truck (Forsberg et al. 2001), the fish may not be able to find suitable habitat and avoid predation. Similarly, largemouth bass reared under artificial circumstances (e.g., pellet-reared) behave differently than wild fish do when searching for food and, consequently, may be more vulnerable to predation (Heidinger and Brooks 2002). For at least 12 h after fish were stocked in our study, large schools of juvenile largemouth bass that we presumed to be stocked fish were observed near the boat ramps. Although not measured, intracohort cannibalism can reduce the survival of largemouth bass in southern ponds and reservoirs (Pine et al. 2000).

Although stocking largemouth bass tended to initially increase the abundance of age-0 fish, increased abundance was offset by higher mortality. Wild fish survived as well or better in the four stocked embayments (pooled average survival between June and October = 24%) as in the two control embayments (pooled average = 15%), and their mortality was not linearly related to the number of fish stocked. Thus, there were no clear negative effects of the stocking program on wild age-0 largemouth bass. In contrast, Buckmeier and Betsill (2002) reported that stocked fish might have suppressed wild fish abundance. They also observed that stocked fish that survived the initial period of high mortality experienced mortality rates similar to wild fish, which we observed in two of four embayments. Jackson et al. (2002) reported that stocked age-0 largemouth bass performed similar to wild fish in terms of survival and feeding in a North Carolina reservoir. Fingerlings stocked into Chickamauga Lake in our study also displayed similar feeding ecology as their wild counterparts.

Our stocking rates (17,000–75,000 fish/stocking site) were intermediate to the rates used by Buckmeier et al. (2003), who stocked Florida largemouth bass at rates of 1,000, 10,000, and 100,000 fish/site to determine the most efficient rate to alter the genetic composition of the receiving populations. Stocking 10,000 fish/site was judged to be most efficient, despite a low (≤5.4%) contribution of stocked fish. The recent findings of Schlechte et al. (2005) hold promise for improving the survival of stocked largemouth bass fingerlings; they showed in the laboratory that habituating fingerlings for brief (15–60 min) periods in predator-free enclosures increased survival of stocked fish. In that study, it was hypothesized that stocked fish were initially too stressed from hauling and stocking to actively avoid predation.

The instantaneous growth rates of largemouth bass stocked in Chickamauga Lake were positively correlated with initial mean catches. In contrast, Miranda et al. (1984) reported an inverse relationship between abundance and growth of age-0 largemouth bass in West Point Reservoir in Alabama and Georgia. Sammons et al. (1999) did not find a relationship between growth rates and density of wild juvenile largemouth bass. In our study, smaller individuals could have died at a faster rate, which would have increased the mean total length in each subsequent sampling period; thus, the estimates of growth may have been positively biased.

The stocked fish in our study maintained an initial length advantage over wild fish throughout the summer. Age-0 largemouth bass are gape-limited (Shelton et al. 1979) and larger fish of the same cohort should have more prey available than smaller individuals (Keast and Eadie 1985). Additionally, large age-0 largemouth bass will accumulate more lipids and have a better chance of surviving the winter than smaller largemouth bass (Miranda and Hubbard 1994). However, stocked fish in our study did not benefit from having a length advantage over wild fish (i.e., they contributed poorly to the cohort). Buckmeier and Betsill (2002) also reported that largemouth bass stocked in a Texas Reservoir retained a length advantage over wild fish for the most of the summer; however, stocked fish also contributed poorly to cohort strength in that study.

Our cursory examination of the diets of 795 wild and stocked age-0 largemouth bass did not indicate poor foraging by stocked fish, unlike the larger, pellet-reared largemouth bass stocked by Porak et al. (2002) into Florida lakes. In fact, the length advantage that stocked fish in Chickamauga Lake had over their wild counterparts should have provided a competitive feeding advantage (Wahl et al. 1995), which we did not observe.

Management Implications

Survival and the subsequent contributions of stocked age-0 largemouth bass were uniformly poor. Their contribution to cohort strength was only 9% by fall and declined to just 2% at age 1. In terms of their contribution to the entire cohort in each embayment, those estimates are inflated because we did not sample the entire shoreline of each embayment.

We used embayment-specific mortality rates to estimate that only about 3% or about 3,500 of the 128,265 stocked fingerlings survived their first 140 d in Chickamauga Lake. Consequently, the cost increased from US$0.35/fingerling at stocking (Tim Churchill, TWRA, personal communication) to over $12/fingerling surviving until October 2002. If mortality remained constant through winter, we estimate that a mere 63 stocked fish survived to April 1, 2003; thus, the cost increased to more than $700 per age-1 recruit. Although this cost-per-recruit estimate is crude, it clearly indicates that managers should pay more attention to the costs and benefits of any stocking program. Although the primary objective of the stocking program was to promote introgression of the Florida largemouth bass genome into the receiving population, the chances of substantial introgression occurring are slight if few fish survive.

The small size of the fish that were stocked into Chickamauga Lake (35–64 mm TL) may have contributed to the poor return rates. Although Porak et al. (2002) also observed poor stocking contributions of pellet-reared largemouth bass in some lakes (2–9%), the contributions of the larger fish they stocked (67–335 mm TL) were higher (12–48%) in other lakes. Additional studies are needed to determine whether stocking larger fish would be a viable alternative on a cost-benefit basis, which is what Buynak and Mitchell (1999) reported for stocking large (about 100 mm TL) largemouth bass fingerlings into a small Kentucky reservoir. Short-term habituation of hatchery-reared fish at stocking sites may also hold promise to increase survival of stocked largemouth bass (Schlechte et al. 2005).

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